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Supply Chain Management

New Perspectives

Edited by Sanda Renko

SUPPLY CHAIN MANAGEMENT - NEW PERSPECTIVES

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Meet the editor

Sanda Renko, PhD, is the Associate Professor at the Trade Department, Faculty of Economics and Business, University of Zagreb. She is the course coordinator for Wholesale and Retail Business, Business Logistics, Retailing Management, Benchmarking, Distribution Strategies, and Category Management. Dr. Renko is involved in numerous scientific projects such as FP7 FOCUS Balkans Project for European Union, the Project of the development of organic food distribution channels and the consumer protection in the Republic of Croatia and the Project of development of sale and distribution systems in Croatian enterprises. In 2006, she was awarded the „Mijo Mirković“ Award for the best scientific paper. She was guest editor in special issues of a number of scientific journals (World Journal of Retail Business Management, Food Product Marketing, and British Food Journal).
Dr. Renko is the Editor in Chief of the International Journal of Sales, Retailing and Marketing.

Contents

Preface

Over the past few decades the rapid spread of information and knowledge, the increasing expectations of customers and stakeholders, intensified competition, and searching for superior performance and low costs at the same time, have made supply chain a critical management area. Since supply chain is the network of organizations that are involved in moving materials, documents and information on their journey from initial suppliers to final customers, it encompasses a number of key flows: physical flow of materials, flows of information, and tangible and intangible resources which enable supply chain members to operate effectively. This book gives an up-to-date view of supply chain, emphasizing current trends and developments in the area of supply chain management. Thus, some important issues through the supply chain are discussed, such as:

- the bullwhip effect in a supply chain
- increasing cooperation and a holistic supply chain to promote environmental awareness
- collaboration in the supply chain as the key to improving quality
- the necessity for the implementation of integrated logistics
- the importance of reverse logistics
- information and communication technology as support tools.

The book is divided into six parts. Part I, “Shifts in Managing Supply Chain” gives an introduction to supply chain management. Additionally, this part presents a retrospective analysis of the evolution of managerial perspectives on supply chain management, strategic roles of the supply chains, and prediction markets as the new tool for managing the supply chain. Part II, „The Role of Cooperative Relationships“ consists of chapters which investigate dominance in the supply chain, and use of negotiation and collaboration for the optimal formation of the chain and for the improvement of the product quality. Part III, “Optimizing Distribution Operations“ gives the illustration of a supporting decisions tool for the design, management, control and optimization of a logistic network, with emphasis on the transport and location problems. Part IV, “Sustainability Issues Through the Supply Chain“ discusses how supply chain management relates to the dynamic situation surrounding sustainable development, and how its practices are affected by the evolving concepts of value-chains, especially in the developing countries. Part V, “Competing Through

Information and Technologies" explains how the use of new technologies contributes to improved efficiency of the supply chain management. Moreover, this part of the book introduces the concept of virtual organization. The last part of the book, Part VI, "A Quantitative Approach" consists of chapters dedicated to modeling and simulation methods for addressing the complexity of problem of the supply chain.

The contents of this book should help students and managers in the field of logistics, distribution and supply chain to deepen their understanding of challenges in supply chain and to make more effective decisions in these areas. Therefore, I would like to thank the authors of the chapters who have contributed to this book with their knowledge and expertise.

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Part 1

Shifts in Managing Supply Chain

1

Supply Chain Management from a Systems Science Perspective

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1. Introduction

Supply chain management (SCM) is going to be the main management process for production systems in the xxi century. This management process will take care of the flow of materials, information, purchased parts, personnel and financial needs supplied from different vendors, sometimes geographically too far from the main production plant. The industry of domestic appliances is a good example of the supply chain management. Before SCM a production system designed their products itself and manufacture all the subassemblies and components and gave after sale service during and after warranty period. After SCM the new production systems "comakership" several aspects of the production process, for example hermetic compressors for fridges, plastic parts and motors for washing machines, electrical components, etc. SCM provides different management principles to help in the designed planning and controlling the network of suppliers in order to synchronize the variability of customer's demand with the variability of capacity of suppliers. One management principle is called Asbhy's law:" the variability of the manager system should be more than or equal to the variability of the managed system".

In order to speak correctly about SCM let see how is the official definition expressed by the Association for Operations Management in their APICS Dictionary (Blackstone, 2008): SCM is "The design, planning, execution, control, and monitoring of supply chain activities with the objective of creating net value, building a competitive infrastructure, leveraging world-wide logistics, synchronizing supply with demand, and measurement performance globally". The previous definition emphasizing the main functions of production systems management as follows: the design of the supply chain when it is going to be a new corporation, the **planning** of operational and strategic activities, the scheduling and **execution** of the production planning, the **control** and solution of conflicts and the monitoring and auditing of the production processes . The financial management to create **net value** to all stakeholders: owners , employers, employees, society and environment. In the following section of this chapter, it is going to be described in more detail each one of the manufacturing functions of Supply Chain (SC), considering a systems approach based on the five components of the Viable System Model (VSM) by Beer (1985). Supported by the popular business/industrial information system called Enterprise Resources Planning (ERP).

After the theoretical description of the SCM via a systemic approach, it will be presented an application of fractal theory to improve inventory management synchronization of supply with demand considering a frequent phenomenon in sequential processes of SCM, called bullwhip effect. The financial management to create net value to all stakeholders: owners, employees, society and environment. An actual example of SCM implementation was reported by Proctor (2010) in the case Dupont, a multinational company with headquarters in Willington, Delaware. The company has operations in more than 70 countries and diverse product lines including agriculture, nutrition, electronics, communications, home products, etc. DuPont managers "credit the corporate survival and success during the recession to their employees 's strong SCM knowledge which has given them visibility across business units. DuPont started in this area with kaisen, Lean and Six sigma. Once low cost sourcing was added SCM was a natural segue" (Proctor, 2010:12). Dupont management started to rely on demand planning (Customer Relationship Management, CRM), raw-material planning (Material Requirement Planning, MRP), finish-to-stock (FTS), package-to-order (PTO) and make-to-order (MTO) strategies, tightened delivered schedules (Master Production Schedule, MPS) logistic flexibility (Distribution Requirement Planning DRP) and effective sales and operation planning (S&OP); all of this functions belong to the management of SCM via ERP. I this chapter it is used the terms Manufacturing Systems and Production Systems as synonymous.

2. Systems Science

In order to be in accordance with the title of this chapter, it is convenient to define some systems concepts:

Environment. The context within which a system exists, includes everything that may affect the system and may be affected by it at any given time.

Function. Denotes actions that have to be carried out in order to meet system's requirement and attain the purposes of the system.

General System Theory. The concepts, principles and models that are common to all kinds of systems and isomorphism among various types of systems.

Human activity system. A system with purpose, that expresses some human activities of definite purpose; the activities belong to the real world.

Model building. A disciplined inquiry by means of which a conceptual (abstract) system's representation is constructed or an expected outcome/output representation is portrayed. There are models of function structure (like a still picture) and models of processes (like a motion picture).

Subsystem. A greater system's component, is made up of two or more interacting and interdependent components. The subsystems of a system interact in order to attain their own purpose(s) and the purpose(s) of the systems in which they are embedded.

System. A group of interacting components that keep some identifiable set of relationships with the sum of their components in addition to relationships (i.e. the systems themselves) to other entities.

Systems Science. The field of scientific inquiry whose objects of study are systems (Klir, 1993:27 in Francoise, 2004) and its structure is composed of a domain, concepts, theories and methodologies.

Variety. Number of possible states that a system is capable of exhibiting (Beer, 1979).

Viable System Model (VSM). It is a system able to maintain a separate existence, capable of maintaining its identity and transcend independently.
The System Science use the constructions of models to represents real systems, for example the Viable System Model (VSM) was elaborated by Beer (1979) to represent manufacturing/productions systems like the SCM.
The VSM presents a new way of looking at an organizational structure. It is a recursive model in which each successive unit is nested within the next larger one. It is a pre- eminent way to manage variety. It is a logical structure which differs from a classical hierarchical organizational chart but helps management to organize effectively the Production System. According to the VSM in any viable system, there are five systems interactively involved in any organization that is capable of maintaining its identity and transcend independently of other organizations within a shared environment (Beer, 1989). If an organization survives in a particular sort of environment, it is viable. All manufacturing systems are embedded in a continuously changing environment of socio-political World Economy. Success in global and local markets with social satisfaction requires constant unrelenting efforts to develop more viable manufacturing systems, aware of quality and sustainability. The VSM is organized on five subsystems/elements that in this chapter are designed as 1) operations management, 2) coordination, 3) auditing/monitoring, production management, 4) general management, and 5) board of directors. In a VSM, System 4 is concerned with the future (the outside and then: Budget of long range forecast and marketing) as opposed to system three's concern with the present (inside and now: the best integration and coordination of existing resources. production logistic such as master production schedule, resources requirement planning, materials & capacity). Sales and operation management (S&OP)is a typical system one function managed by System 3, monitored by System 3 (auditing/monitoring) and coordinated (avoiding conflicts) by System 2.
In order to interconnect the five subsystems of VSM, it is necessary to add an integrated information system like Enterprise Resources Planning Systems (ERP). The ERP have received considerable attention recently, not only in the management of manufacturing industry but also within the services industries and their financial management. The VSM is recursive and ERP supports the management of each recursion. For example, in each component of SC there are 5 recursions levels, starting from Warehouse Management (WM) to Material Requirement Planning (MRP), to Manufactory Requirement Planning (MRPII), to Enterprise Resources Planning (ERP), and to Supply Chain Management (SCM). In each recursion level, there are emergent properties like the two categories of demand: independent demand and dependent demand in MRP; the feedbacks in the closed cycles in MRPII; the local, future and total environments, the interactions between the market and the Production System in ERP and the Law of requisite variety helps to manage complexity of SCM.

3. The Viable System Model: Description

Human organizations are much more complex than we are usually prepared to admit. Organization charts do not show how the organization really works, and in fact, real-world systems have variety which is effectively mathematically infinite. Consider the system as a traditional production model in fig. 2. The Operation is the element which does things. The Management is the element which controls the doers. And the Environment is the surroundings in which they function. The variety in the surrounding Environment will always be greater than that in the Operation, which in turn will be greater than that in the

Management of the Operation. In order to cope with its environment, the Operation needs to match its variety to that of the Environment. In order to manage the Operation, Management needs to match its variety to that of the Operation. The Operation can cope with its Environment, as long as it can successfully absorb the variety from it, by attenuating the incoming variety, and amplifying its own variety back to it. Likewise, Management can cope with the Operation as long as it can successfully absorb the variety from it, by attenuating the incoming variety, and amplifying its own variety back to it. Here it is very important to take into account the Ashby's Law of Requisite Variety, which stated that control can be obtained only if the variety of the controller is at least as great as the variety of the situation to be controlled (Ashby, 1957). If these requirements are met, the system can maintain itself in a state of dynamic equilibrium, which is called self-organized system. If these requirements are not met, the system will become unstable and eventually leading to its collapse.

What persists in self-organized systems is the relationship between the components, not the components themselves. They have the ability to continuously re-create themselves, while being recognizably the same. This ability to maintain identity is related to the fact that these systems have purposes. These purposes provide the framework for their maintenance of identity.

The Viable System Model (VSM) claims to reveal the underlying structures necessary for a system to meet the criterion of viability. The VSM methodology was developed by the cybernetician Stafford Beer (Beer, 1972). The criteria of viability require that organizations are or become ultra stable, i.e. capable of adapting appropriately to their chosen environment, or adapting their environment to suit themselves. The VSM models the structures of the organization and the relationships between them. This includes key processes, communications, and information flows. The VSM has been used as a diagnostic tool in different contexts (Espejo & Harnden, 1989). Not only in the management of the manufacturing industry e.g. the explanation of the general production management model of the Enterprise Resources Planning Systems (Tejeida *et al*., 2010), but also in the financial management and in the service industry. The model is composed of five interacting subsystems. Kinloch *et al*., (2009) states in summary, that systems 1-3 are concerned with the "here and now" of the organization's operation, system 4 is concerned with the "there and then" - strategical responses to the effect of external, environmental and future demands of the organization and system 5 is concerned with identity, values, mission and polices directives which keep the organization as a viable entity.

Briefly: System 1 Produces the system refers to the fundamental operations within a viable system which enclosed several primary activities. Each primary activity is itself a VSM. System 2 consists of a regulatory center for each element of system 1 and allows system 3 to monitor and coordinate the activities of system 1.

System 3 is responsible for system 1 control and provides an interface with Systems 4/5. System 3* has an audit function to monitor various aspects of the accountability relationship between System 3 and System 1. System 3* might assure that the quality of service, safety standards, financial information, internal control, etc are in order. System 4 has the purpose to look outwards to the environment to monitor how the organization needs to adapt to remain viable and need a feed back through system 3. Strategic Planning plays a big roll into this system to pursue a well connection between System 5 and System 3. System 5 is responsible for policy decisions. The former role effectively defines the identity and ethos of the organization - its personality and purpose.

In addition to the subsystems, there are some principles to make the system viable (Beer, 1979): a) Managerial, operational and environmental varieties diffusing through an institutional system tend to equate; they should be designed to do so with minimum damage to people and cost. b) The four directional channels carrying information between the management unit, the operation, and the environment must each have a higher capacity to transmit a given amount of information relevant to variety selection in a given time than the originating subsystem has to generate it in that time. c) Wherever the information carried on a channel capable of distinguishing a given variety crosses a boundary, it undergoes transduction; the variety of the transducer must be at least equivalent to the variety of the channel. d) The operation of the first three principles must be cyclically maintained through time without hiatus or lags**.**

3.1 Modeling a general SCM with VSM and ERP

In fig. 1. it is presented an SCM according to the VSM interconnected with ERP

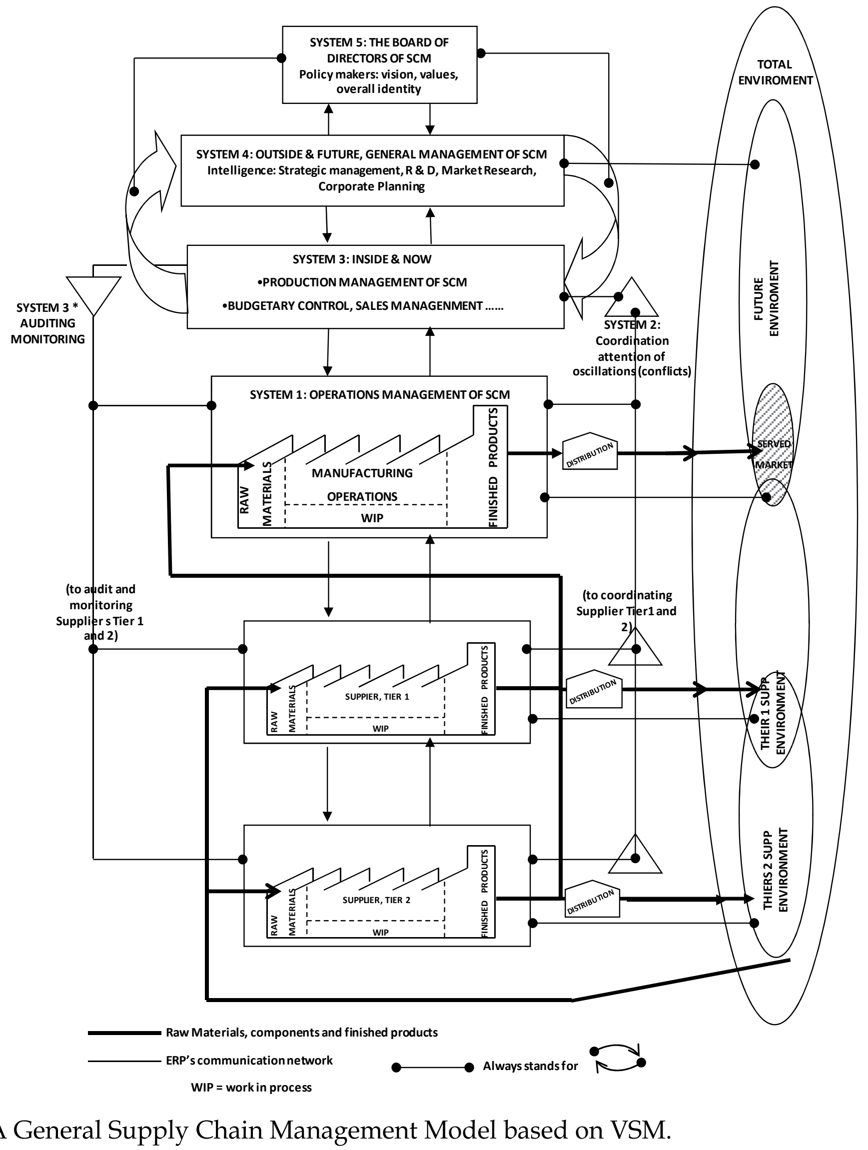

Fig. 1. A General Supply Chain Management Model based on VSM.

System 1: The System 1 of a production system produces the system and consists of the various components directly concerned with carrying out the tasks that the production in a system is supposed to be doing, such as the tasks performed by some of the following ERP modules (See Table 1).

Each manufacturing department and or supplier is connected to the wider management system by the vertical communication channels to receive instructions and to report performance, preferable on standard electronic screens to manage variety. In order to be viable systems each manufacturing department or supplier should be autonomous and be able to make its own decisions according to the Master Production Schedule (MPS), shared thru ERP. The multiuser ERP system helps to reduce the bullwhip effect.

System 2: This system has a coordination function whose main task is to assure that the various manufacturing departments and or suppliers of a production system act in harmony, damping their oscillations so that common resources and support services are run smoothly avoiding the archetypical situation know as the "tragedy of the commons". Decisions of System 2 are based on what is best for the whole which is often different from the best for a particular manufacturing department (Leonard, 2008). It is the System 2's job to oversee the interaction between departments and to stabilize the situation to obtain a balance response from system 1. Normally this coordination function is located inside the Manufacturing Engineering office and uses some modules of ERP (see Table 2).

1. Sales and operation management (SOP) to develop tactical and strategical plans to achieve competitive advantage	2. Customer Relationship Management (CRM) to understand and support existing and potential customers needs
3. Quality Function Deployment (QFD) to ensure that all major requirements of the "voice of the customer" are incorporated in the product or service	4. Master Production Schedule (MPS) to reflect the anticipated production schudule
5. Material Requirement Planning (MRP) and informatics algorithm that processes data from BOM, IM and MPS	6. Capacity Requirement Planning (CRP) to determine in detail the amount of labor and machine resources required to accomplish the MPS
7. Bill of Material (BOM), a file of the product structure	8. Bill of Processes (BOP)
9. Shop floor Control (SFC)	10. Production Activity Control (PAC)
11. Suppliers Relationship Management (SRM)	12. Total Quality Control (TQM)
13. Maintenance Management (MM)	13 Distribution Requirement Planning (DRP)

Table 1. ERP's Modules for System 1 of VSM.

- Production Scheduling (MPS)	- Quality control of major Raw Materials
- Work procedures / Bill of processes (BOP)	- Maintenance Management (MM)
- Supply Chain Event Management (SCEM)	- Manufacturing Auditing (MA)

Table 2. ERP's Modules for System 2 VSM.

*Systems 3 and 3**: System 3 is a command control function. It interprets policy in the light of internal data from System 2 and monitoring or auditing reports from System 3*. The task of the last one is to give system 3 direct access to the state of affairs in the operations of System 1, of each manufacturing department and or suppliers.

Through this channel, System 3 can get immediate information, rather than hinged on information passed to it by the localized management of manufacturing departments and or suppliers. For example to check directly on quality, maintenance procedures, employee comfort, etc.

The ERP modules that help System 3 to command and accomplish its management and control functions are shown on table 3.

From the accounting and financial perspective, there should be one of two fundamental objectives in a production system. One is to obtain the capability to produce a product or service that can be sold at a profit represented by A/R, A/P, F/A, etc. The second, is to improve an existing product or service so as to improve performance and customer acceptance, or reduce cost with the help of "Activity Basic Costs" (ABC) without sacrificing customer acceptance either of which would lead to higher profits. From the information processing point of view, the capacity of managers in System 3, of carrying out the control function, needs to be in balance with the current information flowing through the three incoming channels: 1) Coordination from system, 2) auditing / monitoring from system 3*, and 3) command from System 1.

Shop Floor Control (SFC)	Financial Business Modules like:
Manufacturing Execution System (MES) (to control and monitoring of plant-floor machines and electromechanical systems)	Activity Based Costing (ABC) to get real cost of finished products or services
Input – Output control and Production Activity Control (PAC) (to control details of production flow)	Accounts Payable (AP)
Human Resource Management (HRM) (for payroll, time management benefits administration, etc.)	Accounts Receivable (AR)
Plant and Equipment Management (FA) (Fixed assets management)	General Ledger (GL)
Shop Floor Control (SFC)	Fixed Assets (FA)
Manufacturing Execution System (MES) (to control and monitoring of plant-floor machines and electromechanical systems)	Payroll (PR) for salary administration
	Profit and cost center accounting, etc.

Table 3. ERP's Modules for System 3 and System 3* of VSM.

*Systems 2 (coordination), System 3** (monitoring) and System3 (production management) are highly dependent on timely and accurate reporting of what is happening in System 1 (operation management, manufacturing operations and its environment). It makes no sense to install an expensive data collection subsystem of ERP if the data are not close to real time as possible (Turbide, 2007). The big dream of accountants is not to be faced with the "month end" syndrome and real time data approach to a solution because the ERP systems are updated all the time (Currant & Keller, 1998). ERP changes the accountants´ role in System 3 because they have more time to assist management in System 3 as general advisors who can use the numbers to reduce variety and improve management of System 1. Real time data are subject to statistical filters of variety and processes to help achieving a better management of the System 1's variety.

Real time data contribute to auditing/monitoring coordination and control of System 1 through some additional ERP´s modules and functions such as: 1)Advanced Planning System (APS), 2)Available to promise and capable to promise functions (ATP), 3)Production Activity Control (PAC), and 4)Inventory Management (IM).

System 4: System 4 performs the research and development function of a manufacturing SC system, it has two main tasks:

1. Translate Instructions and reports between System 5 Board of Directors and the lower – level systems.
2. To capture all relevant information for the production system, about its total environment.

If the manufacturing SC system is to be viable and effective it has to, somehow, match the variety of the environment in which it finds itself. To do this it must have a model of the environment that enables predictions to be made about the likely future state of the environment and allow the production system to respond in time to threats and opportunities.

System 4 is the point where internal and external information can be brought together. Activities such as Strategic Planning, Market Research, Research and Development and public relations should be located there.

The ERP modules that can help perform the tasks of system 4 are shown on table 4:

Human Resource HR	Advanced Planning System (APS)
Product Life Cycle (PLC)	Long Range Forecasts (LRF)
Legal and Fiscal Planning	Business Planning under various scenarios

Table 4. ERP's modules for System 4 of VSM.

The data base of the Human Resources module (HR) helps to build a portfolio of human resources, evaluated with high potential, for HR Requirements planning in order to have the right managers in the right amount and in the right time.

The Advanced Planning System/Master Production Schedule (APS/MPS) are feed forward systems which processes current information of operations with future ideals and adjust the output model accordingly.

One of the most important responsibilities of system 4 is to keep adaptation mechanisms of the production systems with its future environment, represented by groups of investors, shareholders, governments, unions, communities, etc.

System 5: System 5 is responsible for the direction of the whole production system; it is where identity and coherence are focused by the board of directors. System 5 activities include formulating policy on the basis of all information passed to it by system 4 and communicating the policy downward to system 3 for implementation by the manufacturing departments and or suppliers. System 5 must ensure that the production system adapts to the external environment while maintaining an appropriate degree of internal stability. It is the thinking part of the production system. There are no modules of ERP to help activities of system 5. It is recommended for developers of ERP systems to design modules for consensual agreements, strategies and policies based on methodologies such as Syntegrity from S. Beer, (1994) Interactive Management from J. Warfield (1994) or CogniScope from Christakis (2007) Algedonic information coming directly from system 1 to system 5 helps to manage critical situations.

4. A VSM approach for after-sales spare parts service in telecom firms

The service sector encompassed "all economic activities whose output is not a physical product or construction, is generally consumed at the time it is produced, and provides add value in forms (such as convenience, amusement, timeliness, comfort or health) that are essentially intangible concerns of its first purchaser" (Quinn *et al.*, 1987). The service industry including OEM's telecom firms plays an important role into the economic activity in any society. Fitzsimmons and Fitzsimmons (2007) stated that during the past 90 years, we have witnessed a major evolution in our society from being predominantly manufacturing-based to being predominantly service-based. Nowadays the last constitutes the new engine for global economic growth. Modern telecommunications are like a catalyst of States sustainable development: these represent a vital element to the proper functioning of enterprises, and it is part of the quotidian life of almost every individual in this planet (Kuhlman & Alonso, 2003). Into the telecom industry: repair, spare parts, installing upgrades, technical support, consulting, training, field corrective maintenance, etc., are typical after-sales services offered by the Original Equipment Manufacturer (OEM). By offering effective after sales services, the operating margin contributions outweigh the benefits of increased revenue by approximately 50% if the service is efficiently manage by the OEM, although most companies either do not know or do not care to provide after-sales service effectively (Cohen *et al.*, 2006a). What follows concern only to the level of an OEM dedicated to after sales spare-parts service.

Today, operator customers are pursuing to outsource services for a number of reasons. Of particular interest among them are: reduce capital expenditures (CAPEX) and operational expenditures (OPEX) in inventory investment and management respectively, cash flow improvements, reduced operational complexity, network availability improvements, etc. According with the consulting firm Pyramid Research (2006), 47% of the mobile Costumer Operators (CO), outsource some or all of their spare parts management activities while wireline (CO) just 21%. This represents a growing opportunity of revenue streams and profit for OEMs, but capture this profit is not easy and the OEM after-sales service parts need to face different challenges, e.g. customer needs and behavior, logistic management, budget limit, IT infrastructure, product upgrades, phase-out products support, product quality, warranties, worldwide repair vendor network, import/export processes, customer support, customer network installed base visibility, long supply and repair lead times, intermittent and probabilistic demand, integration and coordination between different echelons within the supply chain, variability across the entire supply chain, etc.

In the realm of service parts management, relationships between OEMs and CO are often established through service agreements that extend over a period of time. The details of these service agreements vary in nature depending on customer requirements, e.g. response time, customer budget, etc. Then customer concern would be high network availability and OEM challenge would be to allocate and optimize resource to commit the agreement.

The objective of this section of the chapter is to show a systemic approach to support the after-sale spare part service using the VSM methodology (Beer, 1989), involving strategy, tactical and operational aspects into an integrated manner that helps the after-sales service organization to design and operate the supply chain. The SC designed and organized according to the VSM will achieve a more effective service to profit SC due to: 1) reduced operating conflicts, 2) improvement of quality services due to better auditing and monitoring, 3) improvement of the level of service (punctuality on deliver of spare parts, opportune attention of customers claims), and 4)better management of inventory and financial information due to ERP. Section 5 describes the process concerning the spare parts service, section 6 describes the modeling of the spare parts service using the VSM, and ERP.

5. The spare parts service in OEM's telecom firms

OEM telecom firms offer different after-sales services portfolio to their customers, e.g. technical support, return for repair (RfR), advance & exchange (AE) spare parts, field corrective maintenance, etc. As stated before, OEMs and CO established the service scope through an agreement. This must clearly defined and integrated the service with tools and processes that define the technical aspects of service delivery as well as the metrics that quantify the effectiveness of the service (Hartley, 2005). Also, this must identified the product hierarchy that is going to be support by geographic region (Cohen, Agrawal and Agrawal, 2006b). The Service Level Agreement (SLA) must be attainable, affordable, and measurable and must focus on the customer's primary business (Hartley, 2005). Once negotiated, CO concern must be network availability through the SLAs, and OEMs must focus on achievable SLAs that distinguish their services from competitors.

This part of the chapter will focus only on RfR and AE services which are both related with spares. In a RfR service, the operator send a faulty part to the OEM, then the commitment is to return a good part to the operator in a contractual specified time, e.g. 30, 60 or 90 days[1]. Depending on the repair cycle time[2] and the contractual time, the OEM needs to balance the differences between these two times through the use of a spare pool, e.g. if 30 days is contractually established and the repair cycle time is 90 days, then the OEM will need to allocate a spare pool to meet customer agreement. The repair system faces different challenges: thousands of items management, worldwide repair vendor network, operator cumulated demand[3], different import / export country requirements, material handling damage risk, etc.

Regarding the AE spare parts service, consider a two-echelon distribution/repairable system as shown in fig. 2. The process is as follow: the customer requests part(s) to the OEM's call center. Then this captured the required information to properly make the delivery. The delivery might be according with the SLA, e.g. 2 hr, 4 hr, Next Business Day, etc., from an specified local warehouse (W_i) $i = 1, 2, ..., n$ nearest to the customers. In parallel to the delivery process, the central warehouse Distribution Center (DC) replenishes the local

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[1] Likewise, there are another metrics that can be measure in this process, e.g. Not Fault Found (NFF), same serial number repair rate, not repairable units rate, etc.

[2] This time includes the repair time and all transportations/custom times.

[3] This means that the operator does not send the unit to repair once this has failed; he accumulates faulty units during a time and then sends all of them to repair. This could cause a delay delivery respond to the operator or an OEM investment in inventory to meet the contractual time.

warehouse to keep a specified inventory level. Once the customer receives from the OEM the good part, he returns a defective unit back to the OEM in an agreed (in practice it is random) number of days. Then the defective part is send to Repair Center (RC) and once repaired, the part is allocated in the pool of good units into the distribution center. When units are not repairable, these can be sent to scrap. Also when the OEM has excess inventory, this can go to the scrap process. The time elapsed since the delivery of the good unit from the OEM to the operator until the units are repaired and returned back to the inventory will be called the Turn Around Time (TAT). This includes the defective collect time and the repair cycle time[4]. Generally, the AE service is used to support critical Customer Operator customer network elements that can affect the continuity of telecommunication services.

It is very important to mention that the customer-echelon has an important role into the supply chain performance due to the service / supply process variability introduced by the customer. Basically there are two types of variability: (i) the first is related with the demand/failure parts process which includes the activities that use and thus subtract material from the warehouse inventory, (ii) the second is linked with the defective collect process, where the customer is an active participant into the TAT formula. In order to tackle the first variability, OEM uses operator installed base database and part failure rate[5] (Trindade & Nathan, 2005; Meeker, 1998) to predict demand; the second variability reduction depends on OEM-operator's effort to return the defective units back, and it's up to them how much effort they apply to the task (see Frei (2006), who outlined strategies for managing this variability).

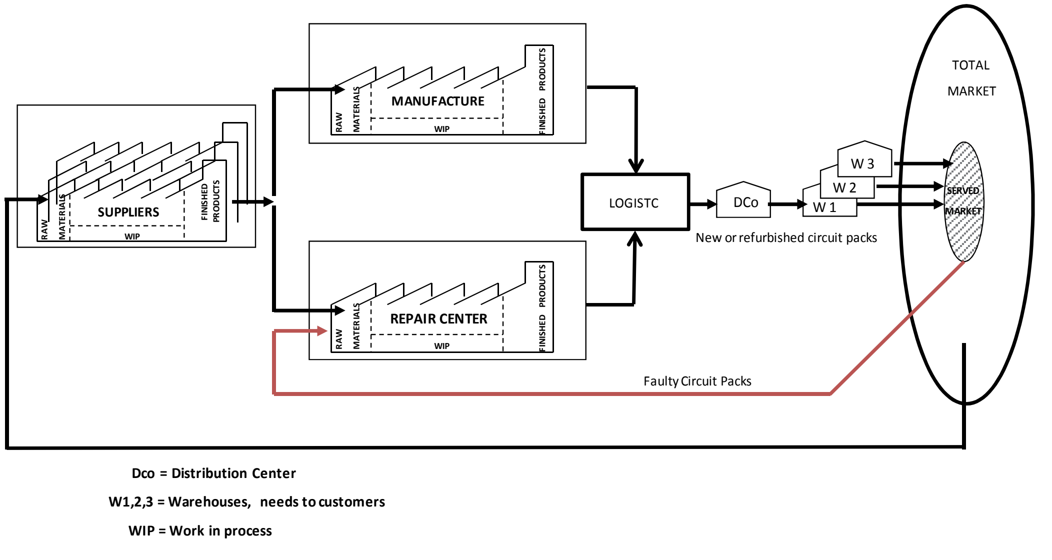

Fig. 2. Schematic of materials flow in an After-sales *AE* spare parts service SC.

[4] Notice that this time is exactly the same in the RfR service.

[5] There are two statistical tools to predict failures: Mean Time Between Failures (MTBF) for constant hazard rates or Mean Cumulative Functions (MCF) for non constant hazard rates.

6. Modelling a OEM's SC spare parts service, with VSM and ERP

Organizations need a link between the strategy and operations. OEMs compete on services but they need to make a trade-off between the service level vs costs. This trade-off can be depict through and efficient frontier curve shown in fig. 3. This represents the most efficient (lowest cost) system for achieving a given performance level. Points below these curves are infeasible and above inefficient. Taking into account this trade-off and the VSM principles, this section will apply the VSM to the after-sales spare part organization in order to link the strategy with operations and to do the system viable.

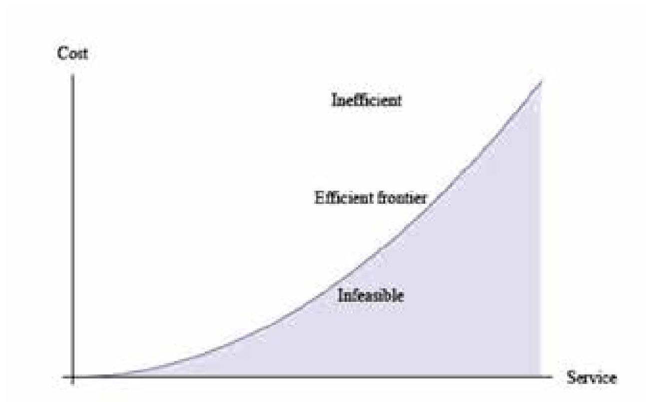

Fig. 3. Service-Cost trade-off and the efficient frontier.

6.1 System 1: Operations management OEM's SC

After-sales spare parts service operations were described at the beginning of section 5. This system encompasses all the primary activities to provide the AE & RfR services. Fig. 4 shows how the different entities are related each other. The OEM is the core operation center[6]. Basically the inputs and outputs through the supply chain are: inventory/spare parts, information and financial transactions. Considering a systemic approach, these three elements act as an interface between subsystems. The connection between the Customer Operator request and the OEM is through a Call Center with the help of a ticket system. If an AE service is required, then the Customer specifies the required part number, the delivery address, contact, phone number, etc., then the OEM must deliver the requested unit, according with the SLA, from the appropriate warehouse. The faulty unit is returned back accordingly with a contractual number of days. Once the OEM receives the faulty unit then this is send to repair with a specific ticket number. Another activities that take place in the operations are the replenishment, rebalance, redeployment, new buys[7] and scrap inventory transfers. All these activities are registered into the ticket system and the ERP system, and each transaction has a cost associated.

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[6] A common practice in the industry is to outsource all or part of the operation with a Third Party Logistics (3PL), e.g. warehouse and transport, and according with Simchi-Levi, Kaminsky & Simchi-Levi (2003), the 3PL relationships are true strategic alliance.

[7] Inventory new buys as well as scrap, are not common processes, they occur occasionally. If the OEM has a shortage of inventory, then a purchase order to the manufacturer can be issue under an Estimated Time of Arrival (ETA). But this needs to be evaluated by System 3.

RfR services are slightly different from AE services with less inventory investment and less service failure risk, but use the same elements shown in fig. 4. The process begins with a repair ticket requested by the Customer Operator. Then the OEM received the faulty unit and this is sending to repair. Once repaired the unit is returned as refurbished to the Operator under a specific SLA. All transactions are registered also in the ERP system.

6.2 System 2: Coordination and anti-oscillatory actions

The supply chain[8] shown in Fig 4 involves multiple levels and organizations. Coordinating the stocks and flows of inventory in such multilevel system is a central challenge. In order to be viable and into the efficient frontier curve (see fig. 3), the Operations need to co-operate with each other, and maintain a suitable state of balance between them. As stated by Hopp (2008) the relevant insights which are related with the inventory coordination in the supply chain are: (i) bottlenecks cause congestions, (ii) variability degrades performance, (iii) variability is worst at high utilization resources, (iv) batching causes delay, and (v) pull is more efficient than push. An interesting phenomenon that occurs in supply chains is the observed increased in demand as we travel up in the supply chain. This increase in variability is referred to as the bullwhip effect (Lee, Padmanabhan & Whang, 1997) and causes significant operational inefficiencies. Thus, it is important to identify strategies to efficiently coordinate the supply chain and cope with the bullwhip effect (see section 6). Another concern of coordination is that the flows of spare parts differ from the information flows in some ways. As stated before, the topology of the OEM, the (CO) and the Repair Centers is spread worldwide. This characteristic creates different complexities to manage the flows of spare parts and information. Spare parts flows tend to be longer to process than information flows. The former may be slower to receive and slower to process. Errors in spare parts flows may be costly and time consuming to correct (Bailey, 2008). To cope with last issues, the coordination among the (CO) and the OEM as well as between the OEM and the Repair Vendor may take place through contracts which establish and align in some manner how the units will flow in the supply chain avoiding conflicts in the use of resources.

The structure of the hierarchical organization coordinates also the task of different individuals into the supply chain. Bar-Yam (2004) mentioned that today real organizations are not pure hierarchies. They are hybrids of hierarchies and networks. There are many lateral connections corresponding to people talking to each other and deciding what to do[9]. Finally material flow into the supply chain in some degree is also data flow. This must be properly registered and coordinated into the ERP and Ticket system. Later the data needs to be converted into information in System 3.

6.3 System 3: OEM's SC management and 3* technical audit and monitoring

System 3 is occupied basically on tactical tasks related with the after-sales spare part service. The principal concerns are customers, so the KPI metric review is in the top of different management tasks. Here, on-time delivery (OTD) is the typical metric used to measure the

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[8] A supply chain is a goal oriented network of processes and stock points used to deliver goods and services to customer (see Hopp (2008)). In this case the supply chain is composed basically by the OEM the Operator and the Repair Vendor. The Manufacture is part of the supply chain just in case the OEM needs new material to buy to allocate into the stock pool.

[9] Bar-Yam (2004) stated that if a single individual is in control of an organization, the organization is limited in complexity to the overall complexity of that single human being (in some manner, this is the same as Ashby's Law of Requisite Variety). Two ideas are illustrated by him: 1) there is a trade-off between complexity and scale, and 2) the success of the organization depends on both complexity and scale.

OEM performance. Important information to properly allocate and optimize resources is the entitlement database of each customer contract. This information is commonly used into the planning process and into the KPIs elaboration. Data analysis is also an important task to review around customer's behavior. This part of the process can be supported by a Customer Relationship Management (CRM) system.
In terms of material planning: demand analysis, TAT analysis, supply chain queue analysis, and stock optimization, are part of the analysis. This provides the basis for operations decisions in System 1 such as replenishment, rebalance, repair and defective collect priorities, new buys and scrap. All these analysis are managed by a Decision Support System (DSS).
In the supplier relationship management (SRM) system the goal is to streamline and make more effective the process between the OEM and the 3PL and the Repair Vendor. The financial management takes care of the inventory turnover metric, the gross and net inventory plan through the new buys and scrap process control and also the logistics and repair costs associated with all the customer contracts.
System 3* Audit allows System 3 Management to be in directly contact with operations. This provides a feedback loop which creates a continuous improvement environment. Once System 3 received all the information and, based on System 4 guideline, it established the critical success factors (CSFs) which will ensure the success of the services and establish the Master Operation Plan.
System 3 knows that sales forecast and other variables are always wrong. Following (Schlegel and Murray, 2010), Sales and Operations Planning (S&OP) is where team members of systems 1, 2 and 3 achieve consensus to operationalize strategies of system 4, corporate polices of System 5 and start scenarios planning, using data from ERP systems to identify historical behavior and uncertainties of all relevant factors, including: lead times, capacities, demand levels, productions schedules etc.
In section 7 of this chapter, we apply the fractal theory to characterize the number of failures of telecom cards in order to improve inventory management of spare parts considering bullwhip effect.

6.4 System 4: OEM's SC strategy management

System 4 is strongly future focused and more involved in strategic management. Here the service portfolio must be elaborated and this should be associated with strategic resources and information, e.g. the warehouse network to commit the service, the repair vendor network, budget, human resources and organization definition, market research, strategic planning, IT, etc. System 4 translates System 5 Board of Directors instructions and, in the other way, translates System 3 information.
Another important role of System 4 is to be in contact with the environment. Then, System 4 is the point where internal and external information can be brought together. System 4 needs to determine where on the efficient frontier to locate (see fig. 3). In order to analyze either external as well as internal data, System 4 uses different DSS or data mining tools to determine the trade-off into the efficient frontier curve for long-range plans.

6.5 System 5: OEM's SC board (policy purpose)

System 5 supplies a logical closure of the system as a whole and defines the identity and ethos of the organization. The main roles of Policy are to provide clarity about the overall direction, values and purpose of the organizational unit; and to design, at the highest level, the conditions for organizational effectiveness. One of the key conditions for organizational effectiveness relates to how the Strategy and Management functions are organized and interconnected. According with Bar-Yam (2004) "the rule of thumb is that the complexity of the organization has to match the complexity of the environment at all scales in order to increase the likelihood of survival"[10].

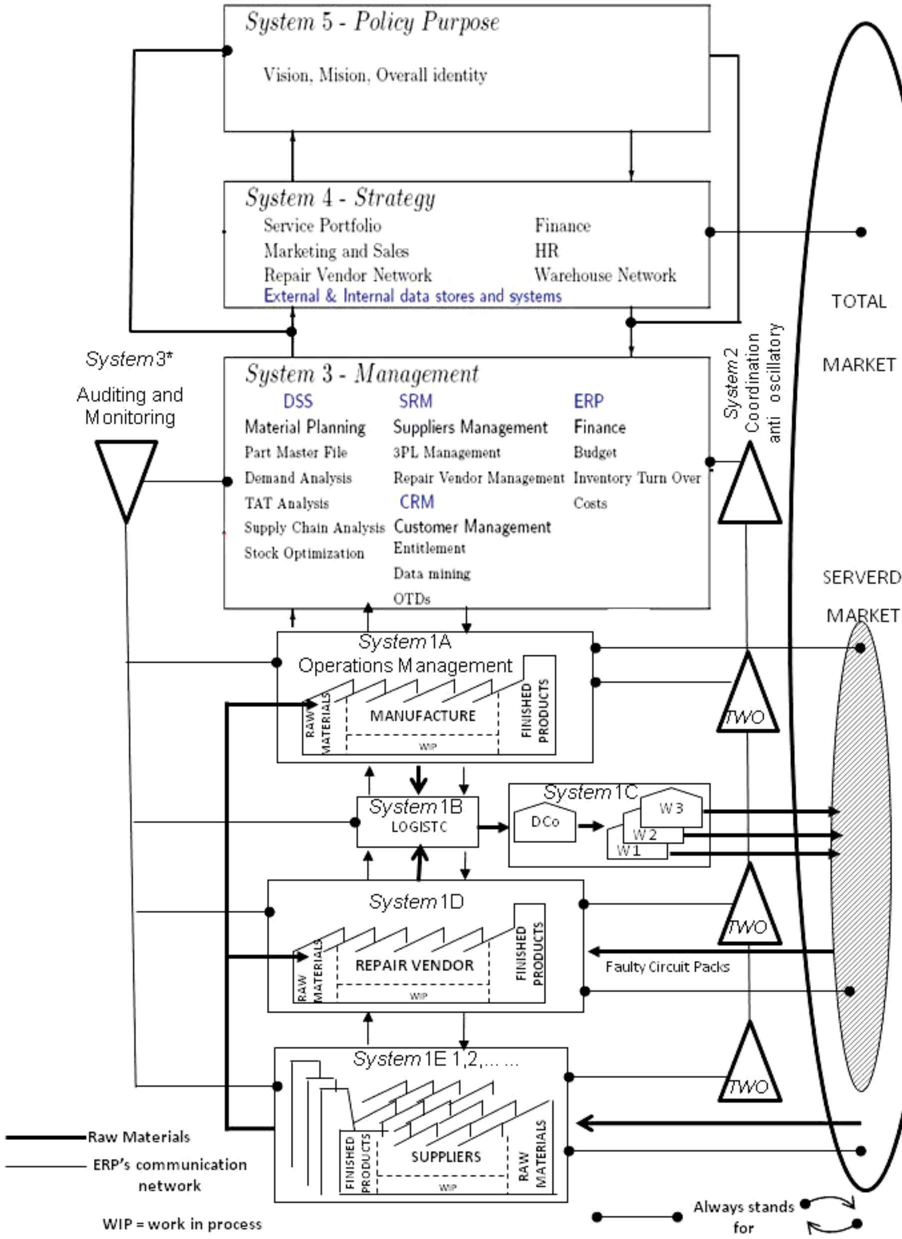

Fig. 4. The OEM's SC after-sales spare parts services according to VSM and ERP.

[10] Although System 5 organizational effectiveness concern is Strategy and Management, this rule should be apply and permeate through all the organization.

7. Bullwhip effect in after - sales spare parts supply chain, case: Telecomm firms

7.1 General description

The “bullwhip effect” refers to the phenomenon that experienced supply chains when replenishment orders generated by a stage exhibit more variability than the demand the stage faces. For instance, by examining the demand of Pampers disposal diapers, management people in Procter & Gamble realized that retail sales were fairly uniform, however the distributors’ orders issued to the factory fluctuated much more than retail sales (Lee, 1997a). Because all variability must be buffered, the bullwhip effect has important consequences for the systemwide efficiency of the supply chain. Hence, it is necessary to understand what cause this phenomenon. Lee, Padmanabhan and Whang (1998b), identified four factors that lead to the bullwhip effect: batching, forecasting, pricing and gaming behavior, which suggested some options for mitigate it. Bullwhip effect has been analyzed in academic for some time. This phenomenon suggests that demand variability increases as one move upstream in a supply chain. Forrester (1961) observed that factory production rate often fluctuates more widely than does the actual consumer purchase rate and stated that this was consequence of industrial dynamics. Sterman (1989) reported an experiment of a simulated inventory distribution system played by four people who make independent inventory decision without consultation with other chain members, just relying on orders from the other players instead. This experiment was call “Beer Distribution Game” and shows that the variance of orders amplify as one moves up in the supply chain i.e. bullwhip effect. Sterman attributes this phenomenon as misperceptions of feedback of the players.

Lee *et al*,. (1997b) analyzed the demand information flow in a supply chain and identified four causes of the bullwhip effect: demand signal processing, rationing game, order batching and price variations. By identifying these causes, the authors concluded that the “combination of sell through data, exchange of inventory status information, order coordination and simplified pricing schemes can help mitigate the bullwhip effect". Chen et. al. (2000) quantified the bullwhip effect in a simple supply chain of two stages. The model includes the demand forecasting and order lead time, which are commonly factors that cause the phenomenon. The work is extended to multiple stage centralized and decentralized supply chains. The study demonstrates that the bullwhip effect can be mitigate but not eliminated. Daganzo (2003, 2004) has been studied the bullwhip effect in the frequency domain. He argued that the bullwhip effect is trigger with all operational inventory control policies, independent of demand process but showed that advance demand information in future order commitments can eliminate the bullwhip effect without giving up efficiency under a family of order up-to policies. Dejonckheere *et al*., (2003) used control theory to analyze and illustrate the bullwhip effect for a generalized family of order-up-to policies.

The study of supply chain from the point of view of complex dynamical systems theory has started only recently (Helbing, 2008). Concepts from statistical physics and nonlinear dynamics have recently been used for the investigation of supply networks (Radons and Neugebauer (ed.), (2004)). Helbing (2003) generalized concepts from traffic flow to describe instabilities of supply chains. This work remark how small changes in the supply network topology can have enormous impact on the dynamics and stability of supply chains. In order to stabilize the supply chain, some strategies are mention on Radons and Neugebauer (ed.) (2004).

By simulation a supply chain model, Larsen *et al*. (1999) showed a wide range of nonlinear dynamic phenomena that produce an exceedingly complex behavior in the production distribution chain model. Hwarng and Xie (2008) used chaos theory through the Lyapunov exponent across all levels of a specific supply chain. They showed that chaotic behaviors in supply chain systems can be generated by deterministic exogenous and endogenous factors. They also discovered the phenomenon "chaos amplification", i.e. the inventory becomes more chaotic at the upper levels of the supply chain.
After-sales spare parts supply chains in telecom firms are use to support basically two services: Advance & Exchange (AE) of spare parts and Repair for Services (RfS).
This section studies only the dynamics of the AE service in one particular firm[11]. The AE service is trigger when a critical network element of the carrier[12] fail, then the Telecom Equipment Manufacturer (TEM)[13] must send to the carrier a good circuit pack from their

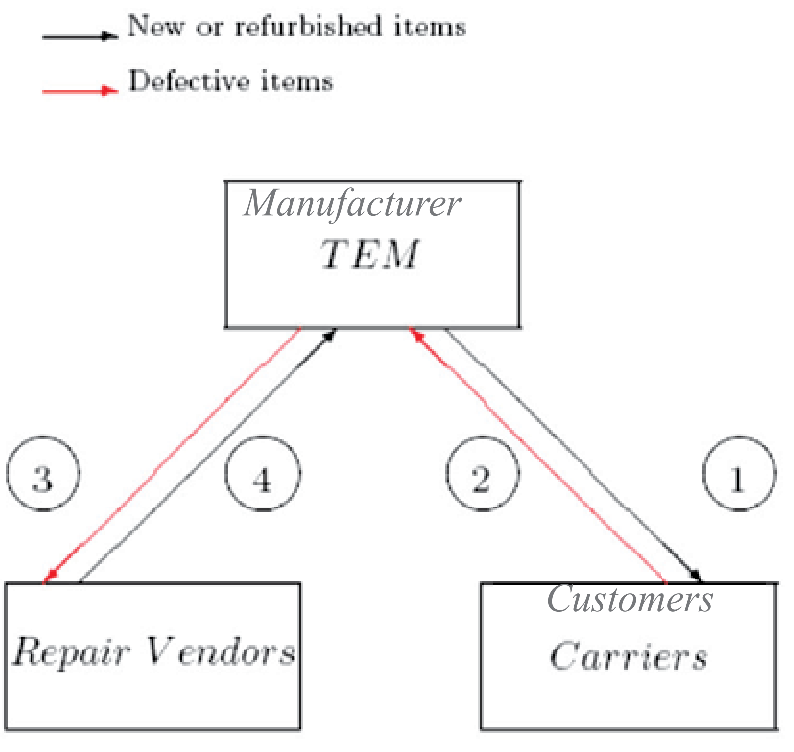

Fig. 5. Closed loop supply chain of repairable items.

[11] Because of confidentiality the name of the company and the customer is not shown in this paper.
[12] In the Telecom industry the carrier refers to the customer.
[13] In the Telecom industry the Telecom Equipment Manufacturer refers to the provider.

stock under a determined Service Level Agreement (SLA), once received, the carrier must return the faulty unit back to TEM's warehouse, so this one can be repair and return back to the pool of good stock (see fig. 5).

The activities that feed and consume the spare parts into the pipeline compose an enormously complex system. The study of complex systems in a unified framework has become recognized in recent years as a new scientific discipline. This approach studies how relationships between parts give rise to the collective behaviors of a system and how the system interacts and form relationships with its environment (Bar-Yam, 1997, 2004). The study of complex systems in a unified fractal framework has become recognized in recent years as a new scientific discipline. The fractal behavior study of complex systems consists in general, in three major approaches: theoretical, experimental and computational. The goal is to have the most parsimonious description of the phenomena under study and the most faithful representation of the observed characteristics (Morales *et al.*, 2010).

The after-sales spare part system to support AE services will be characterized applying fractal theory on the time series of each process described in fig. 5 of the supply chain.

7.2 Fractal analysis

Taking into account the different schools of complex systems, this paper will be focus only on fractals analysis, which is a branch of complexity theory. A fractal can be seen as an object or phenomenon under an invariant structure in different scales. There is no universally agreed definition of exactly what we should mean by a fractal but tow points are central: it should be an object with some type of non-integer dimension, such as Hausdorff dimension[14] (H) and it should be approximately (or statistically) self-affine (Mumford *et al.*, 2002).

The standard definition of self-affine said that a process of continuous time $Y=\{Y(t), t>0\}$ is self-affine if the distribution probability of $\{Y(t)\}$ has the same distribution probability of $\{a^H Y(at)\}$ for $a>0$ (Gao *et al.*, 2007).

The parameter H takes values between 0 and 1 and it is known as the Hurst exponent. This parameter measures the correlation persistence of data of the process a long time.

- For $0<H<0.5$, the process is said to have antipersistent correlation.
- For $0.5<H<1$, the process has persistence correlation and infinite variance.
- For $H=0.5$, the time series is said to be memoryless or short-range dependence.

To estimate H we use the method rescale range (R/S) analysis. This method allows the calculation of the self-similarity parameter H, which measures the intensity of long-range dependence in a time series (Mandelbrot, 1982). Mathematical calculation details are shown on Annex 1.

The time series are plotted using cumulative data of each echelon of the process of the supply chain (Daganzo, 2003) (see fig. 6). The vertical difference between two curves represents the queue of material which exists in the process and the horizontal difference means the elapse time one unit use to go from one echelon to the next one.

In order to avoid the bullwhip effect the value of H might be almost statistically the same in each echelon into the supply chain, i.e. that each curve in graph shown below might be statistically symmetric.

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[14] See the definition of Hausdorff dimensión in Barnsley (1988)

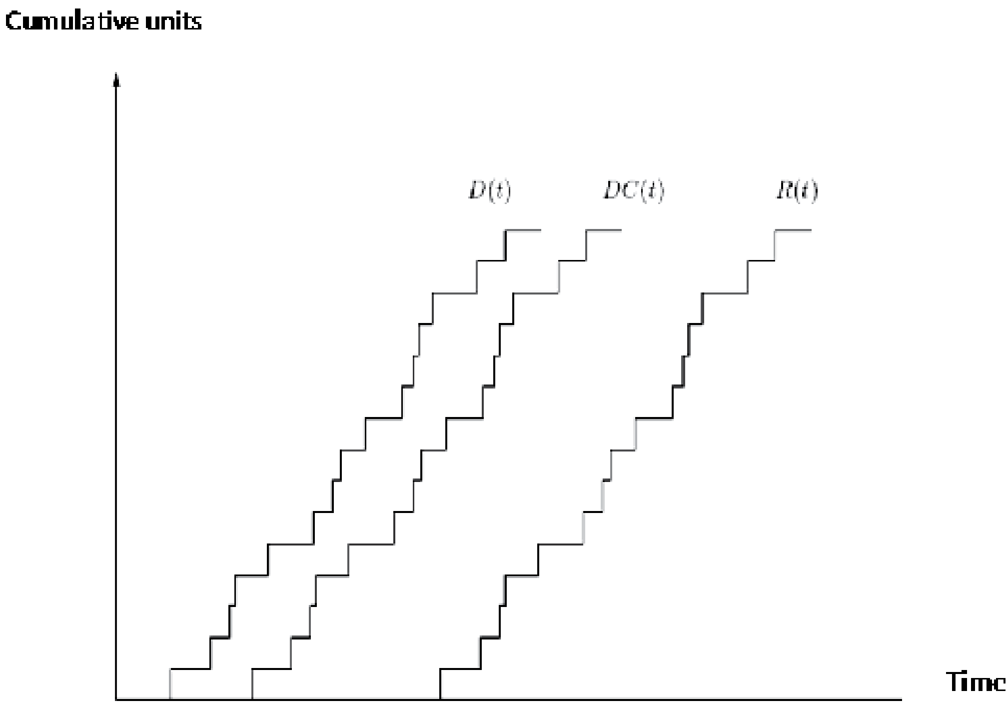

Fig. 6. Supply chain cumulative data of demand, collect and repair process.

7.3 Results

The time series encompassed one year of failures (demand of spare parts) of 4217 units. Unfortunately not all defective units were collected and/or repaired. Then, only 3617 units completed the entire process, i.e. since they were demanded until repaired. Fig.7 shows the cumulative data of the real time series of each process of the supply chain. We can observe on this graph that there is some symmetry between each process. However, some simple statistics of these time series (see table 5) show an increased in the variance between the demand and the other processes. This suggests the presence of the bullwhip effect in the supply chain[15].

	Demand	**Defective Collect**	**Inbound Repair**	**Outbound Repair**
Media	9.909589041	8.334101382	8.334101382	7.795258621
Standard Deviation	7.087757678	8.592998291	11.46805537	9.128734872

Table 5. Simple statistics of the time series of the supply chain

[15] This analysis considers a different perspective of traditional definition, where the creation of the orders is considered in the analysis and in this paper is the completion of them.

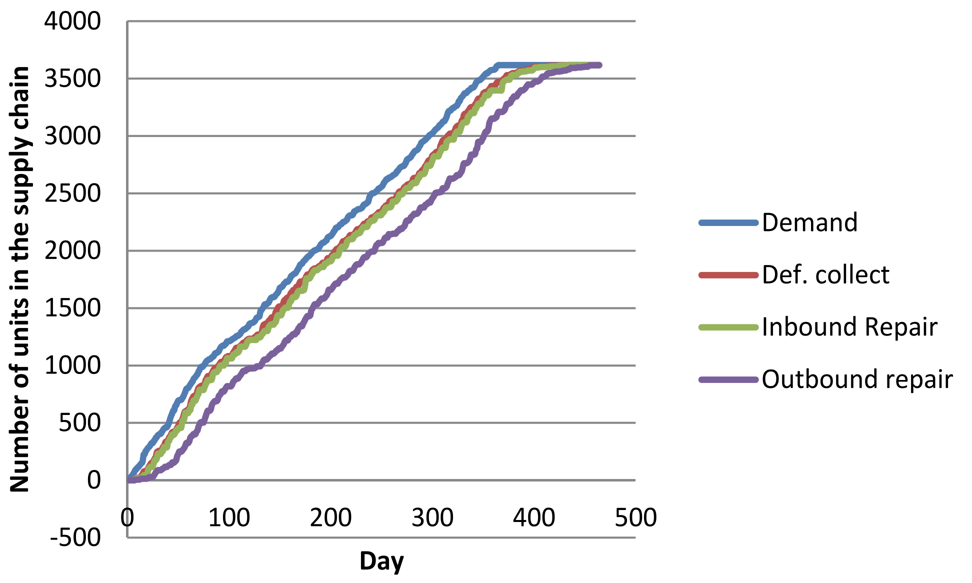

Fig. 7. Cumulative real data of the supply chain of spare parts.

Another way to look at the data is by calculating the difference among two cumulative curves of the process, i.e. the queue of material pending to be process by the following steps of the supply chain.

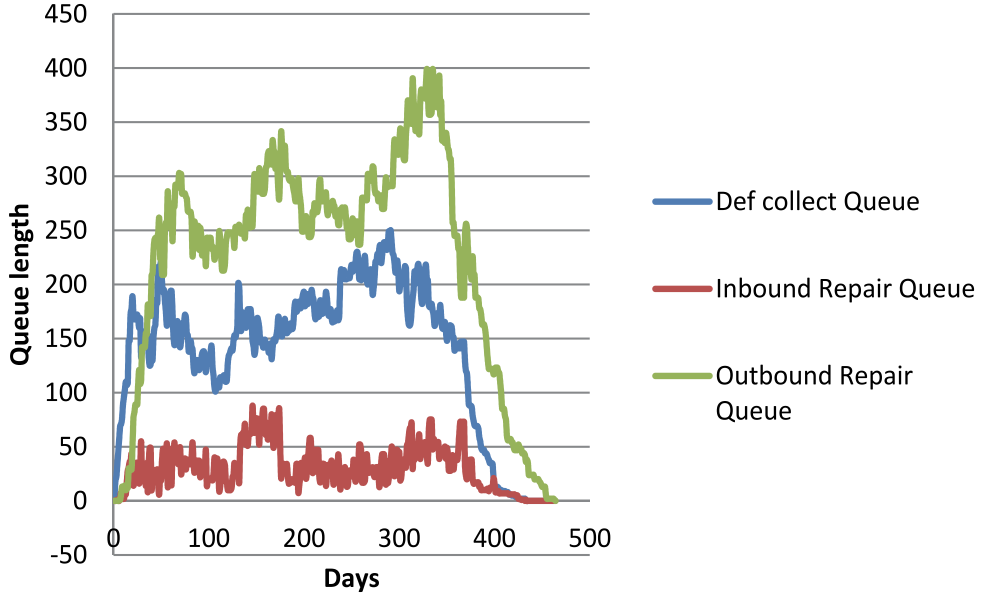

Fig. 8. Queue of parts pending to process in each echelon.

Fig. 8 illustrates the difference among each queue length. The repair queue has an average of 223.42 units and standard deviation of 105.03 units, which is the largest queue. The defective collect queue has an average of 147.70 units and a standard deviation of 60.91 units, which is the second largets queue. An the small one, is the queue related with the units pending to be inbound in the repair process with an average of 32.40 units and a standard deviation of 19.49 units. The formation of these queues are closely linked to the time and uncertainty of each process.

To conclude this analysis, the Hurst exponent estimated through the R/S method, suggests that the demand process in the AE service shows persistence with a Hurst exponent value of 0.8449, and the defective collect process indicates still the presence of persistence with a Hurst exponent value of 0.6481. However in the following steps of the processes, the value of the Hurst exponent decreased with a value close to 0.5, which suggests that they follow a Brownian Motion process (see Annex 2).In other words, it is notorious in this analysis that the system started to have strong long-range dependence but at the end it became almost memoryless.

Summary	**H**
Demand	0.8449
Defective collect	0.6481
Inbound repair	0.5164
Outbound repair	0.5649

Table 6. Hurst exponent value of each process of the supply chain.

In Annex 2 there are four figures that refer to the log-log graphs of the Hurst exponents analysis, computed with the Benoit 1.3 software, for Demand, Defective collective process, Inbound to repair process, and Outbound process.

These results come up with a different way of detecting the bullwhip effect. By intuition, the bullwhip effect would not occur if a statistical symmetry between each time series of each process in the supply chain is not broken, but unfortunately in this case, current models in the literature has this assumption (Sherbrook, 2004; Muckstadt, 2005).

8. Conclusions and recommendations

The Systems Science perspective provides a framework to better comprehend the Supply Chain Management System. This approach described how to adequate the VSM and ERP to the case of OEM's SC of a Telecom Firms. Each subsystem of the VSM represents several functions from the operations to Board of Directors. The idea of this work is to provide also the ability to balance both internally and externally factors, making the SCM adaptable to changes.

Bullwhip effect is a phenomenon experienced by supply chains when demand at the top tends to exhibit more variability than demand at the bottom. This work provides new insights to develop a new model of the spare part management which capture the characterization of the supply chain.

Some recommendations Follows:

1. Avoid barriers due to lack of trust between suppliers and manufacturers

2. Collaborate with suppliers to interface the ERP modules to their production systems
3. Integrate ERP with all Tiers of critical Suppliers
4. Educate an train suppliers in operation of specifics ERP modules such as: MPS, MRP, BOM, IM,CRP, DRP and S&OP
5. Other concepts from systems theory, systems dynamics, knowledge management, complex systems, etc. can also be analyzed in a future research to incorporate methodologies or concepts that help better understand the dynamics of the supply chain service part system; however, this initial proposal can be use as a guide for diagnosing.

Annex 1

The fractal analysis begins with dividing a time series of length *L* into *d* subseries of length *n*. Next for each subseries $m = 1, ..., d$: 1° find the mean (E_m) and standard deviation (S_m); 2° normalize the data ($Z_{i,m}$) by subtracting the sample mean $X_{i,m} = Z_{i,m} - E_m$ for $i = 1, ..., n$; 3° create a cumulative time series $Y_{i,m} = \Sigma^i_{j=1} X_{j,m}$ for $i = 1, ..., n$; 4° find the range $R_m = \max\{Y_{1,m}, ..., Y_{n,m}\} - \min\{Y_{1,m}, ..., Y_{n,m}\}$; and 5° rescale the range R_m/S_m. Finally, calculate the mean value $(R/S)_n$ of the rescaled range for all subseries of length *n*.

It can be shown that the R/S statistics asymptotically follows the relation $(R/S)_n \sim cn^H$. Thus the value of *H* can be obtained by running a simple linear regression over a sample of increasing time horizons (Weron, 2001).

$$\log(R/S)n = \log c + H \log n.$$

Annex 2

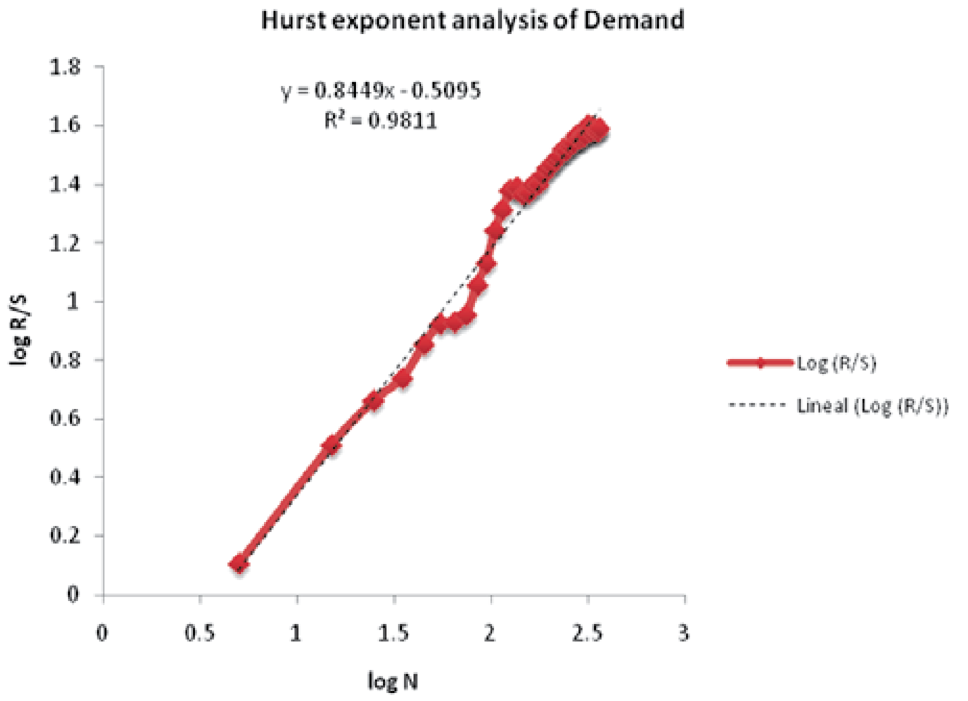

Fig. 9. R/S analysis of demand data (*H*=0.8449).

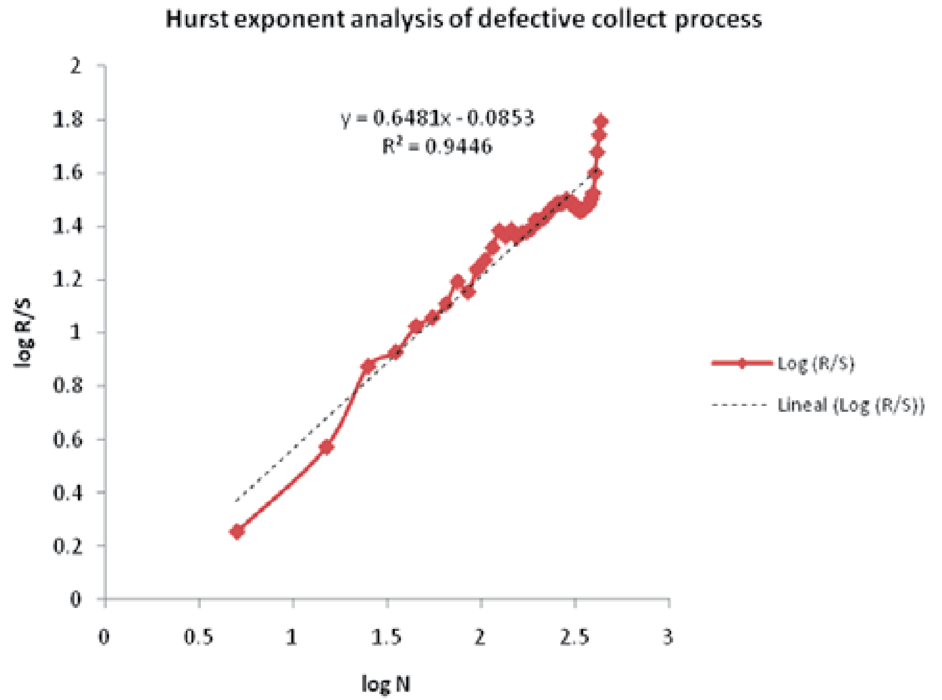

Fig. 10. R/S analysis of defective collect process data (H=0.6481).

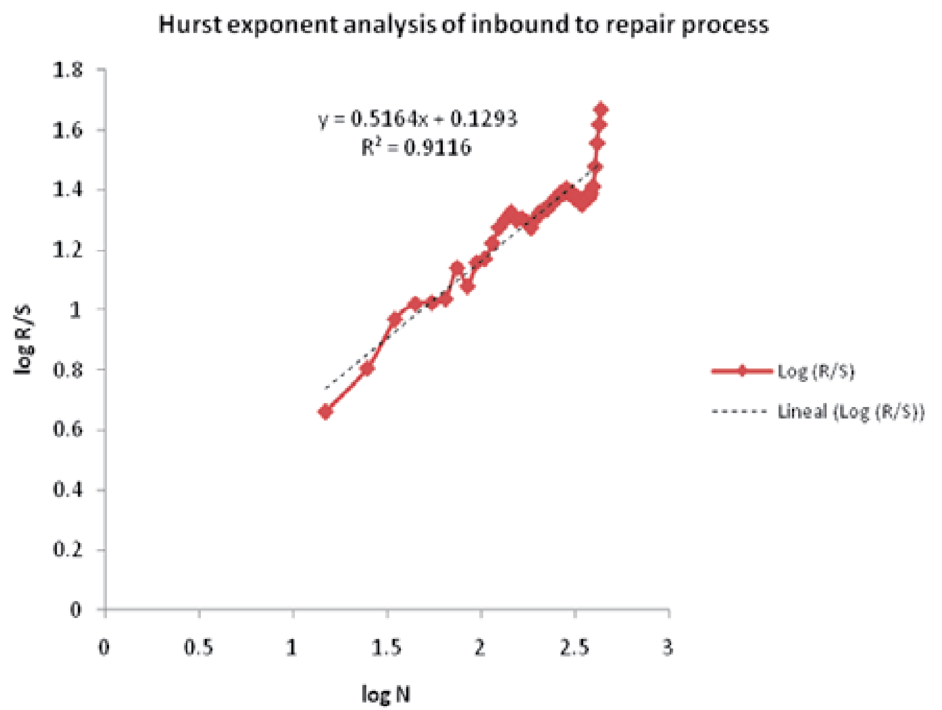

Fig. 11. R/S analysis of inbound to repair process data (H=0.5164).

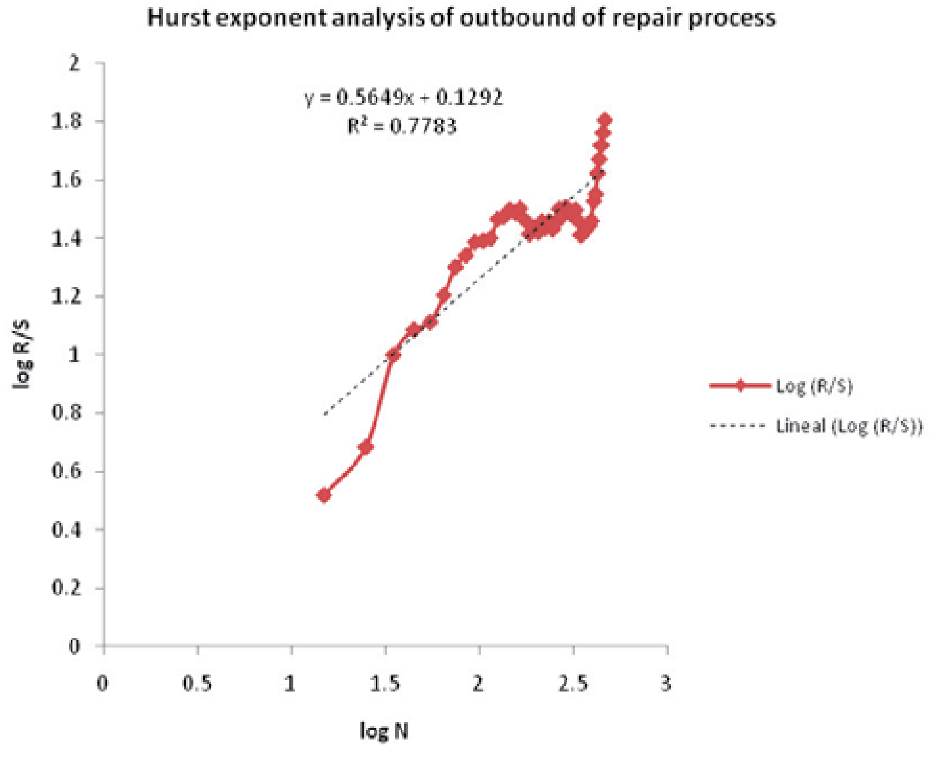

Fig. 12. R/S analysis of outbound of repair process data (*H*=0.5649).

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2

Supply Chain Management in Industrial Production: A Retrospective View

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1. Introduction

In the manufacturing industry the problem of setting up and managing supply chain relationships has recently become of an unprecedented complexity and importance. Today even the most common products are obtained through processes that are highly complex as regards the production technology, the required knowledge and the number of stages involved. The processes in the value chain are spread upon several different technological areas and they require the application of specialized and advanced knowledge in all phases. Consequently firms involved in the development of a new product must coordinate with the other actors in the chain from the earliest stages of design and engineering.

In this chapter we present a retrospective analysis of the evolution of managerial perspectives on supply-chain management (SCM) in industrial production. In our view the philosophy underlying the management of Purchasing and Supply (PS) in industrial firms has reflected, over time, the managerial paradigm at the basis of the strategic choice of the firm. Thus, as well as for all main firm's processes PS has evolved in order to provide an adequate response to changes in the competitive environment. From an early stage, mainly characterized by a major attention to costs and contract terms, supply policies have developed to become part of articulate relational strategies based on variables such as:

- the positioning of the firm along the production chain, hence the identification of core activities opposed to those that can be conveniently outsourced,
- the strategic assessment of the role and the relevance of the various suppliers,
- the suppliers' potential for technological and innovation development,
- the actual reversibility of investments on a specific relationship and/or on a specific technological trajectory,
- the risk associated with dependency on suppliers and the opportunities of multiple and/or parallel relationships, and so on.

Generally speaking, SCM activities are focused on creating value, either through innovation in processes and through the improvement of products and services to the end customer.

Our aim is to summarize the reasons that led to the transition from the traditional procurement policies to the SCM approach and the main variables involved in the process of defining SCM relations.

The birth of the concept of SCM lies in the growing importance assigned to procurement and logistics, such that they become strategic elements of operational management (Oliver & Webber, 1982; Kraljic, 1983). However, the logistical and operational aspects and the strategic ones have evolved and have been dealt with separately until the '90s (Tan, 2001). The concept of SCM has several definitions; Mentzer et al. (2001) identifies three main categories of SCM definitions in literature: a) a management philosophy, b) the implementation of a management philosophy and c) a set of management process. Cooper, Lambert and Pagh (1997) argue that the concept of SCM is, to an extreme, used as a synonym for logistics and, at the other end, as all-encompassing business integration. In fact some authors (e.g. Ellram & Cooper, 1993; Lummus & Vokurka, 1999; Lambert & Cooper, 2000) somehow equate SCM with the management of anything that stands between the raw materials and the product delivered to the final customers, including after sales service. In brief, since academic literature has probably identified for the SCM all the possible definitional combinations that are between the mere logistics and business operations as a whole, to list all the past and present definitions of the concept would not be too meaningful. Other contributors (e.g. Harland, 1996; Croom et al., 2000; Svensson, 2002; Chen & Paulray, 2004) has provided wide reviews of the literature in this field. Such a variety in the conception of SCM is aided by the fact that SCM involves many fields of analysis and by the fact that it can be approached from different perspectives. Moreover, in the everyday experience firms are far from having a unique and/or a uniform approach towards this matter (Frohlich & Westbrook, 2001), but often SCM activities are focused on a limited set of supply & production stages (Fawcett & Magnan, 2002).

In this chapter the conventional procurement is labeled as "traditional" or "Purchase & Supply" (PS) approach, while we call SCM an advanced managerial approach to the management of supply chain relationships which aims to make supply activities coherent with the firm's strategic objective. Basically, we agree with Svensson (2002) who argues that SCM can be seen as a management philosophy; according to this author, the SCM approach is rooted in the functional dependency that ties firms as a result of their specialization and complementarities in production networks. Of course, SCM philosophy implies an effort that is justified, for instance, in the relationship between an assembler and its first-tier suppliers, or anyway in relationships that are more relevant that a mere purchase.

According to the various interpretations, SCM is of an intermediate complexity between PS and the organization of any activity connecting the raw materials and the product delivery, then it reasonably remains a process which require a considerable degree of effort and involvement. Therefore, it is not convenient to adopt an advanced / complex SCM approach in all relationships with third parties (Tan, 2002). Better try to differentiate the approaches according to the characteristics of each relation, specifically according to their impact on competitiveness. Williamson (1981) suggests the choice between make or buy (in fact, the elementary level of choice as far as the PS policies are concerned) to be taken by evaluating the supply specificity and the frequency of transactions. Kraljic (1983) identifies different policies according to the strategic importance of supply and the complexity of supply market. Krapfel et al (1991) classify supply relationships on the basis of the commonality of interests and of the power position; then describe six different policies, from the simple bargaining to strategic agreement, to be implemented according to each specific type of relationship. Olsen and Ellram (1997), propose to manage the supply portfolio taking into account four main set of factors: factors influencing the strategic importance of supply, factors describing the difficulties in managing the purchase relationship, factors influencing the relative supplier attractiveness and factors describing the strength of the relationship.

Kaufman et al. (2000) underline the differences in possible collaboration policies arousing from the technological linkages between supplier and customer.
Firms could probably obtain more advantages from an approach to supply relationships that distinguish different policies for each relation rather then adopting a generic method. Therefore, some key points should be highlighted in order to better understand to what extent the SCM approach is actually coherent with, and/or necessary for, the fulfillment of the firm's strategic objective:

- SCM emerges as the systemic response of the firm to the increasing complexity and uncertainty of the environment; such complexity pushes towards the adoption of a holistic perspective about process management (Davis, 1993; Svensson, 2002).
- SCM is embodied in the integration of the supply process within the strategic analysis process. It involves/affects strategic decisions and it has (or can have) a specific relevance for the competitiveness of the firm (Waller, 1999).
- SCM is a process far more extensive and pervasive than the traditional purchase & logistics function. It assumes the possible role of third parties in supporting the competitiveness of the firm and implies cross-boundaries coordination processes, therefore it underlies concepts of network management (Chandrashekar and Scary, 1999; Tan, 2002).
- SCM tries to overcome the traditional duality between hierarchy and market. the first typically has a connotation of flexibility and reversibility, while the latter is generally put in relation with benefits of control and of stability (Thorelli, 1986).
- SCM approach, when actually applied, requires a strong commitment and a relevant effort by the firms involved, since once the SCM relationship is implemented the switching cost is relevant both for supplier and customer, while an eventual poor performance of one of the contractors will affect its partners (Tan et al., 2002).

2. From purchase & logistics to supply chain management

In the second half of the 20th century the evolution of the industrial competitive environment has deeply modified the reference framework of supply-chain relationships.
Until the early seventies the issue of supply relationships has received a limited attention. The dominant paradigm was focused on mass production and little room was left for strategic cooperation. The emphasis was rather on the advantages of vertical integration on the one hand and in the bargaining power on the other.
During the oil shock of the '70s the incidence of logistics and raw materials on costs breakdown increased dramatically, bringing attention to criticality in purchase & logistic activities and towards the development of tools aiming to improve the efficiency of operation management, like the earlier Material Requirement Planning systems (MRP).
Efficiency remained the buzzword until the early eighties, when it was sided by concepts oriented to innovation and to customer satisfaction: time-based competition, product life-cycle, value for customer, and so on. Effectiveness and quality (variously defined) started to pose the issue of an evaluation of supply relationships which goes beyond the mere costs analysis. Specifically, the evolution of production systems that started around the eighties, with the shift from the mass production paradigm to the "flexible" one, has increased dramatically the intricacy of product and process architecture. Throughout the nineties the spread of the lean philosophy, together with the globalization of markets, contribute to drive both theory and practice to a constant improvements and broadening of the SCM

concept (Cooper 1993). In the common orientation towards the application of the lean philosophy within and between firms, SCM comes to fore as a natural evolution of processes towards a general integration. At the same time, the opportunities brought by the technological hybridization of products (that is opportunities deriving from incorporating complementary technologies within products in order to enhance its features and performance) gained a critical role as a competitive advantage. In those industry whose products are complex and require the confluence of technological expertise and advanced knowledge in several technical and scientific areas, the policies of SCM are significant and pervasive enough to require a managerial coordination involving not only procurement and operations, but also functions such as marketing, R&D, and the financial area.

In a market avid of innovation, whose demand is highly fragmented and volatile, firms continuously have to update their knowledge on technologies and on the competitive environment. Decision-making processes involve a large number of variables and this increasing complexity is managed through a tendency towards specialization. In fact, faced with the difficulty of effectively supervising all the necessary expertise, the firm might benefit from partners who can contribute with their knowledge to its production processes (Handfield et al, 1999; Wagner & Hoegl, 2006).

The technological complexity of processes and products makes it convenient to outsource to specialized providers the production of components and parts that need continuous innovation. Strategic suppliers are then invited to contribute with their own knowledge to the competitiveness of the final product and therefore they participate, more or less directly, to the formulation of operational and strategic plans of development of customer firm. The assessment of suppliers' capability to improve the competitive advantage of the network becomes a major parameter for the selection of providers.

Consequently, regarding the innovation processes the attention moves from the presidium of peculiar patents & technologies towards the capability of founding value network and of applying combinatorial knowledge.

More recently, the major attention paid by markets and stakeholder to the sustainability of products and processes has pushed leading firms to introduce further and even more selective criteria in the choice of suppliers' park. Nowadays leading companies are asking their suppliers to develop programs to reduce emissions and, in general, to certify their commitment to corporate social responsibility and environment (Sristava, 2007; Carter & Rogers, 2008; Sukla et al., 2010).

The list of tasks assigned to SCM includes all the traditional purchasing & logistics, plus:

- the definition of criteria for supplier selection and for the evaluation of their performance;
- the definition of different policy supply for different types of supply;
- negotiation and trading;
- the coordination of complex and diverse activities carried out by third parties, such as the co-design and co-engineering of specific components to be manufactured by the supplier;
- the convergence of supplier and customer on targets which might be partially or totally in contrast, such as the decision about the innovation trajectories to be implemented;
- the joint development & innovation of new products, processes and forms of distribution;
- the management of cross-boundaries investment,

- the development of programs and joint projects to improve the service to the end customer
- the strategic analysis of market and technological trajectories.

The traditional approach to purchase management is not abandoned; rather it is combined with a perspective of value creation. This perspective goes beyond the traditional PS criteria since it introduces: i) principles for the assessment of the strategic capability of the suppliers to create value for customer, rather than just being able to fulfill the assigned task; ii) a tendency towards a unified analysis and coordination of processes occurring outside the firm; iii) the spread of customer's satisfaction principles to all ring of the chain. The traditional supply approach, mainly cost-oriented, remains in use for simple, standardized, and low-value goods.

The peculiarities of both PS and SCM are the elements driving the most opportune policy to be adopted, depending on the type of procurement. At the same time, such peculiarities describe and explain the transition from one perspective to the other as a consequence of the increasing complexity presented over time by the competitive environment.

The two ideal-typical approaches to supply relationships here described certainly have common roots but in fact present significant differences (see table 1) as a result of the different set of problems and the different degree of complexity they have to solve.

	Traditional PS approach	**SCM approach**
Key-drivers of vertical integration policies	Technological skills, relative efficiency of the involved processes	Technical skills, Know-how, coordination and relational capabilities (network management)
Variables discriminating make-or-buy decisions	Production costs compared to purchase & transaction costs	Present and future competitive capability
Main make-or-buy decision criterion	Breakeven analysis	Breakeven analysis, strategic constraints and opportunities
Key-drivers in supply policies	Cost of supply	Cost of supply, firm's strategic objective, long term competitiveness
Supply policy approach	Bargaining power, protection of firm's interests	Bargaining power, protection of firm's interests, product and process prerequisite, reciprocal benefits.
Main objectives of the negotiation	To maximize firm's share of value added (zero-sum game)	To maximize value for customer and for the supply chain (positive-sum game)
Relationship regulation and coordination	Contractual formalization of performance to fulfill	Contractual formalization and definition of common interests / objective
Criteria for supplier selection	Quality/cost ratio, negotiation power	Quality/cost ratio, negotiation power, innovation capabilities, technological and organizational knowledge

Table 1. Main differences between PS and SCM approaches

3. The supply relationship according to the traditional approach

Four key-aspects characterize the ideal-type of the PS perspective.

A. *Skills and efficiency are the main determinants of make-or-buy strategies*. Key-decision about the extension of vertical integration and about the positioning along the production chain are taken primarily according to technical knowledge and to the expected relative efficiency, the latter measured by the comparison between the sum of market costs and the costs of internal production. According to this criterion vertical integration is a feasible and effective solution if the firm has the technical capability to implement the upstream production stages with at least the same efficiency of the firms that already operate in those stages. On the contrary, if the company can find components, parts and pre-products on the market at a price that is lower than the cost of internal production, then the firm adopts a policy of outsourcing and focuses only on higher value-added stages of production. Once assured the availability of resources and know-how, the key information for this make-or-buy decision, comes from an analysis of breakeven. No evaluation about strategic opportunities or threats is taken into consideration in such perspective.

B. *Short term, cost-based perspective*. Decisions on the supply policies are taken mainly by evaluating the economic efficiency of each transaction. Each company formalizes its objectives, then directs the negotiation with the third parties assuming such objectives as a reference point, given the constraints imposed by the autonomous decisions of the counterparts. In other words, in this view each contractor evaluates its best strategy in advance, and then negotiates with its suppliers and customers by putting its own constraints and challenging the counterpart on the basis of negotiating power, each one of the parties aiming at bringing the agreement towards its own optimal situation. Other possible elements are relatively less important: the potential impact of the contract on future costs or on competitiveness, the idiosyncrasy of the relationship, the reversibility of the investments.

C. *Win-lose oriented relationship*. The negotiations are based on bargaining power and oriented towards the appropriation of the value added. The prevailing attitude in the negotiation is inspired by the rules of a zero-sum game in which the increase in the share of value added of one contractor is at the expense of the others. In such view neither strategic advantages nor synergies take place in supplier-customer relationships. The managerial perspective that is framed in this model tends to interpret the system as the mere sum of its parts. The coordination of the supply chain is the sum of bilateral decisions and negotiations among the only firms that are in direct contact with each other. The chain's activities are coordinated sequentially, usually through adaptive response to the requests of the final rings. There is no cross borders management activities and the main coordination levers are: i) vertical integration, ii) the production of supplies on the customer's specifications or, conversely, the make-to-stock production, iii) the application of bargaining power.

D. *Contract-oriented commitment*. Contracts, and consequent firms' behaviors, tend to pay more attention to the compliance with contract terms than to the improvement of performances. The supplier-customer relationship is almost entirely framed within contractual rules that are strongly committed on mutual protection from possible contingencies and opportunist behavior. The majority of clauses are focused on transaction conditions and on the solution of possible exceptions or unexpected events. Aiming at preventing the emergence of situations that could radically change the conditions of the exchange, contracts seek to formalize *ex ante* all possible contingencies relating to the specific relationship.

This does not imply, however, that the relationship must necessarily be rigid, or prevaricating. The agreement can be declined in many ways, can be written in very simple forms up to an extremely complex structure, and may provide numerous exceptions aiming at renegotiating the terms of the deal to face situations of potential uncertainties. Contracts can also be determined according to a logic of collaborative and mutual concessions, as in the case of a partnership. Nevertheless, formalization and predictability are the central reference point for the terms of agreement, and uncertainty is managed through an attempt of predicting rather than leaving room for flexibility and re-negotiation.

The approach to supply relationships which emerges in this traditional view might be weak or effective depending on the specific context. In theory, if properly applied this approach allows the company to evaluate the different possible relationships of supply from a very self-centered perspective. It reduces the risks related to uncertainty and opportunism by establishing contractual links and activating instead adjustment mechanisms for those factors on which uncertainty weighs more.

It is an effective approach in a broad range of situations, since in many cases firms can not interact with the rest of the chain or have no interest to do otherwise, such as in cases of sporadic and minor purchases. For instance, non-specialized companies, small businesses, firms suffering from preponderant bargaining power, often work in contexts where the economic efficiency of the classical PS approach (with all its many improvements that have led to define a large number of type of arrangements, of brokerage, of facilitators, etc..), works very well since it keeps their supply chain relationships efficient and effective.

On the other hand, the ideal-typical PS approach shows limited or otherwise unsatisfactory effectiveness in those situations where more intense and pervasive relationship are requested to gain a competitive advantage, due to the dynamism and complexity of the market. Of course, in management we often hear "the increasing complexity of environment" or the "increasing competition" to be the mother of all changes and of any new trend. However, we think that the crucial role in settling the conditions for the shift towards SCM has been played by relatively few phenomena.

4. A different order of complexity

In a context of rapid and radical changes such as those that have invested the majority of the industries, the strategic intelligence is required to extend its range of analysis to the implications of different choices of supply-chain positioning. In our view the evolution of the philosophy underlying the SCM reflects, over time, the managerial paradigm at the basis of the strategic choice of the firm and some specific structural conditions of the market. Specifically, the main drivers of changes that led to the transition from the traditional PS towards the SCM approach can be traced in the increased uncertainty and criticality of the supply activities in general, even in cases that should instead be considered routine activities.

Due to the growing dynamism of markets and technology, and the consequent systemic instability of the competitive environment, three critical sources of complexity can be identified:

- The interdependence between various stages of the production chain increases as a result of firms' focus on core competencies and of the diffusion of the lean production principles.

- The coordination of upstream and downstream phases requires technical and organizational efforts that have the connotation of long-term investment rather than that of a purchase / sell contract.
- The control upon all stages of product development assumes a strategic importance but vertical integration strategies face new barriers; firms are therefore forced to look for different ways of quasi-integration.

The interdependence of the suppliers' and customers' production processes has increased significantly together with the diffusion of lean concepts in production. The interdependence increases the need for coordination and for a comprehensive view of the strategic consequences of supply decisions. Generally speaking, the application of lean principle requires, among other things, an intense coordination and the sharing of operational information between supplier and customer, mainly with the goal of: i) reducing time-to-market, ii) reaching a higher rate of innovation iii) reducing the life cycle, iv) shifting from a make-to-stock logic to a build-to-order one, v) increasing customization. In this evolution the crucial factor is that consumers are more and more demanding as regards timing, innovation, quality, variety and customization. Pressed by the demand, firms are forced to shorten the product life cycle, to increase the rate of innovation and to boost differentiation of products and services. At the same time the fierce competition doesn't leave significant leeway for price policies. In addition, as a result of frequent technological innovation, products and services have assumed a very high level of complexity, so that even commonly used products are obtained through a process of design and development which involve different firms highly specialized in their phases. Consequently, a higher reliance on suppliers is required, since the client firm become vulnerable on non-core activities developed by the supplier (Prahalad & Hamel, 1990). In order to exploit supplier's know-how and innovation abilities, the firm involves the supplier in the decision- making processes related to new products development (Wagner & Hoegl, 2006; Roy et al., 2004). Information about plans and production processes are shared by both parts and the contractors activate specific units to assure the coordination and the exchange of information, giving birth to a "strategic integration" process (Volpato & Stocchetti, 2002), that is an integration of the strategies of separate firms through the definition of common goals about product development, customer's satisfaction performances, etc. The strategic integration is effective in reducing the time-to-market, through the elimination of idle times during the R&D and engineering process, as well as in reducing failures and second thoughts during product's development (Flint, 2004). Of course such a pervasive relationship arises a number of issues including, to name the most delicate: i) the issue of transparency, about the mutual possibility to track time, phases and cost of partner's production process, ii) the problem of defining the control and supervision responsibilities with regard to the stages involving the shared resources, iii) the sharing of responsibilities, costs and benefits arising from the development of joint projects.

In conclusion, a strategic integration relationship has the typical features of long-term investments; it requires an analogue process of evaluation, negotiation and goal setting.

Another crucial developing factor is the increasing strategic relevance of supply policies and of make-or-buy decision itself. Supply chain relationships, in fact, gained a strategic importance among firms' processes since they ultimately determine the firm's ability to create value for itself and for the whole chain. Consequently, the control over performance variables (like quality, time to market, innovation, etc.) becomes critical. In the traditional view the full control over critical resources is obtained through vertical integration, but when the competitive environment becomes unstable, particularly when the rate of innovation in processes and products is particularly high, the quantification of costs and benefits of vertical integration is subject to great uncertainty. Even the most structured and comprehensive evaluation of cost-effectiveness, in fact, cannot give answers on the side of the strategic implications and about the possible reversibility of the conventional make-or-buy decision. Thus, intermediate forms of coordination between market and hierarchy are taken into consideration, with the aim to face uncertainty with flexibility.

In such context several elements of uncertainty arise, specifically:

- uncertainty regarding the development of costs of resources, that has a significant impact on the efficiency of processes and influences not only the choices with respect to production technology, but also the vertical integration decisions;
- uncertainty about the evolution of technology embodied in the components. When components technology requires highly specialized processes and / or peculiar know-how, supply decisions almost always involve the choice of a technological trajectory, with a series of long-term implications on the market positioning of the product and its market competitiveness.

To better understand this aspect one can consider the supply chain as a system that replicates, on a wider dimension, the internal value chain of the enterprise. Both the company and the supply chain can be seen as a sort of complex mechanism in which a series of coordinated activities are carried out in order to generate added value and margins, in a word to create "value". Each link in the chain has its *raison d'être* in the fact of being part of a wider process aiming at a definite final result. Indeed, the value of the output of a supply chain depends on the ability of each firm to coordinate its activities with all the others involved in the same chain.

For instance, despite the technological excellence of its products, a car producer who wants to develop an electric vehicle would hardly be able to create durable value (both for customers and the company) in absence of a developed supply chain of companies in the battery & electronic industry. The actual competitiveness of both the carmaker and the supplier depends on the reciprocal coordination / process & products integration and on the capability to fulfill final customers' requests. On the other hand, once a whole set of product is based on the proprietary technology of one specific supplier, the relationship with this supplier becomes highly idiosyncratic in both directions. This is the case, for instance, of the Renault/Nissan group, who has developed models of electric cars which can substitute the entire set of batteries thanks to a specific technology designed & developed by a third company named "Betterplace". On one side this new technology has an advantage in that overcomes a typical weakness of electric cars (the long time required for full recharge). On the other side, to introduce and develop such a radical change in the industry, highly idiosyncratic investments are required (development of the platform and its widespread diffusion), generating sunk costs that could not be easily recovered in case one or both companies decide to withdraw. In this case the choice of the supplier comes with the choice of a specific technological trajectory and vice versa. Assessing costs and technical quality of the available alternatives is just part of the problem, since it is also necessary to evaluate elements that require a scenario analysis, like for instance: competitors' reaction (what if no other carmaker adopt the same platform?), degree of improvement of traditional technology (what if the time for a full recharge at the plug decreases radically? What if new batteries are developed?), chances for competing innovation (what if a new kind of hybrid car is developed?), and so on.

When the competitive and technological environment is characterized by high uncertainty the "make" alternative suffers from the risks related to direct investment in research and development, while the "buy" alternative suffers the risks of technological dependence and the limited differentiability of the product on its key components. In both cases the decision will affect the competitiveness of the product, thus implying the involvement of several other functions in the firm: marketing (for demand forecasting, customer's analysis, product positioning, and so on), R&D (for the analysis of alternative technologies, their possible developments, etc..) and production (product engineering, analysis of the process, estimate of material requirement and costs, etc.). In short, supply policies shouldn't be restricted to the purchasing manager evaluation, but they require the involvement of top management and a strategic overview of the various possible occurrences.

SCM then emerges primarily as a response to those situations involving the development of a pervasive relationship with suppliers, such as for instance: choosing a peculiar type of production process in relation to the expected trend of the cost of resources; the choice of a new plant location in relation to the development of regional logistics and productive infrastructure; the costs of local resources, and so on. In these cases the supply relationship are an issue of great importance since it heavily affects the range of feasible options, the possible future conversion to different technologies, the profitability of new plants or new locations. The complexity of a make-or-buy choice in such a context, in which the survival of earlier decisions or the possibility to correct errors of planning is far from being guaranteed, suggests that the evaluation of alternatives is a matter of strategic analysis even more than a matter of cost.

However, up to the '70s, the growing interdependence of production processes and the increased need for coordination mentioned above would have been solved, in the majority of cases, through a choice of vertical integration. Still now, large companies who have access to wide financial resources and who have an adequate organizational and managerial structure would in fact take the in-sourcing options into consideration. However, over time in many industries the degree of vertical integration of enterprises has decreased dramatically. The increasing complexity of products and their hybrid technology (i.e. the convergence of different technologies such as electronics, chemistry, mechanics, etc..) entails the adoption of increasingly sophisticated production processes. Therefore the adoption of highly specialized skills and knowledge is necessary and/or more cost-effective. Such specialization, in an era of rapid proliferation of technological innovations, discourages the vertical integration: i) the investments required to remain updated in several fields of R&D are not justified in comparison with the possibility to partner with specialized companies; ii) investments are highly idiosyncratic, while partnerships could be changed according to the technological trajectory and standards selected by the market over time; iii) the integration of a specialized ring of the chain increases the overall risk since the higher the number of alternatives the faster their development, the higher the failure rate of new products.

All of these reasons on the one hand pose new problems to vertical integration as regards risk, costs, technical and organizational capabilities, then limiting the number of feasible options. On the other hand they bring the terms of the comparison on new and quite different dimensions, putting in evidence strategic opportunities and threats instead of quantifiable costs. Contrary to the assertions of the traditional approach, which suggest to follow the vertical integration strategy for critical and specialized parts, the firm may find more convenient to outsource also critical and tailored parts, while avoiding a relationship of dependency on the supplier (Ellram 1991).

In essence, in the face of the situations outlined above, the traditional PS approach cannot provide a satisfactory basis for evaluating alternatives in terms of all relevant issues.

The SCM approach is developed to achieve apparently irreconcilable objectives:

- Meet the requirements of flexibility,
- reap the benefits of decentralization,
- coping with the demands of innovation,
- all this without giving up the prerogatives of control.

Through the SCM approach the firm extends its management activities beyond its own boundaries and adjusts its supply relationships on a broader basis than that contractually defined, even beyond the supplier-customer relationship where both are directly involved and interacting with subjects which are not in reciprocal contact within the chain.

5. The supply relationship according to the SCM approach

The situations outlined in the previous paragraph, which led to the current configuration of supply chain relationships, became more common and widespread at the beginning of the nineties. Since then, of course, both theory and practice have witnessed a rapid evolution of knowledge to support policies of SCM. However, some of the pivotal principles in the strategic management of supply chain relationships have been developed as early as the eighties, and among the first contributions there are important points of reference. In those years, the transition from a period of relative market stability to an environment characterized by rapid changes has increased the criticality of monitoring all areas of the business and invested the activities related to the supply, prompting firms to identify the main variables capable of distinguishing the situations which would require an advanced approach to supply relationships.

The complex set of concepts, guidelines and operational tools that goes by the name of supply chain management (SCM) is driven by above mentioned changes. In such a perspective firms operating in the same value-chain coordinate their strategies with the purpose to increase the overall value rather than compete for the allocation of the existing one. Firms' network of suppliers and the relational capabilities assume a critical role in order to coordinate the value creation processes within the chain. For this reason, firms develop new tools for managing and coordinating the interrelationships between the production processes of supply-chain contractors, joining the strategic perspective with the traditional, somehow simplistic, make-or-buy evaluations.

SCM is a complement to (not a substitute for) the traditional approach and is characterized by some ideal-typical key features that both complement and contrast with the four key issues listed in part 3:

A. *Partnership opportunities and competitiveness are the main determinants of make-or-buy strategies*. Vertical integration decisions are taken also according to the relational and coordination capabilities. The decisions about the degree of vertical integration and about the positioning along the value chain depend not only on technological skills (in broad sense) and efficiency, but also on the relational and coordination capabilities. For instance, successful firms that operate downstream of the value chain in most dynamic sectors can exploit their knowledge of demand and customers' needs to assume a proactive role and to pull the entire chain towards projects of improvement and innovation. These capabilities will then put the firm in a crucial role within the supply network, feeding a situation in which the leading role of the firm allows it to control the critical phases of the value chain without the need for internalization. In contrast, a firm that for various reasons suffers the bargaining power of suppliers for critical components and parts, will be more oriented to choose the path of integration even with a cost disadvantage.

B. *Medium/long term, strategy-based perspective*. Supply decisions involve the assessment of the medium or long-term strategic perspective. Without neglecting the economic assessments, supply policies also take into account opportunities typical of a medium to long term perspective (eg.: innovation, learning economies, flexibility), then adopting choices that may also have sub-optimal effect in the immediate future, but against a upcoming better result or a strategic necessity. The key-principle of assuring the long-term profitability is not neglected. Rather it is declined on several dimensions, including evaluations that are not directly translatable into monetary or financial terms, such as quality, competitiveness, technology leadership, customer satisfaction, and so on.

C. *Win-win oriented relationship*. Supply chain relationships are managed with the perspective of seeking a win-win outcome or according to an overall optimization. Firms aim to increase their share of added value by increasing the value generated by the whole chain rather than through its division. The competition in the research for individual optimum is seen as leading to a systemic sub-optimal outcome. Usually, the coordination promoted by one or a few actors in the chain, typically downstream firms or those with the largest potential market and technology.

D. *Goal oriented commitment*. The regulation of supplier-customer relationships is in part ruled by orientation to common goals rather than by contractual clauses. The adjustment of the supplier-customer relationships, while being formally established by the enforcement of contractual terms, indeed is largely determined by the orientation to common goals, which may be, for instance: the development of a new product, the opening of a plant, the entry into a new market, and so on. This does not imply the loss of constraints: common contractual obligations are added to targets systems that cannot be placed in explicit terms as they go beyond the firms' boundaries.

In conclusion, the SCM approach includes the management of issues related to procurement and placement of products on the market; then goes further, analyzing and regulating relations with other firms in order to build up the convergence of interests among industry players and in order to build common processes aimed at improvement of processes and products. For this reason we can say that the SCM is a process, including assessment of the competitive implications of decisions on supply. Therefore, it must involve the coordinating role of the top executives at least in the design of strategic guidelines.

6. The drivers of the choice between PS and SCM

The identification of variables relevant to the supplier-customer relationships is the first step in the evaluation of different possible strategies of SCM. In theory, there are several variables that can affect SCM strategies and the most appropriate way to handle each specific supply relationships. Some of them are of major importance and are all closely interrelated with each other:

a. start-up and management costs of supplier relations,
b. the complexity of the finished product and the degree of technological hybridization,

c. availability and customization of supply,
d. convergence or divergence of goals between firm and supplier.
a. Supply policies are influenced by the different incidence of costs arising from the start-up and from management of supply relationships. In brief, costs can be broadly divided into:
- transaction costs (launch of the relationship, coordination and negotiation, opportunism),
- costs of inventory management (purchase of equipment, cost / opportunity arising from capital equipment, maintenance stock, obsolescence and decay, logistic),
- costs related to the quality (in broad sense) of supply (defects, technical and quality level, degree of innovation of the product)
- switching costs / idiosyncrasy of the relationship.

The general principle that suggests choosing the supplier who minimize the sum of those costs, can hardly be followed in practice, since those costs are actually quantifiable only after the supply relationship is activated. The uncertainty in itself is often the first source of disagreement. Traditionally, in order to avoid or reduce the occurrence of disputes, contracts include a number of clauses meant to foresee and solve any situation that may bring the actual scenario to deviate significantly from the one predicted (e.g. changes in supply costs due to external causes, changes in prerequisite due to new laws, the occurrence of problems related to the rate or quality of supplies, and so on).

A contract structured to try to solve in advance all possible situations is "closed" because it seeks to regulate in a single definition all the predictable conditions rather than contemplating the possibility to redefine the basic terms of the agreement. However, this option only applies to stable and predictable occurrences. With increasing turbulence it is extremely complicated and risky to address the problem with closed contracts. Rather, contracts rely on "open" agreements that instead include terms of adjustment or the possibility of renegotiating the terms. A predictable scenario will not create specific incentives to a SCM approach, while uncertainty is one of the main drivers that lead firms to include strategic evaluations in the decision related to supply relationships.

b. Products that require specialized parts or materials and know-how involving several advanced technologies (electronics, electrical engineering, chemistry, etc.) need intense inter-firm coordination, due to the complexity of engineering and development and to the difficulty in coordinating multiple firms that have different specializations, procedures and *modus operandi*.

In this situation the role of the supplier is particularly important, since one firm alone may not (and usually doesn't) possess the technological and market knowledge required for the design and development of the final product.

In cases like this the convergence of objectives on the project development of the final product is essential to guarantee an effective coordination. The supplier tailors parts and components on the firm's needs, then involving a specific commitment of resources from both parts, then leading them to provide mutual guarantees to offset the risk related to the low reversibility of dedicated investments.

c. The availability of a resource on the market has relevant strategic implications and it is (or might be) connected with the degree of customization. Besides from having a significant impact on supply costs and supply relationship management, it has a key role in determining the balance of power in the supply chain and the presence of a certain amount of local supplier is one of the main factors taken into account when the location of a new plant is decided. Of course a scarcity of supplier for a specific resource will tip the balance of bargaining power of the supplier. On the other hand the widespread presence of suppliers with high-value know-how, in a relatively circumscribed geographical area is, quite often, a strength point that affects the entire chain. When an area has a high concentration of a particular type of work and expertise rarely found elsewhere, that area (usually defined in terms of cluster or regional cluster) often becomes a place of excellence as regards research and innovation in the field. This triggers a virtuous circle: on the one hand the productive specialization and expertise generates added value and attracts investment. On the other hand these investments support further research & development. This circle will generate innovation and new knowledge more effectively and efficiently than could be done elsewhere, in the absence of that "production culture" consolidated in that specific region.

d. The convergence of the contractors on issues of common interest produces a significant boost towards the cooperation. The requests of the two contractors are not necessarily incompatible. The real issue is that every concession implies an additional commitment for the lender, and potentially lower margins if the increased commitment does not find an adequate payment. But if customers and suppliers believe they can achieve mutual benefit (thus adopting a view of a positive-sum game rather than that of a zero-sum game), then one of the cornerstone of the negotiation consists in mutual requests for guarantees about the opportunity to: i) improve efficiency, ii) strengthen their competitive positions, iii) achieve satisfactory results. The most important among the key-drivers of the negotiation process are the sharing of risks and opportunities, and the reciprocal transparency on strategies and market trend (Swink & Mabert, 2000).

7. Conclusions

The frenetic changes of recent years have led firms to suffer from conflicting pressures. In particular, the tendency towards specialization contrasts with the increased need for coordination; new and higher barriers to vertical integration challenge the need for direct control of the most critical stages of production. Over time both theory and practice have developed tools to enable firms to respond effectively to environmental challenges. Faced with unprecedented complexity, firms have extended the strategic coordination outside their boundaries and across the supply chain, trying to merge the advantages of integration with those of flexibility and specialization. The result is the development of an extremely diversified range of relationships.

In those industries characterized by high technology and high rates of innovation, the relationship between companies and their suppliers are generally much more intense and pervasive than the traditional market agreements For this reason the SCM perspective tends to give great importance to the sharing of goals rather than the to contract itself, according to a logic that relies on the mutual interest in flexibility. These relationships settle long-term cooperation that, if successful, increases the competitiveness of each contractor. Concretely, the competition between companies is evolving towards a competition between supply chains. However, the SCM approach requires significant efforts and it is not without risk. It is therefore necessary to understand the conditions of effectiveness of this perspective to discern those cases where SCM is appropriate. Indeed, to understand if a particular supply can be critical to the competitiveness and to future strategies it is probably more important than the terms of the contract. The retrospective analysis of the competitive scenario that led to the birth and evolution of this approach is a useful element for understanding the strengths and the limitations of SCM. Through the review of the main factors in the evolution of supply issues, SCM emerged as an organizational / systemic response to complexity. Its application is appropriate in dynamic and uncertain environments, while in other cases the traditional PS alternative might bring equal or greater benefits.

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3

Supply Chain Configuration Revisited – Challenges and Strategic Roles for Western Manufacturers

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1. Introduction

Globalization is revolutionizing the way manufacturers operate and perceive themselves (Coe et al., 2008). A key question in the pursuit of excellence in global value chains remains: from where does the firm primarily derive its competitive advantages? Does the firm primarily rely on the marketing- and positioning-oriented aspects, which it derives from product/service development, or from its operations resources and capabilities? Arguing against current governing beliefs, this chapter claims that sustainable competitive advantage may be gained through excellence in operations capabilities, as firms purposefully work their way around traditional tradeoffs. Forward-thinking companies see their global value chain as an opportunity to innovate their operations systems, seeking lower cost, new manufacturing capabilities, improving customer responsiveness, and entering new markets, but also realizing that tapping into these opportunities requires a fundamental rethinking of their current supply chain configuration. In the pursuit of this rethinking, these companies have succeeded in developing innovative and robust operations networks, from which they build and sustain competitive advantages. This chapter takes its outset in four such companies that have been through this transition, but with different initiating conditions, different sets of choices with regards to process and content, and with different supply chain configurations as outcomes. We know of their success, but have little knowledge about why. Therefore, in this chapter, we aim to map and understand the current conditions and process for supply chain configuration and its effects on the resulting supply chain configuration.

The increased scale and scope of global operations, both with respect to markets and supply, has broadened the scope of manufacturing and supply chain management. The supply chain has undergone a radical fragmentation geographically as well as in terms of functional sub-categories and organizational boundaries, leading to an ongoing reorganization of the value chain on a global scale. This has partly rendered the division between operations management and supply chain management obsolete.

At the same time, drastic reductions in product lifecycles and delivery times have eliminated inventories and, as a consequence, have called for management of interdependencies among subsystems. This means that increased complexity has worked its way into supply chain management partly induced by the nature of activities and partly by the organization of these activities. In addition to this increased complexity, the environment has become more dynamic. Not only do we experience more frequent changes in customers' preferences, but we also see them in products and processes. But the direction of change has become more difficult to predict. This calls for an unprecedented capability of a supply chain system to become agile, but also to make the most from the global resources the company appropriate.

In the midst of these transitions, the role of manufacturing in Western economies has been questioned, and the quest for higher-value-added activities has been strong, leading to an unprecedented wave of outsourcing and offshoring initiatives. This wave, however, builds on the basic assumption of manufacturing as a cost function, which reduces the strategic role of manufacturing to complying with global cost structures. This assumption may, though, prove to be faulty (Benedettini et al., 2009), and this chapter makes a call for reconceiving the strategic role of the manufacturing function in Western economies in the midst of global value creation.

The need to look at manufacturing and the supply chain in a new way is supported by the European Union initiative Manufuture. A "Vision for 2020" report (European Commission, 2004) describes, among other things, a needed transition in four main areas:

- From resource-based to knowledge-based manufacturing
- From managing a linear process to dealing with a complex operations set-up
- From individual sources of competitive advantage to systems-based competition
- From mono-disciplinarity to trans-disciplinarity

The report emphasizes the need to innovate within manufacturing and to integrate multiple perspectives and disciplines. This also applies to the supply chain, where the above-mentioned challenges to industrial firms call for a capability to quickly reconfigure the supply chain at the same time that increased emphasis should be placed on knowledge and competence development. In response to these transitions, it is argued that we need to provide a broader approach to configuration of supply chains. In this chapter, we shall, therefore, introduce four generic supply chain roles (Full scale, benchmarking, ramp-up, and prototype) and, based on case studies, discuss their implications for the configuration of supply chains.

In the next section, we shall first review the literature on operations networks and manufacturing strategy to provide a background for introducing four generic strategic roles of supply chains. This is followed by a section with four case studies, introduced by a discussion of methodology and concluding with a cross-case analysis. The last section will deal with implications for the configuration of supply chains.

2. The network perspective

Literature on the management of multinational enterprises (MNEs) - and in particular the Network Theory, which views the multinational organization as a web of inter- and intra-firm relationships – provides the conceptual foundations of this chapter. According to Bartlett & Ghoshal, an MNE consists of a group of geographically dispersed and goal-disparate organizations that include its head-quarters and the different national subsidiaries (Bartlett & Ghoshal, 1993). Such an entity can be conceptualized as an inter-organizational network that is embedded in an external network consisting of all other organizations such as customers, suppliers, regulators, and so on. These types of organizations exist in increasingly rugged competitive landscapes, which they need to deal with through ongoing and often non-linear adjustments of internal operations and its supply chain links. This moves the focus away from the simple dyadic relationships between, e.g., the HQ and its subsidiary, the functional domains within the value chain, or the specific decision to invest in a foreign location, to the task of managing a network of established subsidiaries and analysis of the competitive advantages that arise from the potential scope of economics of such networks.

In industrial systems, companies are engaged in R&D, purchasing, production, distribution, and the use of goods and services. We describe such systems as networks of relationships among firms with different levels of task-based interdependencies. There is a division of work in a network, which means that the individual entities develop interdependencies with each other. This also means that coordination is not achieved through a central plan or an organizational hierarchy, nor does it take place through the open-market price mechanism. Rather, coordination is often found to take place through interaction and mutual adjustment among firms in the network, in which cost is just one influencing condition alongside market-serving and knowledge-seeking potentials. The operational environment of the production company is often treated as an exogenous entity and is reified as a source of undefined uncertainties as opposed to being seen as an organizational field consisting of specific interacting organizations. This remains a key problem of our understanding of the operations network, as the discussion remains too abstract to form a basis for concrete decisions.

Shi & Gregory discuss manufacturing networks as integrated rather than aggregated from its parts (Shi & Gregory, 2005). This introduces a systems dimension, which remains poorly understood. The systems perspective calls attention to issues beyond isolated location and capacity choices, and emphasizes the coordinated aspects of operations networks. In the operations literature, this coordination has typically been addressed in discussions of plant roles. Ferdows (1989) defines the operations system as a network of factories, where each site plays a different role, although this framework is biased towards the role of the single plant rather than considering the faculties of the integrated or coordinated network (Ferdows , 1989). While the level of analysis within the discussion of plant roles remains that of the plant, the network perspective points to a need to look at the interaction between plants to understand the dynamic configuration of plants. Today’s operational reality points not only to the network of autonomous plants or to the dominating corporate center, but rather raises the need to deal with agglomerates of internal and external partners with changing dispositions and roles.

Conceptually manufacturing networks theory originated in the operations management field, whereas the logistics management perspective dominates supply chain theory (Rudberg & Olhager, 2003). The historical trajectory of the configuration, i.e. whether the starting point is the internal or the external network, influences how the network is operating as well as what capabilities can be mobilized within it (Shi & Gregory, 1998). Research on manufacturing networks has its roots in the manufacturing management of a single factory, resulting in an inclination of scholars to study the network as a wholly owned and internal network where all facilities are under full control. Conversely, research on supply chains from a logistics perspective tends to analyze the network as an external network with facilities owned by different organizations. Logistics research has traditionally focused on the links between the nodes, whereas manufacturing network research tends to focus on the nodes themselves and their internal efficacy.

Rudberg & Olhager introduce the term Value Network as a means to integrating the manufacturing and the logistics-based perspectives, cf. figure 1 (Rudberg & Olhager, 2003). They describe the value network as a network of facilities, possibly owned by different organizations, where time, place, or shape utility is added to a good in various stages such that the value for the ultimate customer is increased. Various purposes may be associated with this network and thereby influence its capabilities, such as the following:

- The market-seeking network; this type of subsidiary is formed around the objective of initiating their operations in emerging economies to capture the local market with an existing range of products, possibly with local adaptations.
- Parallel operation network; within this type, the subsidiary is expected to reproduce, possibly at a smaller scale, the operations at the MNE's original base.
- Efficiency-seeking network; seeks to establish rationalized product subsidiaries specializing in the production of a smaller part of an MNE group's existing product range, aiming to supply this in a cost-effective manner to a wider market.
- Knowledge-seeking network, which at the subsidiary level builds on the incorporation of a customized and higher-value-added functional scope. These subsidiaries are likely to be more securely embedded within the distinctive local economic capabilities.

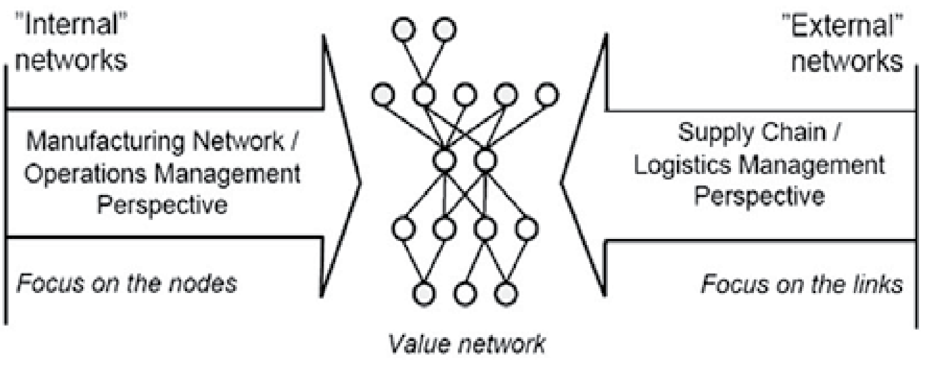

Fig. 1. Value network (source: Rudberg & Olhager, 2003)

According to Wiendahl et al., there are four basic network types (Wiendahl et al., 1998):

- The first type is the Strategic Network; this network is strategically operated through a focal company, mainly a finished product supplier, contractually close to the focal company.
- The second is the Virtual Enterprise, which consists of independent companies working together on the basis of a joint business understanding and aiming to take advantage of an available business opportunity through common operation. The co-operation is confined to a point in time or a relatively short period (like a project).
- The third form is the Regional Network; this is based on a special conglomeration of highly specialized small and medium-sized enterprises within a geographical area.
- The fourth is the Operational Network: The goal of working together is that the company, supported by a comprehensive company information system, is able to capitalize on the performance of partners in the short term, especially in free production and logistic capacity.

In light of these network types, it is necessary to make the case that the ownership ties that exist within the vertically integrated MNE do not necessarily impede the scope of behaviors that are possible among interacting organizations that are not so connected. Control may be limited within multinationals not only because some of the subsidiaries happen to be very distant and resource-rich, but, more so, because they control critical linkages with key external actors. Fiat is present in the MNE, but it may not be the most dominant mechanism of control, and it coexists with local autonomy, which makes inter-organizational theories applicable as a means for discussing operations networks.

The strategic role of distributed facilities is determined by the interplay between several factors, such as the following:

- Geographical proximity to customers (server capabilities, landed cost, responsiveness)
- Operations capabilities and plant dispositions (abilities to deliver on key performance criteria)
- Process stage (vertical network structure and position in the value flow)
- Production volume (different management and technology requirements)
- Product line (compatibility of process technologies and management systems, degree of interdependencies with other facilities)

With an outset in these characteristics of the operations network, there are a number of strategic positions that may be taken by plants, but what is the scope of these strategic positions and what are their key features? This question will be dealt with in the following section and will be summarized into a set of supply chain roles in section 5.

3. Manufacturing strategy

Two articles by Skinner put manufacturing on the agenda of general managers by introducing such concepts as manufacturing strategy, manufacturing tasks, and focused factory (Skinner, 1969, 1974). It was a serious attempt to argue that manufacturing has a contribution to make in the competitiveness of an industrial enterprise. The manufacturing task captures the specific requirements and demands on manufacturing and provides a basis for prioritizing goals. Different tasks lead to different focused factories.

The role of manufacturing indicates the strategic contribution of manufacturing to the competitive strength of a company. Based on empirical findings, Hayes & Wheelwright (1984) identified four different roles of manufacturing: internally neutral, externally neutral, internally supportive, and externally supportive, which they saw as a maturity model of strategic manufacturing, proposing that manufacturing companies make a choice as to how they compete (Child, 1972).

Coming from a different perspective, Senge supports this maturity model, as he identifies three learning waves within the quality movement (Senge, 1996). He argues that companies are highly concerned with improving tangible work processes, which he qualifies as the first wave. The second wave deals with improving how work is conducted, which opens up for an appreciation of the inherent systems dynamics. The third wave gradually emerges from the previous two with learning as a natural part of life in an organization. Applying maturity thinking to the distribution of manufacturing directs attention to the questions of strategic progression and learning within a manufacturing system, and firmly places the view and role of manufacturing in a corporate setting on the strategic agenda.

Positioning manufacturing in its wider environment has become a question of fit and focus. An important contribution was made by the identification of the concepts "Order-Winners" and "Order Qualifiers" (Hill, 1985), which is concerned with matching competitive conditions to appropriate organizational structures. Within the perspective of fit and focus, the strategic role of manufacturing can also be described by its location and contribution to the value chain of a company (Porter, 1985).

Voss introduces three paradigms of manufacturing strategy, which have proved to be quite robust to the test of time: competing through manufacturing; strategic choices in manufacturing, and best practice (Voss, 1995). In the first paradigm, he includes Skinner, Hayes & Wheelwright, and Hill in the second paradigm. In his 2006 revisit to the paradigms, he stresses the need to look beyond the underlying stages/maturity assumption that characterizes each of the paradigms, but rather to see manufacturing development as an iterative process in which each of the three paradigms is revisited regularly (Voss 2006). With the increased distributed manufacturing and increased complexity, there is a need for adding more dimensions to strategic roles of manufacturing.

Another way of characterizing the strategic role of manufacturing was proposed by Johansen & Riis based on the thesis that an industrial company can occupy a number of different positions in the supply chain (Johansen & Riis, 2005). These positions influence the way in which a company develops products and seeks out knowledge, as well as the roles of its production function and the relationships with other companies in its networks. Three archetypal companies were proposed:

- The Focused Firm, which specializes in a particular sphere of knowledge and capability development.
- The Networking Firm, which puts other companies together and coordinates and develops their mutual activity.
- The Integrating Firm, which assembles other companies' components into products or solutions.

In view of the close interaction between the various functions of an industrial company, it is difficult to identify a strategic role that manufacturing plays alone. For example, manufacturing may make a significant contribution by supporting sales in fast ramp-ups of customized products, and product development through its ability to prototype.

The discussion so far has seen manufacturing as one unit of operation, either as one single plant or the overall contribution of the company's plants. However, when a company has several plants spread throughout a region, individual plants may play different roles. Ferdows characterized plants according to their primary location driver and the level of competence in terms of various functional resources and management responsibilities (Ferdows, 1989, 1997). For example, a low-competence site established mainly for reasons related to low-cost production was defined as an *offshore site*. Such a site is established to produce specific items to be exported for further operations or sale. It would not be expected to be innovative, and its managers follow the instructions and plans handed down to them. At the other extreme, a *lead factory* spans a wide range of functional competencies and managerial responsibilities, and creates new processes, products, and technologies for the entire company, drawing on access to skills and knowledge. Other types of factories are *source factories*, *server factories*, *contributors*, and *outposts*.

Most of the contributions to manufacturing strategy take their outset in the focus and fit perspective with its emphasis on offering customers what they want. But manufacturing competencies and their development may also create competitive advantage for the company (Hayes et al., 2005). In view of increased difficulties in predicting market developments and distributed production facilities, the dynamic capabilities dimension of strategic development will be an important issue in the future (Teece et al., 1997). This may change our paradigm of manufacturing based on resources of manufacturing based on knowledge, which explicates the need to look beyond fit, focus, and trade-offs, as they may not be sufficient for competitive success.

Another paradigm shift may take place from managing settled dyadic relationships to managing unsettled networks (Karlsson, 2003). He identifies the new manufacturing challenge as one of managing the extraprise, due to the increased reliance on activities outside the formal boundary of the company. Still, we know too little about managing activities outside the formal reign of control, especially when it comes to handling the dynamic effects of the relationship (Mayer & Argyes 2004) or analyzing the overall network structure and the company's position in it, so as to be able to engage effectively in the reconfiguration of the network (Gnyawali & Madhavan 2001).

In conclusion, the review of part of the literature on manufacturing strategy has presented a variety of different ways of positioning manufacturing as a means for identifying and defining the strategic roles of manufacturing in an industrial company.

The first group of contributions (represented by the work of Skinner, Hayes & Wheelwright, and Hill) relates directly to the extent and selected objectives of the contribution of manufacturing to competitive advantage. The second group positions a company in a value chain or a supply chain (represented by the work of Porter, and Johansen & Riis). The third way of classifying strategic roles focuses on the mutual interplay between functions, leading to a primary role and four supporting roles (represented by the work of Johansen & Riis). The fourth classification identifies different roles that a plant can play in a network of manufacturing plants of a company (represented by the work of Ferdows).

To a large extent, the perspectives are mutually exclusive, which suggests that an industrial company may find it appropriate to use several classifications to find a configuration of strategic manufacturing roles that is in line with the environmental challenges and internal strength.

4. Strategic roles of supply chains

In the following, we shall adopt the broader view of manufacturing presented above as the fourth perspective, seeing manufacturing as an integral part of supply chains or orchestrated manufacturing networks. We are focusing on manufacturing to determine whether it takes place in a plant owned by an industrial company or if it is carried out by a supplier. This allows us to study some of the key issues of supply chain management, for example accessibility of capabilities, reliability of delivery, competence development, and organizational learning in the context of the ongoing network-based reconfigurations. Furthermore, we shall make use of the third classification presented above to support this extended manufacturing process perspective.

In previous work, five different roles were identified (Johansen & Riis, 2005). *Full-scale production* is carried out exclusively by manufacturing, whereas the following four roles support one or more functions, such as *ramp-up* (which builds on the key relations to sales and product development), *prototype production* (with key relations to product and process development, sales and sourcing), *benchmarking* (with key reference to sourcing), and *laboratory production* (with key relations to product and technology development). We take the ongoing reorganization of the global value chain discussed in section 3 as a basis for stating that it is possible to use these roles to identify four strategic roles related to the increasingly fragmented and distributed supply chains. By including "laboratory production" into "prototype production," we obtain four generic roles, which respond to current global supply chain reorganizations by reintroducing operations into considerations of corporate competitiveness and, as a result, raise new demands on operations capabilities:

Full-scale manufacturing and sourcing: This role deals with the daily operation to secure precise and swift delivery to market demand. As mentioned above, this has become a complex task with globally distributed production plants and global sourcing and demanding customers. In addition, market fluctuations call for agility to be able to escalate volume and to down-size.

Benchmarking: This is an important task for an industrial firm to continuously examine, and one consideration a company undertakes constantly is if other suppliers can deliver better, e.g. in terms of reliability, quality, and cost. This should also include the firm's own plants and may result in recommendations for improvement or shift in suppliers. These capabilities are too important today to be embedded within one single functional domain (sourcing), but depend on ongoing collaboration between partners and function across the value chain. In contrast to the Full-scale role where establishment of mutual trust in a supply chain or network is a key concern, the Benchmarking role implies a capability to smoothly shift partners in a network and, thus, introduces process-based robustness and raises demands on the capability to specify.

Ramp-up: As an industrial firm introduces a new product line or opens a new market, a new supply chain needs to be established. This calls for a capability to quickly configure a supply chain, taking into account the specific nature of the product, markets, and suppliers. A design framework based on modular business processes has been a solution for some companies.

Prototype: When an industrial company wants to introduce new business models, new technologies, and new materials, strong cooperation between all functions is needed. The supply chain has the task of engaging potential suppliers in new product and process development.

Four roles – four working modes

The four roles respond to different types of supply chain configurations, with the full-scale and the prototype roles positioned at either end of a continuum from a tight to a loose supply chain structure. But at the same time, they also represent different types of demands that the supply chain configuration has to cater for. Therefore, in a specific company situation, the four strategic roles of the supply chain may not have equal weight. Yet, any role cannot be neglected, as it presents the company with important supply chain dilemmas, the reconciliation of which may turn into competitive capabilities. As they may already have become apparent, the strategic roles ask for different organizational working modes and put different capabilities to the fore of attention. For example, the Full scale operation requires a well-oiled business system, often based on many pre-programmed decisions, whereas the Prototype role relies on personal contacts and tacit knowledge shared by several individuals and/or companies.

5. Methodology: A framework for network configuration

As pointed out above, we need to view supply chain issues in a larger context, for example to address the inter-linkages between manufacturing and procurement in a global context, and to include the interdependencies between manufacturing, supply chain, sales/marketing, product development, and purchasing. Furthermore, configuration should be seen as an evolutionary process and not as a once-and-for-all design effort. This has led us to develop a framework for configuration of supply chains and global operations systems, cf. figure 2.

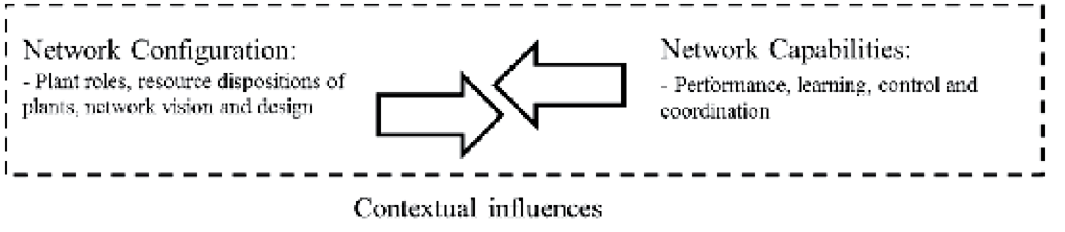

Fig. 2. An analysis framework for network configuration

This model will in the following serve to structure the discussion of our case studies. Four case studies, representing four different industrial situations (context influences), will be presented. The strategic choice and preferences will be dealt with by discussing the strategic roles of supply chains introduced above, and the emerging operations network will describe the operations structure (network configuration). Organizational issues to be discussed will touch on operations infra-structure, and the case studies will include the development over time of the elements of the framework (Network Capabilities).
As already mentioned, the five generic manufacturing roles that we have transferred to supply chains were identified as part of a series of workshops with industrial managers and researchers in an effort to support an industry-driven development process. In other research projects, we have undertaken a number of case studies, some of which are action research-oriented covering different industries and spanning a spectrum of different situations. As illustrated in figure 3, we have selected two dimensions to capture the influencers from the industrial context: the rate of change and the need for coordination of the operations network. We have selected four case studies, one in each of the four cells.

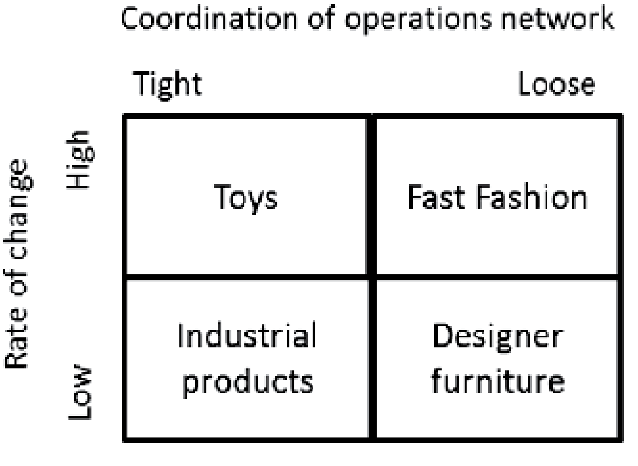

Fig. 3. Four different industrial contexts

Case-study company 1 - Toys

The company is a producer of products characterized by high seasonality, volatile demand, and exposure to fashion trend fluctuations, creating an eminent challenge of balancing its capacity for demands, while constantly updating its product line. The company had traditionally been committed to its fully owned operations in its domestic base in Denmark. In spite of its global sales, very few production facilities of the company had been established abroad. However, with dropping sales accompanied by negative financial results, a new management group, which entered the company in 2004, urgently started rolling out plans for a design and implementation of the transfer to external suppliers in low-cost countries. A preparation stage included a comprehensive cross-functional analysis, which focused on the development function, sourcing, production, and distribution, leading to a number of initiatives. On the development side, the main focus was on reducing the complexity of products, which over the years had grown considerably with a growth in the number of suppliers, product variety, and component variety. The reduction in complexity was not only meant to drive costs out of the supply chain, but also to prepare the company for quick response delivery.

While the reduction of complexity coming out of product development started right after the end of the analytical stage, it was decided to run a pilot study on offshore outsourcing. The major pilot project included moving a product line to an external supplier in Hungary. The supplier was selected after a careful multi-staged process involving initial screening of shortlisted companies, a number of rounds of negotiations, and on-site assessments. The case-study company's previous experience with offshore outsourcing was limited to low-volume complex specialty tasks and components for which the company had no internal resources. Now, the company was outsourcing the entire product line, something it had never done before. The economic benefits of the transfer were obvious. In addition, an important aspect of this pilot line was a learning experience, as it was the first outsourcing initiative of this caliber for the company. When the pilot project was half-completed and proved to be successful, the company started negotiations for outsourcing the rest of the supply chain with this manufacturing services provider, assigning it the role of a strategic finished goods supplier. However, the relative success of the test case proved to be more difficult to replicate than expected. The specific nature of the pilot line provided limited insight into the effects of interdependencies in a distributed production network. The test case was based on a single-site production set-up with its own internal component base while the other product lines were formed from components produced in multiple locations. The transition from the single- to multi-site set-up also revealed that documentation of products, processes, and technology was not sufficiently developed to make a clean shift. The documentation had been adequate for in-house and long-term domestic relationships. However, it appeared to be insufficient for the effective use by the new strategic partner. This meant that major tasks became documentation, process mapping, and data structuring. In addition to capturing tacit knowledge and creating a transferable repository of knowledge, there were many more challenges ahead of the transition team. A big challenge lied in coordinating the interfaces between the company and its strategic partner. With a very high employee turnover at partners' sites, getting stable reference points became an apparent difficulty. When the Danish company was ready to start transferring knowledge and to learn how to develop the strategic supplier relationship, all of a sudden a key person at the partner's side was leaving. Hence, a more coordinated approach to the transfer was lacking.

The very high speed and wide scope of the transfer constituted another challenge. The case-study company tried to deal with the situation by increasing the number of its own employees at the partner's sites as part of daily operations and making sure everything was done according to specifications; for example, senior quality engineers were based in the partner's sites in Mexico and Hungary. This approach incurred a hidden/unexpected cost, but according to the company's estimates these costs did not exceed 10% of cost savings generated by the outsourcing initiative. However, the challenge of absorbing the amount of knowledge transferred from Denmark represented only part of the problem. Another was in the lack of motivation to learn from the suppliers' side. Over time, it emerged that the supplier was reluctant and struggled to learn. On the one hand, the fragmented approach that the supplier had to organize its sites all over the world might have hampered the company's ability to learn and absorb effectively the inflow of new competencies. On the other hand, this could not be solely blamed on the supplier, as from the inception of the relationship the Danish case-study company, in its representative's opinion, focused more on its own goals rather than investigating what the suppliers' goals and motivations were.

Another area where the relationship was facing difficulties was in securing smooth operations when faced with a volatile market situation. The Danish company was used to tackling enormous market dynamics, seasonal fluctuations, and unpredictable demand; in addition, approximately 60-70% of the company's annual turnover is generated through continuous launching of new products. Such dynamics were completely in contrast to the much more stable operations the supplier was used to and prepared for. Besides creating another challenge for the transfer, this situation also caused a gap between flexible and market-responsive solutions the Danish company was looking for and what its partner could deliver. Eventually, the fact that neither dispatching nor receiving companies could reap all the benefits expected by both parties contributed to management's considerations of bringing the sites back in-house. The relationship was remarkably resilient against the individual challenges it faced. However, their concerted effect eventually led to the break-up of the relationship. At the beginning of 2008, the company announced its plan to 'backsource' or bring back in-house one plant run by its partners, followed by announcements in July, 2008 of further 'backsourcing' of two more plants.

It is obvious that the high rate of introductions of new products and the seasonal variation call for tight coordination, explaining the location of the company in the upper left corner of figure 3. The case illustrates, among other things, that outsourcing brought into the open the interdependencies between operations and the other functions primarily based on tacit knowledge. If the company had analyzed the strategic roles of supply chains, the course of actions and configuration decisions would most likely have been different. The network structure is likely to be changed in the future, as a new balance needs to be developed between specialized production processes and the need to be close to the markets. For example, an effort will be made to develop new technology for plastic molding, and regional assembly units will be established for low-volume products and parts with high unpredictability.

Case-study company 2 – Industrial solutions market

The company is a Danish equipment manufacturer holding a market-leader position. With production in twelve countries and a global sales presence, it is working from a strong international base. Every year since 2000, the company has acquired two to three companies, and has furthermore been signalling a change in mindset from the earlier ideology of making everything in-house to joint ventures and acquisitions. Some of the newly acquired firms still control their own R&D agenda, while others are fully integrated. The pace of acquisition has quickened recently on par with the restructuring of their main product's market characterized by increased concentration, and firms moving from component to system suppliers, adding more competencies. When referring to product development, an executive talks about a "Centrally driven, global approach - with a local presence." Denmark has the strategic vision and remains in firm control through corporate functions, but business units have their own budget and latitude to select projects and allocate resources.

The company has developed proprietary product and process technology built on the understanding and the nurturing of the interaction between production, product development (PD), and its technology center (TC). Being responsible for technology development and establishment of production lines, the technology center needs to coordinate its activities with its two customers, namely Production and Product Development (PD). Production has already been offshored, and with PD moving out of Denmark, it makes sense that TCs follow customers in their global expansion. Consequently, local TCs have already opened in Hungary and China, and a new site is planned in Mexico/USA. Cooperation between foreign units is limited to brief collaboration on assignments and sharing of patents. However, there is a shared agenda at a higher level in relation to operations in different market segments. Although R&D manpower in China is growing fast, they have not launched any product range of their own yet, and are solely supporting central development activities. It is expected, however, that future responsibilities of developing specific products will be taken over by the Chinese. A focus on the Americas is also needed, as the group is relatively weak here, where the company introduced some product ranges over 50 years ago, but can only claim less than a 10% share of the market. In time, each "Triangle" (TC/Production/PD) will grow increasingly independent and specialized, replicating best practices, but developing its own particularities, compatible with local cultures and markets. TC Denmark, which designs production equipment for all factories, including testers and tools, is to remain the lead factory for the next few decades. Electrical parts of testers, for instance, are manufactured in the Netherlands, mechanical parts are purchased in Denmark, and assembly takes places in Denmark. TC Hungary provides more capacity and cost reduction in the tester area, supplying spare parts, IT support, or any competencies needed around the tester area. Similarly, TC China focuses on tools with 7-8 people building documentation on the tool and automation equipment areas. The operations started with a small base, but are expected to grow rapidly. The global organization is nurtured through a positive iterative process by gradually increasing the level of complexity of tasks. For example, both China and Hungary have cast-iron mechanical construction units that are routinely assigned tasks by the project manager in Denmark. These parallel activities in Denmark and abroad will continue until it makes sense to move key competencies abroad.

As part of the overall globalization strategy, a production line was transferred from Denmark to a green field site in the Americas where a future triangle was intended to be. In spite of ample previous experience and a corporate focus on developing an organizational transfer capability, this project was challenging in a number of ways. First of all, the production line consisted of proprietary technologies, which had been amended in Denmark over a long period of time with very little documentation. In Denmark, semi- and unskilled people were operating the line with a wide delegation of autonomy for solving problems, while support staff, including skilled set-up fitters along with an engineering team, was supporting the line at disturbances, for maintenance, and for malfunctions, in addition to a more elaborate division of labor that was planned for the receiving unit. Secondly, this was seen as a test where the company was navigating in unknown territory with regard to location, to the approach, and to the scale of initial operations.

Preparation for the transfer was intense and focused on establishing a robust working template of the manufacturing process. The existing level of documentation was limited and did not reflect the historical modifications of the manufacturing process; for this reason, the work to capture and standardize the process was comprehensive and lasted for more than half a year. The company was able to maintain high motivation among employees in the dispatching unit during the preparation. The receiving context was assessed in an intensive investigation of its capacity to absorb the line, but was not involved in the transfer. The transfer itself was planned as a Big Bang exercise, where everything was packed and air-lifted to its destination in order to ensure minimum down-time. The line was delivered as a turn-key solution, and onsite initial training was structured and supported by the sending organization. This support team included very experienced operators and set-up fitters. The team was pulled back after four weeks of intensive training. They witnessed a capacity of the new organization for operating the line and an eagerness to prove itself. Later, project management found that they had underestimated the difficulties of transferring tacit knowledge about disturbances, malfunctions, and non-normal operation. This called for much more education and training than expected. Incorporating corporate DNA was seen as a key to success at the new site, which was planned to be secured through the internal training program with senior management attending as well as through a strong pull from an internal customer. It soon became clear that this was difficult to install in the immature organizational unit. Having spent a year with ramp-up at the new site, it was realized that drastic means had to be undertaken, and local management was replaced by experienced internal people with a strong focus on establishing flow-oriented capabilities, after which performance slowly started to pick up.

The acquisition of new production sites and fast growth of new markets have required the tight coordination of production and supply chain activities. At the same time, the rate of introducing new products has been moderate. This explains the location of the company in the lower left cell in figure 3.

The establishment of new production facilities in the Americas has revealed the close interrelationship between production sites, the central production technology center, and the predominant tacit nature of the production knowledge.

Awareness of the "Triangle" (TC/Production/PD) that mirrors some of the strategic roles of supply chains has been useful for planning a globalization trajectory. It appears to take place in waves, with operations first, followed by establishing a local production engineering capability, and a present effort to bring about phases of product development at regional centers.

Similarly, the structure of operations and supply chains has evolved from a star configuration, with the Danish headquarters in the center, to a complex network with regional nodes holding competence centers in various areas.

Case-study company 3 - Fast fashion

The fast fashion company is a leading player in its field. Just a decade ago, it could be described as a traditional production company; however, the competitive environment has made it necessary to change the profile of the company. The changes involved a transition from production to sourcing, which has had a number of implications for the operations capabilities of the company. The operations governance has changed from the tight control of the production process with total control over materials to trimming the products to a set-up based on arms-length contractual relationships. As the company started this journey, it lost control of the piece goods, reducing the activities to trimming, which is associated with buttons, zippers, and interlining. With the closure of the last production facilities in 2005, the company's role was reduced to design and quality control. The finished items are today sourced from suppliers based in China/Hong Kong with 70% of the volume, Bangladesh with 15%, and India with 10%. The remaining volume is purchased from Pakistan and Vietnam. The changes in the production platform were mainly driven by an increased price-sensitive market. Even though aspects such as Corporate Social Responsibility, ecology, and clean and environmentally friendly products have become more important, price remains the most significant parameter when choosing suppliers. This is also the reason why production is moving from China to Bangladesh, Vietnam, and Pakistan. The COO predicts that within three years, the volume share will change so that China delivers 40%, Bangladesh, 20%, Vietnam, 15%, and Pakistan, 10%. There are two main reasons for moving the production: (1) access to cheap materials and (2) cheap labor. Wages in Pakistan are higher than in Bangladesh and Vietnam; however, they are one of the largest producers of cotton and fabric, which entail low material costs. In China, the sewing facilities are moving from the traditional production areas such the Pearl River Delta to more remote areas, where the labor cost is lower. The old facilities work as shell companies, which aid in establishing and managing the new facilities while handling the customer relations.

Currently, 200-225 suppliers are used, 3-4 of which are regarded as main suppliers with a volume turnover of 10-20%. They are also the only suppliers where general or framework agreements have been made. The agreements imply that the company promises to purchase a certain share of the production volume, which may ensure a faster response to market changes. However, this conflicts with normal practice of autonomous individual brands. It becomes difficult for the individual brands to control such things as quality and price levels in accordance with brand identity. This practice ensures that the division of responsibility is very clear when something turns out either above or under budget. However, the general tendency is to have fewer suppliers and to increase the number of framework agreements in order to gain access to the right prices and better-performing suppliers.

The focus has changed from production to development of new collections and sourcing, which have now become the heart and soul in the company. The other leg for a successful business is being able to create benefits from high volume, hence being able to source at the right price at the right quality from the right location. The activities performed by the brands can be summarized to *design*, *product development*, *sourcing*, *selling-in*, and *whole sales management*. Selling-in includes preparing agents for selling the products to the retail link. Wholesale management encompasses activities related to supporting the retail units and includes follow-ups on sales, local accounting, branding, and advertising.

Sewing and fabricating cloth are very labor-intensive tasks, as machines do not possess the flexibility required for trimming the cloth to the right dimensions. The task of sewing has not changed significantly since the introduction of the sewing machine. Thus, the manufacturing of cloth has two significant cost drivers: (1) labor and (2) raw material. Since consumers are very price-sensitive, the pursuit of ever lower costs has had an unavoidable impact on the textile and clothing industry's internationalization process.

As the company started to shut down its factories in Denmark, new plants were established in southern and Eastern Europe. At the same time, it started to source from external partners for the first time. Partnerships with tailors were made in Yugoslavia, Portugal, Greece, Morocco, Albania, and the Baltic countries. During the same period, the company decided to expand its business scope to cover more customer segments, as they believed that the old brand, with its up-market position, could not create sufficient growth. The purpose of introducing new brands was to capture a larger share of the clothing industry. This was done by acquiring and establishing new brands, which were structured like individual companies. The process of developing new brands has continued since then, and today the group has 17 individual brands in its portfolio. The same applies to the sourcing activity, which has become a central parameter for success. Due to the never-ending goal of reducing costs, the internationalization and relocation of activities have continued. With the economic liberalization of China, the fabrication of cloth moved to the Pearl River Delta and Southeast Asia. Today, cloth manufacturers have moved to Vietnam, Bangladesh, Pakistan, and more remote areas in China.

In 2008, the company closed down its last production facilities in Poland and Bulgaria. Today, the activities are focused on the input and output ends of the value chain. The restructuring of the company was intended to create a service platform that could support and release resources in order to enhance value-adding activities. These include brand development, design collection, sourcing, wholesale management, sales, and marketing. The COO recognizes that the competitive situation in the textile and clothing industry forces the company to continuously trim and develop the value-adding activities. However, he also recognizes that the activities related to the input of the value chain are difficult to copy, as they require intangible knowledge about Scandinavia fashion, trends, and market needs.

In addition to the sudden changes in fashion, the frequent relocations of production sites to low-wage areas have determined the locations of companies in the upper right cell of figure 3. Furthermore, the strategy of supporting the growing number of individual brands in defining and maintaining their unique identify calls for the loose coordination of the operations network.

The case illustrates how competition with respect to price leads to frequent shifts in production sites. This calls for a production engineering capability to quickly establish production at a new site, often in a new country, and it identifies the importance of the strategic role of benchmarking and ramp-up. Also, a frequent reconfiguration of the network structure is called for.

Case-study company 4 - Designer furniture

Today, the company is part of a small, exclusive array of luxury brands that are representatives of quality and world-class design. The ambition of the company is to become the preferred and successful brand within exclusive design furniture and to enhance the customers' image by supplying such furniture. The company's self-perception has been based on the fact that they were the producers behind some of the most outstanding design furniture over the years. A number of years ago, the company fully mastered a broad line of in-house production lines of tables and lounge, dining, meeting, and stackable chairs.

In the run-up to the new millennium, the company experienced a slump in sales. Therefore, an analysis to clarify internal and external values was initiated. It showed that the company was facing a paradox: internally, they saw themselves as a company characterized by having a wide and dynamic range of products, created by many top architects and furniture designers. However, externally, only a few products and designers dominated the target group's picture of the company. This initiated a shift towards an increased market orientation with a large-scale investment in a sales- and image-building platform, which would attract new designers and boost the sales profile of the company.

The shift from a product- and production-oriented mindset to a focus on sales and international branding meant that the roles of sales, marketing, logistics, and development processes increased tremendously and emerged as the new core processes that replaced the actual manufacturing competence. As a result, a broad number of production lines and processes traditionally mastered in-house were reduced dramatically by outsourcing, reducing the number of production lines managed in-house to approximately 36%.

Following a period characterized by a strong focus on rationalization and optimization within production and sourcing, a new strategy was developed, indicating how the company wanted to work with their suppliers. The strategy was supported by a set of tools, the introduction of which was intended to lead to considerable changes in the configuration and management of the relationship between the company and their suppliers and to put pressure on the different network actors' ability to change.

First of all, the objective of the new sourcing strategy was to support the overall business plan to create value in the eyes of the customer. Furthermore, the strategy should put focus on implementation and balance of input and output and relate to the differentiated and context-based conditions for the company's sourcing activities. The objective of the sourcing model was to differentiate and consolidate sourcing activities and to enable the formulation and execution of multiple sourcing and relation strategies related to different suppliers. Furthermore, the model served as a tool for securing "risk" sourcing and for measuring performance of the suppliers.

In relation to the activities of strategic and key sourcing, a partnership approach towards suppliers was developed. The decision to undertake a partnership approach was closely tied to the recognition that the competition in sales markets is not only between companies, but also between supply chains. Furthermore, in some situations, close cooperation with suppliers is necessary and beneficial for customers and stockholders. Finally, the development of partnerships was seen as a driver to create synergies and to:

- Increase cooperation and a holistic supply chain to reduce waste,
- Reduce the risk of low-performance and general company risk, and
- Increase flexibility.

Through the partnership approach, the company aims to build long-term relationships to ensure a tight alignment of activities and resources and to improve sourcing performance (strategic KPI) in order to minimize company and customer risk. In addition to coping with established relations with suppliers, the company continues to source key processes, components, and stainless steel, with the main focus on Poland as the number-one sourcing market.

Although new products are introduced, it seems fair to classify the company in the lower left cell of figure 3, thus also satisfying the need to tightly coordinate the many different suppliers so as to maintain its image among customers of a reliable supplier of high-quality designer furniture. The new sourcing strategy implies a significant need to address the supporting strategic roles of supply chains, such as benchmarking, prototyping, and ramp-up. The network structure may be described as a star, resulting in a highly complex sourcing task. It may be relevant for the company to consider shifting to a network structure with a number of loosely coupled networks for product groups using similar material and production technology.

6. Cross-case analysis

As the four case-study companies represent different industrial contexts, it is tempting to look for a pattern of configuring the operations network primarily based on contextual influencers. We, however, find that contextual influence alone cannot explain configuration as companies competing with similar industrial conditions may choose to compete with different means and, as a result, end up with different configurations. To reflect these ambitions of companies to pursue different things with their supply chain set-up, we have used the coordination of the operations network as a proxy for the level of interdependency and commonality between partners within the supply set-up.

With respect to the strategic roles of plants within the chain, companies experiencing a high rate of change may find that prototyping and ramp-up are of significant importance in addition to the full-scale manufacturing and sourcing due to the need to integrate new inputs from process and product innovations continuously. On the other hand, companies with a low change rate will need to address benchmarking in order to push the utilization of available resources. With regards to the overall network structure, the case studies illustrate a development of frequent restructuring in search of an appropriate balance between the request for proximity to the markets and the need for specialized manufacturing in one location (economy of scale). This has challenged production engineering to develop new technologies in support of parallel production and agility. A third issue of configuration is the organizational aspects related to the infrastructure of operations. It seems that the case-study companies have been able to develop appropriate management systems and organizational structures for their full-scale manufacturing and sourcing, and they have even been able to restructure as new markets have been addressed.

However, the companies have been less aware of the importance of developing key supporting and/or indirect roles, which may assist the company in securing a more robust and effective supply chain, as they moved along their globalization trajectory. For example, critical links was unveiled in the processes related to e.g. the cooperation between functions in the value flow of the company (production, production engineering, product development, and sales), which with increased distribution and changing governance structures became even more critical for planning and improvement purposes. The case studies have also shed light on the importance of supplementing the organizational means relevant to full-scale operations with the means of knowledge sharing and development, which are typically found in the other three generic roles.

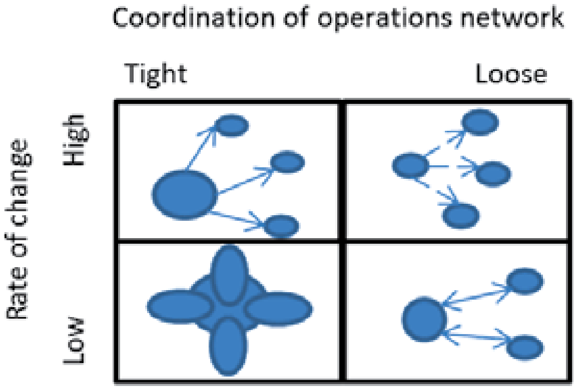

Fig. 4. Types of supply networks

7. Implications for configuration of supply chains

The case studies have given rise to issues of configuration of operations systems and future challenges. In view of the small sample, we have drawn on a number of additional case studies that we have been actively involved in and we have taken note of trends in the literature in an effort to extend our empirical base. This has led to a number of implications for configuration of operations and supply systems to be presented in the form of propositions. In this way, we hope to hand the baton on to other researchers to engage in a continued discussion of configuration issues and means.

P1 – The indirect strategic roles of supply chains will become increasingly important

Without neglecting the significance of the role of full-scale production, it seems that the contributions that manufacturing and supply chain make to competitive advantage in cooperation with other functions will become more important in the future; for example, ramp-up, benchmarking, and prototyping.

In companies with increased customization of products and processes, the role of prototype production will require more attention and, on the other hand, offers potential for a differentiated corporate strategy. As pointed out by Slack et al. (2004), attention should be given to the increased integration of product and service offerings. This ongoing servitization of manufacturing is becoming a dominant driver of supply chain configurations as it brings in new agendas related to serving customer-specific needs through operations processes such as extended logistics services, customized product properties, and life cycle management as is particularly evident within case 4, where an increased focus on service-manufacturing integration has become the new competitive platform for the company.

The scope of this proposition is supported by Maletz and Nohria who point to the need to manage white spaces within organizations, i.e. the large, but mostly unoccupied territory, in every company where rules are vague, authority is fuzzy, budgets are nonexistent, and strategy is unclear — and where, as a consequence, entrepreneurial activity that helps reinvent and renew an organization takes place (Maletz & Nohria, 2001). But the proposition extends the scope of these white spaces to the extended enterprise and the entire supply network, i.e. the participation and interplay in various networks with respect to both daily operations and introduction of new products, technologies and systems. Because of these increased dynamics and uncertainty of demand, the ramp-up production capability is expected to play an increasingly important role. This calls for modular and platform thinking in the design of production systems and well-described business processes.

The case-study companies demonstrate that the key role for operations capabilities in the emerging supply networks is that of managing virtual manufacturing processes focusing not only on supply chain management, but also on the maintenance of sufficient competencies at the suppliers. The case studies also show the increased awareness of the importance of the interplay between product development, handling of customer orders, and production and supply chain management coordination and planning.

As an implication, P1 points to the need to focus attention on developing competencies in managing the interplay between functions, which may not necessarily be under the direct control of the focal company, e.g. sales, product development, sourcing, and manufacturing.

As the indirect strategic roles come into focus and operations take place globally, new competencies are called for. Traditionally, emphasis has been placed on knowledge and

know-how about production processes; and this represents an important challenge for key processes. But increasingly, the capability to manage complex interplay between many actors involved in a value chain becomes equally important for organizational performance. In many companies the competitive strength lies in these complex competencies, requiring holistic thinking, relying on tacit knowledge located in the hands, heads and minds of a group of employees, and in their interplay with the historically generated systemic set-up.
Knowledge sharing across organizational boundaries will become a key issue in the supply network. The case company 2 in particular with its regional set-up has recognized the need for knowledge sharing between its manufacturing sites around the world, not only on specific production processes, but in particular the management practice of stimulating continuous improvements and systematizing cooperation between production development, production engineering, operations and suppliers in the introduction of new products. The company has started to work with virtual communities of practice to share ideas about future production practice (strategic challenges, organizational forms, business processes, management systems and production technologies and processes) and as a vehicle for a joint exchange of ideas and know-how between managers and engineers across the various sites and main hubs. This case has over time progressed through a number of maturity steps as illustrated in figure 5. where it is now appraoching the outer ring where the performance of the individual sites becomes increasingly dependent on the performance of other sites and not only sequentially as it would typically be seen within the traditional supply chain, but increasingly through joint achivements on issues such as sustainability, R&D and sourcing.

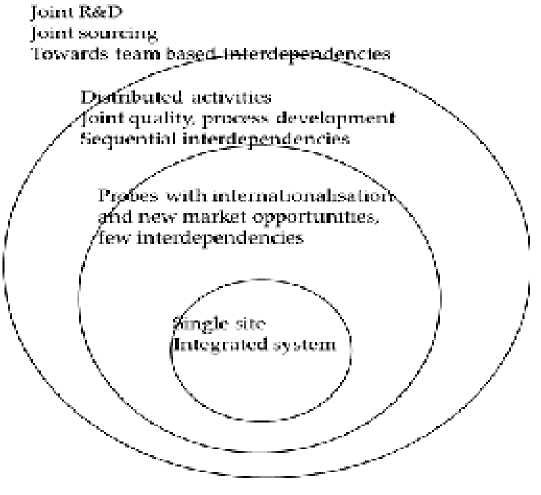

Fig. 5. Evolving network relationships

P2 – From value chain to value netwok

The case-study companies may be characterized as an Integrating Firm serving as an OEM company at the end of a supply chain. Most of them have adopted an outsourcing strategy to focus on product development, assembly, and distribution. However, when we look at manufacturing, a shift of thinking may be observed, for example from a single lead factory in Denmark to several lead factories forming a network of interactions with one factory having been designated a center of excellence in a specific production process.

The archetypal Networking Firm is characterized by a number of nodes (partners) offering complementary capabilities useful for the products and services offered. The new sourcing strategy of case-study company 4 illustrates this trend, as it has adopted a partnership approach with some key partners, and aims to use these partnerships to move beyond the basic tradeoffs its own operations were tied down by. In case company 3 a similar set-up has been established with a pool of preferred partners (capable of supplying flexibility, reliability and speed) and a larger pool of arms-length partners (working with a cost and capacity focus).

A key question is how companies will be capable of retaining sufficient competencies in-house for leading the development of future activities as their operations capabilities become increasingly distant in time and space. Longitudinal studies will be required to study the dynamic effects as competencies unfold within manufacturing networks, but there are key indications that companies can outsource too much leaving them in a position where the ability to influence, coordinate and specify key deliverables becomes increasingly distant.

An implication of the move from a value chain thinking to that of a value network is that the power structure becomes more distributed and diffuse. In most cases, the integrating firm holds the final word, being closest to the customers and being willing to adopt the risk. In the networking firm all complementary contributions are necessary, and the power is distributed among several partners. As a consequence, P2 calls for a shift from trade-off thinking to a capability for working with dualities, e.g.

- Living with hierarchical roles and evolving networks
- Empowering plants and setting direction for the overall network
- Centralizing strategy development and decentralizing operations
- Standardizing for cost, reliability and global reach and on the other hand customizing for responsiveness

An interesting aspect to explore is the potential synergy expressed by Milgrom and Roberts, a point that holds that doing *more* of one thing increases the returns of doing *more* of another (Milgrom & Roberts, 1995). This points to the notion of strategic complementarities, according to which investing in one practice makes it more profitable to invest in another, setting off a potential virtual circle of high performance.

P3 – Shifts in strategic supply chain roles may be seen as a sequence of moves similar to a multi-player game

Case 1 illustrates how an initial set of decisions to establish joint production with a partner in Eastern Europe led to unforeseen consequences, which called for a new set of decisions and essentially set the company off on a new trajectory. The case description talks about three waves of decisions and reactions from the environment (test, full scale, withdrawal).

Case 1 also demonstrates that the initial decision to establish the collaboration might have been justified; but due to the reactions from customers and competitors new challenges and opportunities emerged, changing the foundation of the initial decision. These hidden costs of offshore operations often play a fundamental role in the relocation process, but also influence the longer term strategic role of operations processes within the company.

This and similar case examples have led us to use an analogy to a multiplayer game. A player makes a move, and the other players *react* and make their moves, which leads the first player to make a new move. The ability to foresee more than just one move is a key to success in chess and other games.

Case 1 illustrate that management was not aware of this dynamic process and was caught by the difficulty of reversing decisions made. The company, however, managed to turn the situation into an advantage by using it as a learning process, where it has learnt about the underlying fundamentals of its own operations, which has left the company in a much stronger operational situation with a robust and well-functioning supply network.

As an implication of these emerging requirements, an organizational learning approach is warranted, which emphasizes experiential expansion and connectivity between parts. In a distributed manufacturing network a concerted effort is needed to transfer the work-object and to explicitly codify and transmit sticky knowledge through systemic and social communication channels. The difference between tacit and explicit interdependences is critical for understanding the implications of increased distribution.

Another implication is a need to develop interactive scenarios, perhaps in the form of social experimental simulations, which would explore possible consequences of a series of moves. We find that this way of thinking about strategic planning is quite different from the traditional development of a master plan for the next period. Such experimental simulations may include identification of irreversible elements requiring special management attention.

P4 - Knowledge development and sharing within the supply network will become key

The nature of knowledge development will be different for the four strategic supply chain roles. For example, the Full scale role may better allow for including intelligent systems, whereas the other three types to a larger degree rely on personal contacts and tacit knowledge due to the non-standardized way of working.

A recent study has estimated that a significant proportion of corporate innovation comes from external sources (suppliers, customers, etc.) (Linder et al., 2003). This indicates that firms should emphasize capability buying adding a new level to the sourcing activity beyond materials or modules, which has preoccupied our thinking so far. In line with this MNC literature tells us that knowledge generated in any part of the value chain is valuable not only for the knowledge generator itself, but for the overall value chain (Dunning, 2001). The inherent implication of this is that more knowledge in the chain (of any type) ought to generate a stronger drive for knowledge transfer within the chain. This drive is, however, dependent on the presence of strong intensives, the level of absorptive capacity of the partners, and the availability of a supportive network infrastructure. In other words some level of internal knowledge and systematic support is needed to acquire and assimilate external knowledge, which is valuable to the supply network although it may be less valuable to its individual partners.

P6 - Accessibility will become more important than ownership

The issue of whether to outsource or to offshore production has caught much attention both in theory and in practice. However, an underlying dimension is the extent to which a company has access to competences and capabilities and is capable of appropriating these for its own value creation. The scholarly as well as managerial debate need to discuss how this dimension can be given a more prominent place as a variable when configuring the supply network of the future.

8. Conclusion

The increased scale and scope of global operations has called for a reconsideration of supply chain configuration. For instance, offshoring of operations has rendered the traditional separation of operations management and supply chain management obsolete.

As part of the configuration framework introduced, we have focused on network structures and strategic roles, the latter including interdependencies to other functions, such as product development, sales/marketing, and purchasing.

Four different industrial contextual situations were identified based on respectively low or high rates of change, and tight or loose coordination of operations. Four industrial case studies representing different situations were presented to illustrate configuration issues as they were addressed and managed over a number of years.

Combined with experience from other industrial cases and trends in the literature, the case studies gave rise to the formulation of implications for configuration of supply chains and global operations in the form of a number of propositions. They indicate that

- Managing interdependencies between supply chains, operations, product development, sales/marketing, and purchasing will become increasingly important, all of which emphasize effective indirect strategic roles.
- A shift of focus will take place from value chain to value web with multilayered relations and interdependencies.
- As a consequence of these changes, configuration should be dealt with in a sequence of moves, similar to a multi-player game, as the traditional linear planning-based approach will fall short.
- Building infrastructures in support of knowledge development and sharing will become key, and
- Accessibility of and ability to appropriate external operations capabilities will become more important than ownership.

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4

Prediction Markets – A New Tool for Managing Supply Chains

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1. Introduction

The "Beer Distribution Game", a business simulation game developed at MIT (Sterman, 1989), is familiar to most students of supply chain management. As all good games, the Beer Game teaches some important lessons. The key lesson from the Beer Game is that sharing of information among the members of a supply chain is crucial for the supply chain performance. Information and knowledge in firms, social networks and supply chains to manage decisions with effects in the future is often dispersed, only available to certain individuals or groups and consists of opinions, personal guesses and evaluations. The human component in information sourcing, adapting and processing has largely been neglected in supply chain research. But the adaption of personal information and beliefs are important sources for adaption to an uncertain and changing market environment (Kirzner, 1973).

All business decisions are based on formal or informal forecasts about the future development of the market environment and the possible consequences of the decisions. So forecasts are a key skill in nearly every business situation. Forecasts vary in target, horizon, method, model, the team involved etc. Many approaches to forecast in fields of business interests neglect the information held by people in the respective firm. Inaccurate forecasts can result in substantial costs for a firm (Spann and Skiera, 2003). Instead of acknowledging the importance of good predictions for business success the managers invest in many cases little time and money and put less attention on the forecasting work. And mostly they neglect the information held by other persons in their own firm, e.g. workers in the production process, and outside the firm, e.g. consumers.

There are two different approaches of forecasting methods: The first approach uses statistical methods to result a prediction out of existing data (e.g. by methods of time series econometrics); the second approach collects new data of the predicted object (e.g. consumer and expert surveys) (Armstrong, 2001). Both approaches have major weaknesses; the first approach needs reliable data - only for known settings predictions can be estimated; the second approach lacks information on who to ask and how to aggregate the answers. Prediction Markets (PMs) are forecasting tools which employ digital network technology in order to aggregate diverse personal beliefs (forecasts) about the future into forecasts that tend to be better than forecasts by individual experts or by statistical forecasting methods.

PMs can overcome these lacks of traditional approaches by potentially using all the information available by allowing people to trade their bets. Formerly this used to be costly; modern hardware and internet based markets have driven down transaction costs rapidly. Nonetheless, incentive systems have to be developed to truthfully reveal the information of all participants. In the end all bets are liquidated at a price according to the actual outcome (Spann and Skiera, 2003). PMs are "...markets that are designed and run for the primary purpose of mining and aggregating information scattered among traders and subsequently using this information in the form of market values in order to make predictions about specific future events" (Tziralis and Tatsiopoulos, 2007).

Von Hayek (1945) assigned markets a dual role. They allocate resources and, through the process of price discovery, they aggregate information about the values of these resources. This information aggregation role is widely accepted for stock markets. Stock market prices are interpreted as the consensus judgment about the value of future corporation earnings (Berg et al., 2003).

PMs are widely used to forecast election results, sport games, box office revenues and a lot more (e.g. Berg et al., 2008b, Gruca et al., 2008, Hartzmark and Solomon, 2006, Servan-Schreiber et al., 2004). In these fields PMs created accurate forecasts and mostly these forecasts are better than the standard operated methods. We applied the principle of PMs to forecast future product sales in a firm. This implementation confirms the idea that PMs are a promising tool to manage supply chains. In our case study they show accurate forecasts, both in absolute and relative terms compared to the standard operated methods.

A short description of the functional principle of PMs is followed by two theoretical foundations of the price formation process and the forecasting ability of PMs. Applications of PMs to different topics are described in the next section. Section five describes the requirements of PMs, the design and the results of our own experiment to forecast future sales volumes. The chapter finishes with a conclusion.

2. Functional Principle of Prediction Markets

The use of experimental markets for forecast purposes is based on the idea that private and public information will be aggregated and published efficiently by these markets (Berlemann, 2004). The information aggregation ends directly in a qualitative or quantitative forecast at the PM. The functional principle behind PMs is similar to the big stock exchanges. Certificates, which represent a forecast of a future event, are traded between the PM participants. The prices of the certificates can be interpreted as a prediction concerning the forecasted event. The possible realisations of the forecasted event have to be transformed into values of the tradable certificates. The transformation function determines the certificate value at any time T (Spann, 2002):

$$d_{i,T}=\varphi(Z_{i,T}) \qquad (i \in I) \tag{1}$$

with

$d_{i,T}$ = certificate revenue value,

$\varphi(\cdot)$ = transformation function, transforms the realisation of the forecasted event into the certificate revenue value,

$Z_{i,T}$ = realisation of the forecasted event i at time T,

I = set of events and

T = point in time of the forecasted event.

The transformation function $\varphi(\cdot)$ transforms the possible outcomes $Z_{i,T}$ of the forecasted event into termination values $d_{i,T}$ of the certificates. The expected payoff of a certificate for every participant under the information set Ω_t is at every time t<T:

$$E_t[d_{i,T} \mid \Omega_{i,t}] = E_t[\varphi(Z_{i,T}) \mid \Omega_{i,t}] = \varphi(E_t[Z_{i,T} \mid \Omega_{i,t}]).^1 \quad (2)$$

Every PM participant has to insert his own expectation concerning the forecasted event into the transformation function to receive his expected payoff of the certificate. By comparing his expected payoff with the market offers and trading accordingly, he achieves expected wins at the PM. By doing so he will change the market price towards his own expectations.

An invertible transformation function[2] has the advantage that the trading prices of the certificates can be retransformed into a forecast. The future sales quantity of a specific product shall be forecasted, for example. A possible transformation function for this task can convert every sold quantity unit (QU) into one currency unit (CU) of the certificate. Direct transformation of the trading price into a prediction is possible in this example. Let the trading price at time t be $p_{i,t}$ = 22.34 CU. This implies a forecast of $Z_{i,T}$ = 22.34 QU. The transformation function clarifies that the certificates depend on the outcome of an uncertain future event (Spann and Skiera, 2003). Most PMs use a continuous double auction with or without market makers as trading mechanism. Market makers offer continuously bids and asks for the certificates to increase market liquidity (Hanson, 2009). PMs can be divided depending on the forecasting issue into three types (Spann, 2002):

a. Winner-Takes-All Markets

The prediction of the occurrence or non occurrence of a future event, e.g. the re-election of a candidate, is the simplest example for Winner-Takes-All Markets. Two certificates are traded on such PMs: A represents "Re-Election" and B "No Re-Election".[3] Both certificates are combined in a unit portfolio for the price S. The market organiser sells and buys the unit portfolio to/from the participants during the market operation time for the price S. The unit portfolio represents all possible realisations. The termination value of certificate A is S if the candidate is re-elected ($d_{A,T}$ = S) otherwise it is 0 CU ($d_{A,T}$ = 0 CU). Certificate B is worth 0 CU if the candidate is re-elected or S if the candidate is not re-elected. The market organiser buys back all certificates for their final value after the last trading day. The trading prices of the certificates are interpreted as the probability of occurrence of the underlying event in percent if the price S of the unit portfolio is standardised to 100 CU. The prediction of more than two possible states is realised by more than two certificates; one certificate for every possible state.[4] Example: There is one certificate for every team in the Football World Cup to predict the champion. The price of the unit portfolio, existing now out of 32 certificates, is again 100 CU. The trading prices reflect again the winning probability of the underlying

[1]The risk free interest rate is set to zero and the holding of the certificates is riskless. This implicates for every point in time t<T: $p_{i,t} = E_t[d_{i,T} \mid \Omega_{i,t}] = E_t[d_{i,T} \mid \Omega_{i,t}]/(1+r)$.

[2]The mathematical function $\varphi^{-1}(\cdot)$ can be calculated. So the following relation is valid: $Z_{i,T} = \varphi^{-1}(p_{i,t})$ with $p_{i,t} = E_t[d_{i,T}]$.

[3]"Lock-In-Option", "digital options", "Simplex Options",, "All-or-Nothing-Options" or "Lottery Options" are different common notations of these certificates (BERLEMANN, 2004).

[4]The winning candidate of the election out of a set of candidates can be predicted alternatively. In this case every certificate represents one candidate. The trading prices represent now the winning probability of the candidates.

team. The possible prediction of continuous variables with Winner-Takes-All Markets needs non overlapping intervals of the total event space. Each interval represents one subspace of the event and belongs to one certificate. The calculation of the expected value leads to the prediction (it is the sum over the means of the subspaces multiplied with their probability of occurrence).

b. Vote-Share Markets

Vote-Share Markets are used to predict relative figures, e.g. the market share of different products or vote shares. The market share of three different products A, B and C in one market shall be predicted, for example.[5] Certificate A (B, C) represents the market share of product A (B,C). The unit portfolio includes each certificate once. The termination values of the certificates are calculated by multiplying the actual market share of the product by the price of the unit portfolio S; $d_{i,T} = v_{i,T} \cdot S$ ($v_{i,T}$: actual market share). Product A reaches an actual market share of $v_{A,T} = 0.25 = 25$ % and the price for the unit portfolio is S = 100 CU. Then certificate A has a termination value of 25 CU = 0.25·100 CU. The trading prices of the certificates are interpreted directly as the expected market share of the underlying product.

c. Markets for the prediction of continuous variables

Also continuous variables can be predicted with the help of PMs. Instead of the construction of non overlapping intervals as shown above, continuous variables can be predicted directly. Example: The total sales quantity of product X (Z_T) shall be forecasted. Two certificates are traded on the PM for the direct prediction of the sales quantity. Certificate A represents the sales quantity and certificate B S minus the sales quantity. Certificate B is necessary to create a unit portfolio which is always worth S. S has to be chosen carefully because the forecasted sales quantity has to lie with certainty between zero and S. The typical sales quantity of product X was about 50,000 and it is not expected that the future sales quantity exceeds 100,000. In this case S will be set equal to 100,000 CU. The transformation function converts one sold quantity into one currency unit. The termination value of certificate A is $d_{A,T} = Z_T$ and of certificate B $d_{B,T} = S - Z_T$. If the actual sales quantity exceeds 100,000 units, then certificate A has a value of 100,000 CU and B of 0 CU. One participant expects for example that the sales quantity will be 56,000 units, then certificate A has an expected value of $d_{A,T}$ = 56,000 CU = Z_T = 56,000 units and B of $d_{B,T}$ = 44,000 CU = S – Z_T = 100,000 – 56,000 for him.

Prediction Market Trading

Trading at a PM is divided into two stages. The market organiser sells (or buys) the unit portfolio for the price S during the whole market operation time to (from) the participants at the first stage (the primary market). When at least one participant buys one unit portfolio at the primary market, the participants can trade the single certificates for prices, which may represent their expectations, among each other at the secondary stage (the secondary market). The above description of the termination value structure clarifies that the PM is a Zero-Sum-Game for the organiser. The market organiser sells the unit portfolio for the price S and buys back all certificates at market termination for their final values. The construction of the certificates guarantees that the sum of the termination values is always equal to S. The primary market is a riskless exchange of S CU for a unit portfolio.

The secondary market is the core of the PM. The PM participants trade the certificates among each other at prices that reflect their expectations about the underlying event.

[5] These three products A, B and C represent 100 percent of all sold products. Otherwise an additional certificate "Others" is necessary to cover the total event space.

Normally a continuous double auction is chosen as market mechanism. This design assures the possibility to create buy or sell orders for the certificates at any time. For the case of orders with higher buy than sell prices a trade takes place. The general rules of continuous auctions are applied for the matching process. Open design possibilities are the selection of the allowed order forms (e.g. market order, limit or stop-limit order) and the design of the order book (e.g. open or closed). The trading at the secondary market contains win and loss possibilities for the participants, if the trading prices differ from the actual termination value of the certificate. One participant j shall try to buy all certificates at the market if he can get them for lower prices than $E_{j,t}[d_{i,T}]$ and to sell all certificates at the market if he can receive a higher price than $E_{j,t}[d_{i,T}]$. By doing so he gains an expected profit. Only if two participants j and k have different expectations about the event, the participants trade certificates. The relationship $E_{j,t}[d_{i,T}] \neq E_{k,t}[d_{i,T}]$ must be valid. At time t a PM is cleared if there is no demand for certificates with a price greater than the price of the smallest sell order. The last trading price in this situation represents the collective expectation of the market participants about the future event. The PM produces a new prediction with every trade. Every forecast indicates a different time horizon as time goes by.

3. Theory

PMs show impressive forcasting performances in previous applications[6] in comparison to alternative forecasting methods. We still do not fully understand the well functioning of PMs. Two different approaches for the theoretical foundation of the prediction process can be found in literature. The first approach is based on von Hayek's (1945) insight about the dual role of markets. Markets are well known for swapping goods between different persons. Additionally, markets aggregate the diverse information of the traders by the price formation process. The stock value of a company, e.g., is taken as the collective expectation of the company value. So the first approach is based on the theory of rational expectations and efficient markets. The second approach is based on the toolbox approach by Page (2007), which highlights the importance of diverse forecasting groups.

3.1 Classic market theory

A simple theoretical model based on Kyle (1985) is presented in the following to explain the price formation process on PMs (Wolfers and Zitzewitz, 2006b). The PM is organised as a continuous double auction. The occurrence or non occurrence of an event is predicted on the PM. The participants trade a binary certificate, which has a final value of $d_{1,T} = 1$ CU if the event occurs and of $d_{0,T} = 0$ CU if the event does not occur. The expected payoff of the certificate is for every participant his personal probability of occurrence in CU. All traders have an individual expectation $e_{i,j,t,T}$ concerning the probability of occurrence of event i out of the distribution $F(e_{i,j,t,T})$ and a private wealth of w_j. The traders maximise following logarithmic utility function:

$$E_{j,t}[U_{j,T}] = e_{i,j,t,T} \cdot \ln(w_j + (1-p_{i,t})x_j) + (1-e_{i,j,t,T}) \cdot \ln(w_j - p_{i,t} \cdot x_j). \quad (3)$$

The partial differential of the utility function with respect to x_j results in the net demand of every participant j:

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[6]See section 4 for more details.

$$x_j = \frac{w_j(e_{i,j,t,T} - p_{i,t})}{p_{i,t}(1 - p_{i,t})}.^7 \tag{4}$$

If the individual expectations of the trader $e_{i,j,t,T}$ exceed the price $p_{i,t}$, then he will buy the certificate. Otherwise he will sell the certificate. The PM is in equilibrium if the market is cleared. The market clearing price has to equalise the aggregated demand and supply over all participants. The net demand for the certificate has to be equal to zero. The market clearing price has to fulfil the following condition:

$$\int_{-\infty}^{p_{i,t}} \frac{w_j\left(e_{i,j,t,T}-p_{i,t}\right)}{p_{i,t,T}\left(1-p_{i,t}\right)} f\left(e_{i,j,t,T}\right) de = \int_{p_{i,t}}^{\infty} \frac{w_j\left(p_{i,t}-e_{i,j,t,T}\right)}{p_{i,t}\left(1-p_{i,t}\right)} f\left(e_{i,j,t,T}\right) de. \tag{5}$$

The expectations are furthermore distributed independently from the wealth. So the equation reduces to:

$$p_{i,t} = \int_0^1 e_{i,j,t,T} f\left(e_{i,j,t,T}\right) de = \overline{e_{i,j,t,T}}.^8 \tag{6}$$

Market prices are consistent with the mean of the expectations and they are an unbiased predictor for the participants (Wolfers and Zitzewitz, 2006b). The difference between the mean of expectations and the market clearing price is quite small for different types of utility functions (Wolfers and Zitzewitz, 2006b). The market clearing price differs significantly from the mean of the expectations of the traders in the special case of only one single investment decision and uniform distributed information (Manski, 2006).
Transaction costs have to be considered but they do not change the main result. An area of uncertainty of the market clearing price, depending on the transaction costs, appears around the old market clearing price now. The transaction costs are divided in two modes: the information search costs, these are all well-known costs for the information search and the creation of the expectations, and the common transaction costs, which cover all costs of market participation, e.g. fees. The information search costs are nearly the same for every market type, if the same product is traded. Solely the transaction costs partially exhibit great variance between the market types. These costs are quite small for PMs, because PMs operate over the World Wide Web (WWW).[9] The resulting market clearing price has now an uncertainty of k around the price without transaction costs if all market participants have the same transaction costs k. The new asks and bids differ from the expectations by the factor k. A bid (ask) is higher (smaller) than the expectations. The transaction costs can cause some participants not to trade. The actual market clearing price is now located in a corridor of the size k around the price without transaction costs depending on the distribution of the expectations. The smaller the transaction costs the smaller is the potential deviation between the market clearing price and the mean of the expectations.

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[7] Intermediate solution step: $\frac{\partial E_{j,t}[U_{j,t}]}{\partial x_j} = \frac{e_{i,j,t,T}\left(1-p_{i,t}\right)}{w_j+\left(1-p_{i,t}\right)x_j} - \frac{(1-e_{i,j,t,T})p_{i,t}}{w_j-p_{i,t}x_j} \overset{\text{def}}{=} 0$ and solving leads to: $w_j\left(e_{i,j,t,T}-p_{i,t}\right) = p_{i,t}\left(1-p_{i,t}\right)x_j$.

[8] Intermediate step: $\frac{w_j}{p_{i,t}\left(1-p_{i,t}\right)} \int_0^{p_{i,t}} \left(e_{i,j,t,T}-p_{i,t}\right) f\left(e_{i,j,t,T}\right) de = \frac{w_j}{p_{i,t}(1-p_{i,t})} \int_{p_{i,t}}^1 \left(p_{i,t}-e_{i,j,t,T}\right) f(e_{i,j,t,T})\, de.$

[9] Nearly every person with access to the WWW can participate in a PM. Additionally access has no time limits, so the reaction on new information is always possible.

3.2 Page's toolbox theory

The diversity of the expectations of economic agents is assumed in the classic market theory. The classic market theory gives no reasons for the existence of the diversity. In the case of rationality and identical information all economic agents shall have identical expectations. Page (2007) tries to explain the information aggregation process with his "toolbox" approach. Basis of this and other approaches to model human decisions is the assumption of limited rationality instead of complete rationality (Simon, 1982). Page tries to decompose the decision process into its elementary components (Gigerenzer and Selten, 2002). Furthermore, Page explains why predictions, composed of individual predictions of a group of forecasters, are often better than the predictions of the best forecaster within this group. Finally Page gives reasons why PMs show better predictions than polls.

The assumption that cognitive diversity yields in better results of job completion is Page's basic concern. The diversity can be decomposed in the diversity of the four cognitive tools of decision makers: (i) diverse perspectives or the way of representing situations and problems, (ii) diverse interpretations or the way of categorising or partitioning perspectives, (iii) diverse heuristics or the way of generating solutions to problems and (iv) diverse predictive models or the way of inferring cause and effect (Page, 2007).

The predictive model is based on the concepts of perspectives and interpretations. A perspective is nothing more than a word, which describes a situation, an event or an object. A pack of paper between two covers can be described as a book and we can read it, or we can describe and use it as a doorstopper, if it is heavy enough, or as a missile to banish unwanted persons. It is important that the perspective, the description of the object, indicates its usage for the solution of a specific problem. The perspective differs from person to person and more creative persons have more versatile perspectives than less creative persons.

Perspectives are components of interpretations. Interpretations assign a group of objects, events or situations to a word. Specific attributes of these objects, situations or events are normally not considered. We can categorise persons, who apply for a job, in many directions: age, gender, family status, education and so on. If we just use the two interpretations gender and family status, we get six groups of job candidates: the combination of female and male with single, married and divorced.

The predictive model is a combination of interpretation and prediction. The prediction is the result of the interpretation of an object. For example we classify job candidates for a research job according to their field of study, place of study and exam marks. By doing this we hope to receive a good interpretation of the future research quality of the candidate: good university, useful field of studies and good marks indicates good research work, and so on. As persons have different perspectives they can have different interpretations and use them to receive different predictions in the end.

The predictions from different persons differ because they are based on their diverse predictive models. Therefore the question, how this diversity can be used to create better predictions, is apparent. One obvious idea could be to select the best forecasters. This strategy has two disadvantages: first in the case of long time predictions the selection can only be done with long delay and second there is no reason for the assumption that a good forecaster in one field will be a good forecaster in others too. A good meteorologist, e.g., would not be taken as an investment banker solely because of his good weather forecasts. Page chooses another approach. He explains the phenomena of the "wisdom of crowds", known since Galton (1907), with the help of a theorem and a "law". Page's Diversity Prediction Theorem signifies that *the collective prediction error is the average individual prediction error minus the prediction diversity*. This theorem indicates the Crowd Beats the Average Law: "*the collective prediction is more accurate than the average individual predictions*"[10] (Page, 2007, p. 209). We introduce a few notations to clarify the theorem and the law.

Z_T is the observed realisation Z of a metric variable at a future time T. The members of a prediction collective $k \in K$ forecast individually this variable at time t=T-n. These predictions are denoted $v_{k,t,T}$. We have only one prediction time t and one prediction horizon n, so in the following we leave the indexes T and t out.

Every prediction is afflicted with errors which are measured as the squared difference between the predicted and the realised value: $e=E[(Z-v)^2]$. The individual prediction error of one member is marked: $e_k=E[(Z-v_k)^2]$. The average individual prediction error can now be calculated as: $\bar{e}=1/k\sum_k e_k$. The square of the difference between the mean of the individual forecasts and the realised value is the collective prediction error. The mean of the individual forecasts is $V=1/k\sum_k v_k$. The collective prediction error is calculated as: $\bar{\bar{e}} = E[(Z-V)^2]$. At the end we need a measure for the prediction diversity in the collective, which is the mean squared difference between the individual forecasts and the mean of the individual forecasts: $D = 1/k\sum_k (v_k - V)^2$. By the help of this notation the Diversity Prediction Theorem indicates: $\bar{\bar{e}}=\bar{e}-D$ or $E[(Z-V)^2] = 1/k\sum_k E[(Z-v_k)^2] - 1/k\sum_k (v_k - V)^2$.

This theorem has a lot of beneficial implications. The quality of the collective prediction ($\bar{\bar{e}}$) is influenced by the average quality of the individual forecasts ($\bar{e}$) and additional high prediction diversity (D) is advantageous. In short the forecasting ability of a collective is as important as prediction diversity. Furthermore the collective prediction is always more accurate than the average prediction of its members. Communication between group members has not to improve the prediction quality. If the prediction diversity D decreases more than the average individual prediction error $\bar{e}$, the collective prediction error $\bar{\bar{e}}$ then increases instead of decreases.

The participants of a PM are members of a forecasting collective. In the above description all individual forecasts are weighted equally but the PM participants define the weight of their forecasts with their money at risk. This suggests the assumption that market participants highly confident in their forecasts invest more money and put more weight on their forecasts than less confident participants. This will end up in a reduction of both, the average individual prediction error and the prediction diversity. If the collective prediction error will also decrease depends on the weights, the money at risk, of the market participants. In contrast to polls, which can be responded cost- and riskless, it can be assumed that persons who do not know anything about the forecasted object, are not prepared to invest their own money at PMs. Page calls this the "fools rush out". The prediction quality can be highly increased by the banishment of the fools. In respect to the importance of the prediction diversity Page is cautious about too much incentives for the good forecasters and too few for bad forecasters, because the small fools are necessary for prediction diversity.

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[10] For the special case that the prediction diversity is zero then the collective error is equal to the average individual error. The prediction diversity can only be zero if all forecasters have the identical prediction.

4. Applications of Prediction Markets

A great part of the actual literature describes and analyses realised PMs. We classify the applications according to their main focus into four groups: Policy, Sports, Business, Cinema and Others.

Policy

The most known application are probably the PMs to forecast the US presidential elections and further elections in the US by the University of Iowa at the Iowa Electronic Markets (IEM).[11] The first PM was organised to predict the next US-President 1988 (Forsythe et al., 1992). The PM correctly predicted the win of George Bush Sen. nearly perfect. The last forecast of the PM indicated a 53.2 percent vote share for Bush and 45.5 percent for Dukakis. The final election result was a vote share of 53.2 percent for Bush and 45.2 percent for Dukakis respectively. The forecasts of the PM were in addition very accurate in absolute terms and in relative terms in comparison to the polls. A comparison of the prediction error of the PM and of the polls shows the good relative prediction quality of PMs. The absolute prediction quality is measured by the mean squared error of the forecast against the actual election outcome. The mean squared error of the last PM forecast is 0.00004 and 0.00013 for the best poll (own calculations based on Forsythe et al., 1992, p. 1149).

In real money PMs traders have to invest their own budget. Participation here was restricted to University members and the budget was limited to 500.00 US$ due to an agreement with the US Commodity Futures Trading Commission. This restriction was necessary because otherwise the PM would have been banned by the gambling laws. Thus, PM participants were not a representative sample of the US population. Additionally the traders were predominantly male and educated (Forsythe et al., 1992). A number of scientists, including the three Nobel Prize laureates K. Arrow, T. Schelling and V. Smith, campaign for a separation of PMs from the classical gambling and a licence for Real money PMs (Arrow et al., 2008).

After the first successful PM the IEM organised PMs for all US presidential elections and other political elections in the US. The participation restrictions were lifted over the years. Now everybody with access to the WWW can participate. The number of participants increased from 192 in 1988 to several thousand in 2008. The number of participants had no impact on the forecast accuracy. An analysis of all PMs up to 2008 shows, that the PM predictions were more accurate than the polls in 74 percent of the cases (Berg et al., 2008b, Tables 2, 3 and 4). The PM predictions have furthermore a high consistence with the actual election results. The pairs of values are all very close to the 45°-line. (Berg et al., 2008b, figure 1). The win of Obama 2008 was predicted with a mean absolute error of 1.2 percent points. The PM achieved this small mean absolute error over the time span from June 2006 up to the election in November 2008. Only the last polls have a similar size of error and for longer time distances to the election the errors were significantly larger (Berg et al., 2008a).

After the success in the US PMs have been employed to predict election results in numerous other countries. It is to highlight that PMs are used in countries with more than two relevant parties (among others Canada, Germany, the Netherlands and Austria). The Canadian

[11] The Iowa Electronic Market can be reached under following address: http://tippie.uiowa.edu/iem/index.cfm.

election 1993 was accurately predicted by a PM. The special feature of this election was that two new parties took part for the first time. The 257 participants had no information about the performance of these two parties at former elections. The mean absolute error was only 0.57 percent points at election eve (Forsythe et al., 1995). The election PMs for Germany (Berlemann and Schmidt, 2001, Hansen et al., 2004), Austria (Murauer, 1997) and Australia (Leigh and Wolfers, 2006, Wolfers and Leigh, 2002) reached comparable results. The PM for the election in the Netherlands produced poor forecasts absolutely and relatively in comparison to the polls (Jacobsen et al., 2000). The authors mention the false-consensus effect as one possible reason. The false-consensus effect describes the curiosity that persons estimate themselves as being representative for the whole group of voters and finally expect a false election result. The number of participants ranged from 21 to over 1,000. The number of participants seems to have no influence on the accuracy of the PMs. Chen et al. (2008) analyse the PMs to forecast the election results in the single states of the US and control these results with the winning probability of the US President candidates, which was forecasted by an additional PM. They show that the PM participants interpret correctly the forecasted results in the States into the winning probability in the US presidential election. Wolfers and Zitzewitz (2004) and Snowberg et al. (2007) research the connection between the winning probability of the US President candidates 2004 with different other events, like the imprisonment of Osama bin Laden or unemployment rates. They show that a better economic development or an imprisonment of bin Laden increases the winning probability of the Republican candidate Bush.

Solely for a part of the German policy PMs has to be mentioned that the correlation between the published polls and the prices at the PMs is significant (Berlemann and Schmidt, 2001). It could be verified for all other PMs that they create independent forecasts. The PMs react to new information and not to new polls (Abramowicz, 2003) and this reaction is faster (Forsythe et al., 1992).

The known betting markets are similar to the PMs because the reciprocal of the odds can be interpreted as the probability of occurrence. Betting markets reached a great distribution in the US to forecast the US presidential elections from 1868 to 1940. Afterwards the betting markets were banned. In 11 of 15 cases the betting markets detected the correct future president. The favourite of the betting markets lost the election in one case only. Three times there was no favourite at the betting markets. The transaction volumes at the betting markets were particularly curiously higher than at the stock exchanges of the Wall Street (Rhode and Strumpf, 2003, 2004). Manipulation attempts were not successful at the betting markets and either at the modern PMs of the IEM. The manipulation had short impacts and the markets reached the pre-manipulation level very quickly (Rhode and Strumpf, 2009).

Sports

Betting markets are very popular for sport events. The odds are an indirect prediction. In the following only betting markets where participants trade the odds directly with each other are taken into account.[12] Participants of sport PMs can react to new information during the event and adjust their forecasts to the new information that might directly affect the outcome. The number of participants is often significantly bigger than 1,000. Most of the PMs for sport events operate with real money and the investment of the participants is

[12] Only these are very similar to PM. The regular bookmaker bets for example are not considered.

unlimited. Some sport PMs operate additionally on the basis of virtual money. Servan-Schreiber et al. (2004) show that virtual and real money PMs to forecast the winner of NFL games have similar accuracy. The forecasted win rates are nearly perfectly correlated with the actual win rates. The correlation is r=0.94 (r=0.96) for the virtual (real) money PM. The additional comparison with opinion pools shows no significant difference in the forecasting accuracy for the 210 analysed games (Chen et al., 2005). The operation with real or virtual money has no significant impact on the forecasting accuracy for sport PMs (Rosenbloom and Notz, 2006).

The PMs predict the winning probabilities in the NFL accurately. The actual winning rates match the predicted ones (Chen et al., 2005, O'connor and Zhou, 2008, Rosenbloom and Notz, 2006, Servan-Schreiber et al., 2004). This relationship is true until the game starts. The actual win rates differ from the predicted ones during the game, especially after new information, e.g. touchdowns or field goals (Borghesi, 2007). Hartzmark and Solomon (2006) detect the disposition effect for the NFL PM. The disposition effect describes the phenomena that persons realise wins faster than losses because they rate wins and losses differently. The transaction prices at the PMs increase after the occurrence of new positive information (touchdown) as expected. Shortly after the significant price increase the prices decrease without new information occurred. This implicates that the traders offered more sell than buy orders shortly after the price increase and realised wins. The prices increase again after the decrease. They rise to their new correct level. The disposition effect appears only if the transaction prices during the game are higher than the pre-game prices. A similar effect cannot be detected if the in game prices are lower than the pre-game prices.

Soccer PMs are also quite popular. PMs predicted the outcome of games (win, draw or loss) during the European Championship 2000 more accurately than the odds from the bookmaker Oddset. A bet at Oddset on the favourite team of the PM yielded positive returns (Schmidt and Werwatz, 2002). The PMs for the European Championship 2004 (Slamka et al., 2008) and the World Championship 2002 (Gil and Levitt, 2007) were accurate too. The initial design of the start depot has a significant influence on the trading frequency. Two PMs with different start conditions, PM1 with only virtual money and PM2 with virtual money and certificates, predicted the World Champion 2006. More than twice as many orders were executed at PM2 than at PM1 (Seemann et al., 2008). The PMs for the English Premiership are semi strong efficient for new goals, which are the most important information next to the game time (Croxson and Reade, 2008). A trader cannot gain a positive return with public information. The PMs were very liquid; the average trading volume was nearly 5.8 mil US$ per game. 44 percent of the volume was executed during the game (Croxson and Reade, 2008). The prices of the PMs during the World Cup 2002 show the same information revelation (Gil and Levitt, 2007). Additionally, price inefficiencies and arbitrage possibilities do not hold longer than 15 seconds. It takes less than 90 seconds to incorporate all new information in the PM prices (Slamka et al., 2008). The trading prices are significantly higher for the scoring team after a goal than before. The trading prices feature a drift. The decreasing game time offers fewer possibilities of new information. The prices for the leading team increase with the decreasing game time on this account (Gil and Levitt, 2007).

The accurate prediction of the game outcome is verified in additional research. An analysis of the PMs for games in the NBA, NHL, NFL, MLB and NCAA[13] show an accurate

[13] These are all North American sport leagues.

prediction though the win rates of the favourite teams are underestimated (Bean, 2005). A single analysis of the NBA and NFL games detects more accurate predictions for the NBA games and the underestimation of the favourites decreases (Borghesi, 2009). The results of English rowing events are accurately predicted (Christiansen, 2007). The PMs for cricket games detect the correct outcome and show efficient information revelation. Only the batting team can score due to the game plan. Thus the trading prices increase for the batting team in anticipation of possible points before the team actually scores. This anticipated increase of the prices reduces with every point scored because the probability of an additional point decreases (Easton and Uylangco, 2007).

Business Applications

The application of PMs to predict economic and business developments and performance figures shows that PMs can reach accurate predictions which are partly better than the standard methods. All described PMs for business events operated as closed groups; the participation was restricted to members of the company or members of special business sections. Siemens forecasted a project termination within the company with the help of PMs. The 62 participants in the PM correctly predicted the delay of the deadline (Ortner, 1998a, b). A small group of 7 to 24 participants forecasted future sales of printers at Hewlett Packard. This small group had the ability to predict the future sales figures more accurately than the standard operated internal methods. The PM traders did not know the internal forecasts (Chen and Plott, 2002). A PM was operated to predict the future sales volume of an unnamed company. The predictions were in 15 of 16 cases more accurate than the internal methods of the company (Plott, 2000). Google used PMs to forecast major business figures and business related figures like number of users of different Google services, general business and hard- and software developments and non business related topics (e.g. sport events) (Cowgill et al., 2008). The PM is an appropriate tool to forecast future developments. The 1,463 traders at the PMs showed significant learning effects during the participation. They show a positive overestimation of the development at their first trades. The overestimation decreases with growing trade experiences. Traders with small spatial office distances have similar expectations concerning the forecasted events. The diversity of expectations grows with increasing spatial distance (Cowgill et al., 2008). The PMs to forecast future gross user acquisitions and user figures of different mobile technologies yielded more accurate predictions than the survey among experts (Spann and Skiera, 2004). Motorola (Levy, 2009) and General Electric (Spears et al., 2009) use PMs in research and development for idea detection. PMs increase significantly the speed and the quality of idea detection.

Cinema and Other PMs

PMs are applied to a wide area of topics. A PM to forecast future infectious disease activity yielded accurate predictions for short time horizons. A time series method reached similar forecast accuracy for time horizons greater than eight weeks (Polgreen et al., 2007). The Hollywood Stock Exchange, a PM to predict the box office results of future cinema movies, is very popular with over 500,000 restricted users. The correlation between forecasted and actual box office revenue is 0.94. The traders detected the future winners of the Oscar awards correctly (Pennock et al., 2001a, b, Spann and Skiera, 2003). The movie PM at the IEM is clearly smaller with about 1,000 traders. But the forecast accuracy is at the same level (Gruca et al., 2005, 2008).

A combination of policy PM predictions and financial market data results in the conclusion, that a higher probability of war with Iraq will increase the oil price and decrease the stock index S&P500. The probability of war was measured with a PM, which forecasted that Saddam Hussein would be ousted until specific dates. A ten percent rise in the probability that Saddam Hussein would be ousted induced a 1 US$ per barrel increase of the oil price and a one and a half percent decrease of the S&P500 (Leigh et al., 2003). Additional PMs forecasted future inflation rates (Berlemann and Nelson, 2002), base rates (Berlemann, 2004), number of hospital patients (Rajakovich and Vladimirov, 2009) and stock prices (Berg and Rietz, 2002).

Summarizing, it can be shown empirically that the prices at PMs react quickly to new information, suffice the law of one price and follow a random walk (Wolfers and Zitzewitz, 2006c). Furthermore, PMs are weak or semi strong information efficient. Traders cannot gain positive returns with the help of public information (Leigh and Wolfers, 2006). The participants of PMs can actually reveal correct information even if they know nothing about the real value of the event (Hanson and Oprea, 2004). The information aggregation capacity of markets is undisputed and is proven by a lot of experiments, although the clear process is still unknown (e.g. Berg et al., 2003, Forsythe and Lundholm, 1990, Forsythe et al., 1982, Plott, 2000, Plott and Sunder, 1982, 1988, Plott et al., 2003).

5. Experiments

5.1 Requirements

For successful applications of PMs to forecasting problems several conditions have to be fulfilled. At least some participants need to have information about the forecasted event. This information has to indicate some asymmetric distribution between participants because otherwise no trade is likely to occur ("no trade theorem", Wolfers and Zitzewitz, 2006a). Former applications of PMs have shown that for 15 to 20 participants accurate results are obtained (Chen and Plott, 2002, Christiansen, 2007). Uninformed persons (noise traders) can take part in PMs. They increase market liquidity and offer potential profit opportunities to informed traders. Successful manipulation will be less likely when the number of participants increase. Manipulative orders offer profit possibilities for the informed traders and can therefore actually increase the PM accuracy (Hanson and Oprea, 2004). This effect is shown by experimental analysis by Hanson et al. (2006). The traders recognise that a part of the orders have manipulative intentions and react to it. If traders can influence the forecasted event, it is nearly impossible to prevent successful manipulation.

The transformation of the forecasted event into values of the certificates is elementary for well functioning PMs. A clear and objective transformation function is necessary to convert the possible realisations into values of the certificates. The transformation function has to be published prior to the PM start and may not be changed afterwards. The transformation factor has to be chosen in a way that even small changes of the forecasted event lead to changes in the expected value of the certificate. The prediction of very uncertain or certain events has to be possible and the transformation function has to account for it. In case of very (un)certain events the favourite longshot bias is a popular phenomena. The favourite longshot bias occurs when individual forecasting probabilities indicate an s-shape instead of a linear shape which was first proven for horse betting. The odds for the horses differ from the actual win rates. While the odds are too high for the favourites, they are too low for the longshots. A bet on the favourite (longshot) yields a positive (negative) expected return (Thaler and Ziemba, 1988).

The reward system is important for inducing information search and revealing them in the PM (Sunstein, 2006). Due to legal reasons real money PMs are forbidden almost worldwide. The operation with virtual money instead has, however, no significant effect on the forecast accuracy (Servan-Schreiber et al., 2004). Wins and losses of virtual money PMs are virtually but some prizes can be rewarded to support the extrinsic motivation. Different immaterial and material incentives can stimulate the extrinsic motivation (Spann, 2002). Gifts or money rewards are the most known material incentives. They are given to the most successful traders or a randomly chosen active participant. Immaterial incentives are rank lists or the publication of the best traders. All these incentives support the desired objective function of portfolio maximisation. The traders can also maximise their portfolio due to their intrinsic motivation. The total trading volume also has a positive effect on the individual trading activity. The average trade volume per participant is correlated with total trade volume (Seemann et al., 2008).

5.2 Design

The experimental PMs were introduced to forecast future sales figures of different products of a well-known agribusiness company in Germany.[14] The firm had a high interest in good predictions because of a long time lag between production and selling. 37 people of the firm, mostly belonging to the sales and administration division, were elected to participate in the PMs. The best participants received prizes depending on their final ranking. The markets started about four months before the actual sales' volumes are known. At the end the market organiser bought back all virtual shares to their termination values that correspond with the actual sales' volumes.

Four different PMs, one for every product, were installed and operated over the WWW. Every PM operated independently. The PMs were organised as type c) with a small change. Only one virtual certificate was traded in every market. The participants traded with virtual money at the PMs. The virtual certificates were named after the products sold. The virtual share represented the sold quantity of the respective product; the transformation function was 1 CU for every QU sold. If for example 100 QU of product X were sold then the certificate would be 100 CU worth. The participants received 1,000 virtual certificates and more than 1,000times the forecasted sales quantity from the last internal forecast before market start in virtual CU at each market. The combination of virtual certificates and money was necessary because there was only one certificate in each market and no unit portfolio exists overall. The participants could not buy additional certificates by trading unit portfolios with the market organiser. The initial certificate endowment increased market liquidity. The markets were named here A, B, C and D. All markets were organised in the same fashion.

5.3 Results

The PMs were open for approximately four months. All PMs started at the same date and had the same market termination time. 37 people were invited to participate in the PM to forecast the future product sales. 22 people actually participated actively, which means they ordered at least once. The total number of orders was 545. 221 orders expired before market termination and 324 orders were executed. PM B, C and D nearly indicated the same

[14] Due to legal reasons we are not allowed to name the firm and the products. Additionally we have to present the results anonymously. All quantities were normalised by their final amount.

number of orders (138, 147 and 165 orders respectively). Significantly fewer orders were observed for PM A (95). Trading was dominated by five participants. They were responsible for 61 percent of the trades at PM A and up to 86 percent at PM C. The five most active traders posted relatively more non-executed than executed orders. Their proportion at the executed orders was 77 percent relative to 85 percent of the non-executed orders.

The trading activity differed during the operation time. The daily trading volume, orders per day, is shown in Figure 1. The activity decreased over time. In the first 25 trading days a total of 259 orders were offered by the participants. In the next 25 days 172 orders were posted. In the following period 85 orders were offered. The participants placed only 29 orders in the last 26 days before the final trading day of the PM. The differences between the four markets were small. The activity decreased significantly. This could be an expression of decreasing uncertainty about the termination value. The possibility of overlapping orders reduces if the traders are more confident about the termination value. The trading success was differently distributed among the participants. 18 participants had the same wealth at the end as in the beginning. Among these 18 participants were the 15 people, who did not trade. The sum of the wins of the 7 most successful traders was equal to the sum of the losses of the 12 least successful traders. The absolute profits and losses were quite small. The best trader made a profit of nearly 3 percent and the worst trader lost about 2 percent.

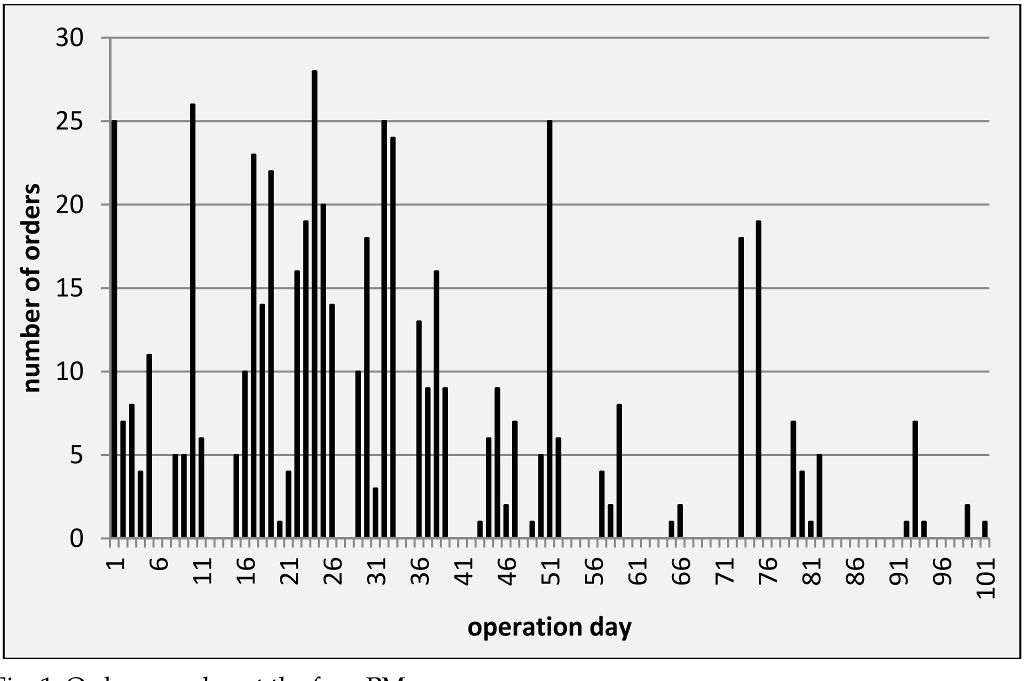

Fig. 1. Orders per day at the four PMs

All market data was collected on order basis. To result forecasts we calculated volume weighted average prices for each day. The forecasts of the PMs were compared to the internal company forecasts (IF).[15] The mean squared forecast error was calculated to

[15] The internal forecast are an extrapolation of actual sales volume to the end time point.

compare both methods in relative and absolute terms. Four updates occurred for the IF during the market operation time. The average daily PM prices and the IF for product C are shown in Figure 2. The actual sales quantity is also shown as a reference for both forecasts.[16] Both instruments underestimated the total sales quantity at the beginning by nearly the same amount. The forecasts of the PM moved away from the IF over time. The forecasts of the PM were closer to the actual quantity than the IF. The forecasts reached a level nearly similar to the actual sales quantity fifteen days before market termination. The IF reached a similar forecast quality three days before market termination. The last forecast of the PM is an actual sales quantity of 1.001. Because all data is normalised by the actual sales, it is obvious that the forecast of the PM is nearly exact for the last fifteen days. Most of the time the IFs showed a larger deviation, the last IF, however, was 0.994, which was also very accurate in absolute terms.

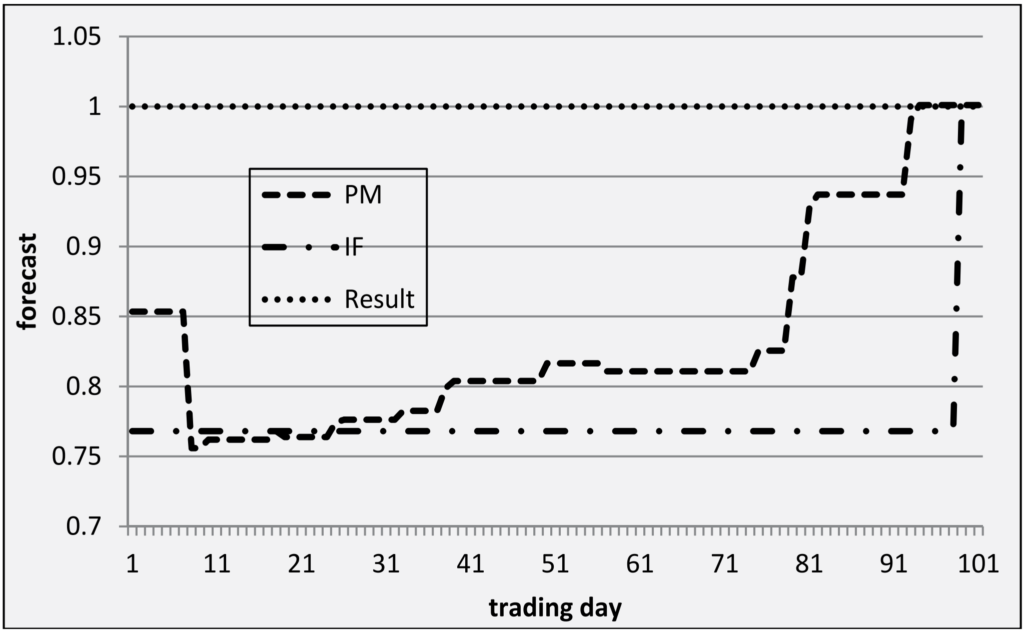

Fig. 2. PM and internal forecasts and actual sales quantity for product C

The average forecast for product C over the whole market duration was 0.8345 at the PM and the IF predicted 0.7747 as shown in the second last column of Table 1. The PM forecast is significantly closer to the actual result than the IF. Bold numbers indicate statistically significant differences (α=0.1). The mean squared errors are measured to determine the absolute forecast accuracy. The average trading price is calculated for every day and the difference between this price and the actual result is squared. Final the mean over the squared differences is determined for the different time spans. The mean squared error gives more weight to larger deviations and treats positive and negative deviations the same way. The mean squared errors are presented for both forecast instruments in Table 1. For

[16] A presentation and description of the three additional products is missed here. The results are presented below for all four products.

product C it is unambiguous that the PM is more accurate over all time spans compared with the IF.

The forecasts and mean squared errors for the additional three products are also shown in Table 1. PMs are more accurate than the IF over all products and all time horizons. In 10 of 16 cases the predictions of the PM are more accurate. IFs are more accurate in five cases of which four cases are product D. And in one case both methods are similar accurate. Product D is the product with the smallest variance of the forecasts and the smallest deviations from the actual sales volume. The internal forecast predicts the sales quantity of product D more accurately for all time spans. The deviations are less than one percent for the internal forecast (last column in Table 1). The PM is better to predict the sales of product A. Though not statistically significant, during the final 50 trading days the IF beats the PM.

		Product	A	B	C	D
	actual result		**1**	**1**	**1**	**1**
last trading day	last forecast	PM	1.0171	0.9848	1.0009	0.9809
		IF	0.9965	0.9999	0.9936	0.9995
last 26 trading days	average forecast	PM	**1.0191**	0.9846	**0.9455**	1.0257
		IF	1.0499	**0.9990**	0.7951	**0.9995**
	MSE	PM	**0.0004**	0.0002	**0.0056**	0.0007
		IF	0.0029	**0.0000**	0.0474	**0.0000**
last 51 trading days	average forecast	PM	1.0656	**0.9767**	**0.8793**	1.0270
		IF	1.0743	0.9681	0.7816	**0.9983**
	MSE	PM	0.0070	**0.0008**	**0.0203**	0.0008
		IF	0.0069	0.0032	0.0506	**0.0000**
last 76 trading days	average forecast	PM	**1.0741**	**0.9631**	**0.8508**	1.0290
		IF	1.0917	0.9553	0.7771	**1.0008**
	MSE	PM	**0.0075**	**0.0022**	**0.0278**	0.0012
		IF	0.0099	0.0043	0.0517	**0.0001**
whole market duration	average forecast	PM	**1.0716**	**0.9735**	**0.8345**	1.0332
		IF	1.1005	0.9593	0.7747	**1.0054**
	MSE	PM	**0.0067**	**0.0019**	**0.0326**	0.0020
		IF	0.0116	0.0034	0.0522	**0.0001**

Table 1. Forecasts and mean squared errors (Bold written numbers indicate significant differences at the 10 percent significance level)

Finally, the hypothesis of independent predictions of the PM is tested. The forecasts of the PMs are tested to be independent from the IFs by regression analysis. The reactions of the PM after an update of the IF are controlled if the PM reacts in the same way as the IF and if

the PM only reflects the same information as the IF. First differences of the IFs are regressed on several differences of the PM prices. Different adjustment periods are considered for the PM to control for the velocity of adaption. Four updates occurred for the IF during market operation time. All but four first differences of the IF are zero so four observations enter every regression for the IF. The first regarded difference (time span) of the PM is from one day before the new IF to the day of the IF update. Afterwards the four first differences of the IF are regressed on the four differences of the PM. The results of the regressions are presented in Table 2 for all products. In all cases the PM prices appear to be independent from the IFs.
The changes of PM prices after the time of the IF update are also considered to control for delayed adaption. In a second step we compute the same regression but now we take longer adaption periods for the PM. The second price difference is the difference of the PM prices one day before the publication of the internal forecast with the price one day after the publication instead of the price at publication as above. Additionally the differences with the prices 2, 3, 4, 5, 6 and 7 days after the publication of the IFs are computed. In all but 2 of 32 cases a significant impact of the internal forecasts on the PM prices can be rejected.[17] A significant relationship is found for product A for 6 and 7 days after the publication of the internal forecast. The factor of the explanatory variable is significant at a level of 0.096.

Product	Constant		Factor of the explanatory variable		Multiple R^2	F-value
A	-0.0134	(0.0051)	0.2287	(0.1062)	0.6988	4.64
B	0.0036	(0.0025)	0.0645	(0.0398)	0.5672	2.62
C	0.0272	(0.0354)	0.1205	(0.3147)	0.0683	0.15
D	0.0095	(0.0070)	-0.3295	(0.5923)	0.1340	0.31

Table 2. Regression PM-price as a function of the internal forecast (first differences, level of significance: * > 0.10, ** > 0.05, *** > 0.01, observations: 4)

5.4 Possible different applications within a supply chain

PMs can be applied to forecast nearly every future event or object as the above experiment and applications show. There are different forecast purposes within a supply chain; upcoming possible sales quantities at the end of the chain, other production figures (quality of products, output quantities) or prices of inputs or output products. Additionally, forecasts of possible future needs and requirements of consumers in the new product development have a high value for firms. Some of these forecasts can be obtained by analysing actual production figures but these cannot take unexpected changes into account and the new product development can only be improved with new data generating processes. And most of the standard processes do not take the wisdom of the workers in the production process, company members, people outside the firm, consumers and suppliers into account.
To avoid high storage costs and missed vending chances accurate forecasts of upcoming sales are necessary. PMs achieved more accurate forecasts in predicting upcoming printer

[17] The presentation of the regression is missed here, due to the limited space.

sales at Hewlett Packard (Chen and Plott, 2002) and product sales in our own experiment than the standard methods. Additionally, PMs generated accurate forecasts in the prediction of future user figures of Google services (Cowgill et al., 2008) and different mobile technologies (Spann und Skiera, 2004). PMs can operate to forecast production figures within a supply chain to enhance the coordination between the chain members. The forecast of production figures in the process, especially product quality, offers the possibility for quick reactions to changes. The workers operating the machines or producing the goods have knowledge about possible changes but normally they do not participate in forecasts. The introduction of a PM to forecast future product quality can enhance the forecast quality.

The forecast of prices of input and output products offers the chance for quick reactions to the changing market environment. It reduces the uncertainty of the price development, if the price forecasts reach good forecasting qualities. The price forecasts offer a high potential to increase the commercial exploitation in the purchase and sales process. The price selection for new developed products will provide great opportunities; it may decide about the success or failure of a product. A PM can be installed to forecast the willingness to pay of the consumers. This offers the chance for a better pricing and reduces the risk of failed products because of their high price.

Another possible application of PMs can be found in the idea generating and selection process in new product development. Different product designs and their sales' potential can be traded on PMs to select the most promising products. Additionally, ideas can be traded and the participants can add new ideas to the PM to result in a guide to future developments. The incorporation of consumers of the possible products with the help of PMs is easy because PMs operate over the WWW. The consumers of future products will increase the quality of the new product development and will value information and knowledge about future needs of the consumers more highly than the workers in the company will do. For example General Electric (Spears et al., 2009) and Motorola (Levy, 2009) introduced PMs in the idea generating process to accelerate the idea detection process and to raise the quality of idea detection. They wanted to involve the workers in the process and their ideas and expectations about possible problems or consumer needs. They succeeded in both with the help of PMs.

PMs offer an easy and cheap possibility to incorporate the diverse information held by workers in the own firm and additional information held by people outside the firm, for example sales people in an electronic market for printer sales. PMs can react instantaneously to new information and reveal it via the price. The reward system causes the participants to trade correctly on their information basis because correct anticipation leads to portfolio increases otherwise they obtain a loss. PMs offer a high potential to enhance the forecast quality within a supply chain in different fields and to improve the involvement of the supply chain members or persons from outside the supply chain and outside the company in the forecasting process.

6. Conclusion

The adaption to the changing environment is a key capability for successful firms. The quick reaction to changes is essential and offers high potentials. Reliable forecasts are needed as a base to plan firm's adjustments. Inaccurate forecasts and/or incomplete adaption to the changing environment can result in substantial costs for the firm (Spann and Skiera, 2003). A good example is Nokia's adaption to the new trend of smartphones with touch screens. The reasons for missing this trend are unknown to us but obviously they misjudged future consumer needs. Most of the standard forecast methods neglect the wisdom of the people in the production process, in the company, or the wisdom of customers.

PMs are a forecasting tool which can achieve better results in predicting future events as the standard methods. PMs are based on the "wisdom of crowds" principle. The "wisdom of crowds" describes the phenomena that groups achieve better prediction results than the single group members. PMs are similar to stock exchanges on which the participants trade certificates of future events. The group members trade their expectations concerning the future development and determine their weight by the money they are willing to bet. This is a great advantage against surveys. Compared with standard statistical methods PMs use new information and aggregate these efficiently over participants. Participants can use a variety of forecasting methods to create their expectations. The information and results of the forecasting methods are still built from expectations of the participants. PMs "...cannot make a silk purse out of a crowd of sows' ears" (Page, 2007).

PMs reach good forecasting results in a lot of applications in a variety of fields. The first modern PMs are used to predict election results (e.g. Berg et al., 2008c). Afterwards PMs are applied to sport events (e.g. Bean, 2005), box office revenues (e.g. Pennock et al., 2001c), economic development (e.g. Berlemann, 2004), future disease activity (e.g. Polgreen et al., 2007), business forecasts (e.g. Chen and Plott, 2002), and a lot more. The PMs often achieve better forecasting results than the respective standard methods in the field. The PMs can produce continuous forecasts.

We implement four different internal PMs to forecast future product sales of an agribusiness company. The future sales of the four different products are predicted with a group of 37 persons. 22 persons trade actively at the PMs. The forecasts of the PM are compared with the internal forecasts of the company. The PMs are more accurate than the internal forecasts in 10 of 16 cases. The prediction errors of the PMs are significantly smaller in these 10 cases. The liquidity at the markets is low. Five participants are responsible for nearly 80 percent of the trades. More participants, more active traders, the introduction of a market maker, or more incentives for participants might have increased the participation rate and thereby the number of trades to further improve the quality of the PMs forecasts. Market liquidity indicates the major task for successfully introducing and efficiently operating forecasting PMs.

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Procurement Strategies in Multi-Layered Supply Chains

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1. Introduction

Procurement departments of almost each and every organization must take on ever more challenging projects in order to overcome deficiencies in other areas of the business. Optimizing supply structures and processes, connecting from the customers' demands through all the tiers of the supply chain and finding reliable suppliers in low cost countries contribute to compensate diminishing returns on assets and on revenue. Well balanced prudency has to be applied to cope with supply chain complexity, stimulate supplier innovation, enhance operational security, and consider the social and environmental impact of the supplier in sourcing decisions. Addressing issues like these requires a high level of talent and commercial acumen, and the challenges reach beyond that of the organizational supply nexus. They have ended up in transforming the traditional way of sourcing into a network of collaborative action, into an "*extended enterprise model*" commonly referred to as a *supply chain*. The following definition is offered by the Massachusetts Institute of Technology (MIT), quoted by Metz (1998): "...a process-oriented, integrated approach to procuring, producing, and delivering end-products and services to customers. lt includes sub-suppliers, suppliers, internal operations, trade customers, retail customers, and end-users. It covers the management of materials, information, and funds flows."

Supply chain management, then, involves the effective planning and execution of activities and processes across the entire value chain. This requires new levels of involvement by materials suppliers, service providers (e.g., freight/transportation and warehousing services), and even distribution customers and resellers. Numerous research and publications have been made on how this is put into operation (see, e.g. the WebSite of Supply Chain Council, http://supply-chain.org, an organization that was organized in 1996 and now has closer to 1,000 corporate members worldwide). However, as with any operational decision-making, supply chain optimization must be preceded by strategic decision-making. The foremost issue is about the objectives which are to be attained by establishing or joining a supply network, and from there, strategic planning will evolve. So the first set of questions would be about those objectives, about how they relate to the mission of an organization altogether and how this ends up in formulating and implementing strategies.

1.1 Supply chains and their strategic objectives

By joining a supply network a business wishes to benefit from synergies and high performance. But, looking inward, the foremost and highly critical issue is the need to align business objectives and supply management objectives.

Every company's supply management strategy fits somewhere within supply-side strategic objectives (acquiring business through massive channeling of goods into the market) and demand-side strategic objectives (acquiring business through attracting pre-identified buyers): For example, WalMart aligns with the supply-side strategy since their goal is clearly to be a *low cost provider*. A company with a goal to be the *market share leader* would align itself with a demand-side strategy (an example would be CISCO's market share in virtual private networks which has been achieved through selective marketing). And a business strategy focused on market share leadership is not very much compatible with a supply management strategy which focuses on supply-side strategic objectives (Littleson 2008).

From there, by taking into account the customers' and suppliers' viewpoints, a company will define its *core competencies and core processes* based on the strategic objectives of its supply management, and it will choose its suppliers and sub-suppliers accordingly, and thus, these definitions will have an effect on the overall supply chain. Hence, on the strategic level, the decisions that are made with regard to the supply chain will reflect the overall corporate strategy that the organization is following, and they will cover the whole breadth and depth of the supply chain. This includes product development, customers, manufacturing, vendors and logistics, because all those areas involve procurement. So, e.g., a company will have to identify the customers for its products and services in line with its strategic decisions on the products to manufacture, and when decisions are made to define the manufacturing infrastructure and the technology that is required, the decisions may lean towards using subcontracting and third party logistics. Also, as environmental issues influence corporate policy to a greater extent, this may have an additional influence on strategic supply chain decisions.

Coming back to the supply-side and demand-side options, leveraging the total company's purchases over many businesses can allow company management to select strategic global suppliers who offer the greatest discounts, or it can lead to a well balanced vendor portfolio which directly relates to the customers' demands. From another angle, the supply-side option takes account of supply-uncertainties, and the demand-side option takes account of demand-uncertainties (Lee 2002). This aspect will be dealt with in detail in section 5. Right now we will only deduce that from this perspective, two major functions can be derived for the supply chain: One is to secure efficient procurement throughout the various levels ("tiers") in which the goods flow upstream from vendor to vendor; this is the *physical function* of a supply chain, and it will dominate if supply uncertainties prevail. The other function is to ensure that the variety of products demanded by the customers reach the marketplace in response to where and how the customers wish; this is the *market mediation function* (Fisher 1997).

Another important strategic decision is about choosing the adequate logistics function, which might be key to the success of the supply chain. This would relate to optimal order fulfillment, the design and operation of the warehousing and distribution center network and transportation modes (see, e.g. Murray 2008). These high level decisions can be refined, as required, to reach the specific needs of the company at the lower levels which allow for tactical and operational supply chain decisions to be made. The intensity of this link between strategic objectives and operational actions depends on the volume and complexity of factors to be reconciled, and supply chain managers today face an unremitting challenge to their capabilities in this regard. Guidance is required to translate a set of objectives into adequate operations, and the best way, possibly, can be found by transforming strategic objectives into performance metrics. Connecting objectives and metrics ("How will I measure the outcome of my strategy?") is one of the most crucial tasks in strategic planning. We will demonstrate this in various sections of this chapter. And once the metrics have been determined, numerical targets must be set. In the context of any collaborative issue, be it a network or just intra-company co-operation, a qualitative strategy map and the corresponding metric compound must be built firstly. Then, what follows, is adopting quantitative techniques such as system dynamics simulation and optimization in order to take managers through the stages of strategy formulation, action evaluation and decision making.

1.2 Formulating a set of strategies

Corporate strategic planning is a continuous and crucial activity. In order to formulate appropriate business strategies, the top management and strategists must have a clear understanding of the company's strengths and weaknesses, the opportunities and threats it is facing, the purposes of the business, as well as the objectives to be achieved. Strategy formulation is an essential part of all management systems. When we look at a widely accepted framework, the *Comprehensive Strategy Management Model* proposed by David (2007), we find that generating the possible strategies for a firm plays a dominant role („Strategy Formulation Analytical Model", see David, op. cit.).

Generating the possible strategies for an organization (a firm, an administrative institution or a supply network) sets out from the internal and external characteristics of this organization. Strategy formulation involves:

- Developing a vision and mission
- Identifying the organization's external opportunities and threats
- Determining the organization's internal strengths and weaknesses
- Establishing long-term objectives
- Checking on alternative strategies
- Choosing the particular strategy/strategies to pursue.

Many strategy-formulation techniques are available to assist in developing strategies. They can be integrated into a three-stage decision-making framework as shown below:

Stage 1 of the strategy formulation framework uses the EFE Matrix, IFE Matrix and CPM Matrix tools to summarize the basic input information needed to formulate strategies:

External Force Evaluation (EFE) Matrix summarizes and evaluates the key economic, social, demographic, environmental, political and technological factors that would have the highest impacts to the organization both as positive opportunities or negative threats. It also records how the organization intends to respond to the key external factors.

Competitive Profile Matrix (CPM) presents major competitors and the organization's relative strengths and weaknesses in relation to the competitor's position.

The *Internal Factor Evaluation (IFE) Matrix* summarizes and evaluates the major strengths and weaknesses in the functional areas of a business.

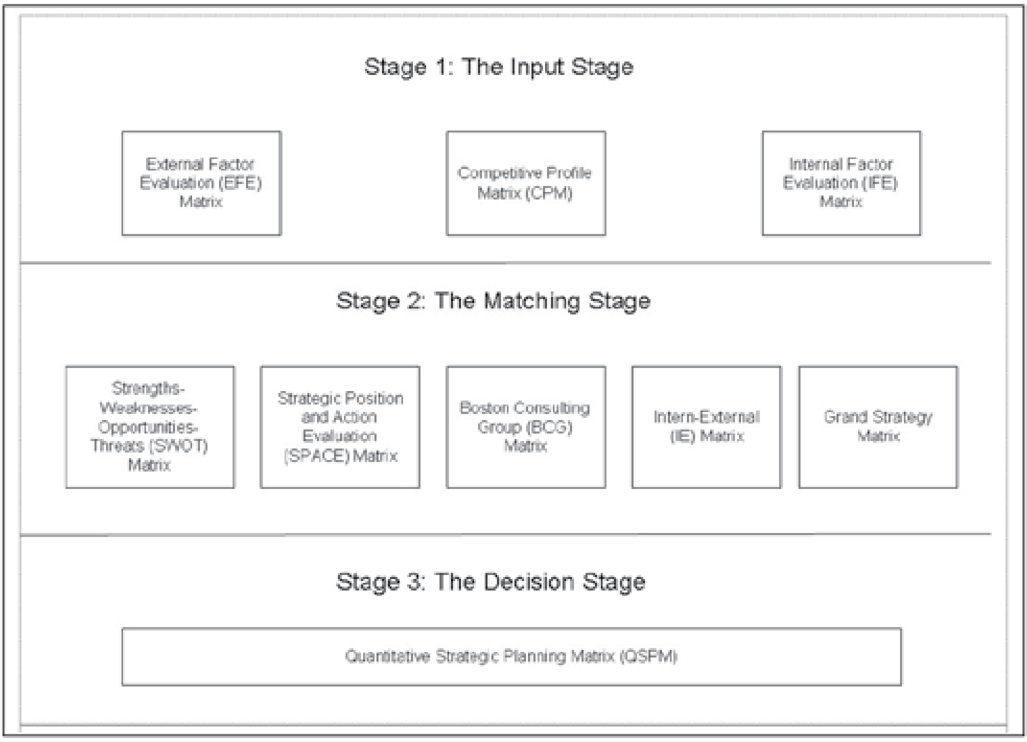

Exhibit 1. Strategy Formulation Model (Source: David 2007)

Stage 2 is the Matching Stage. It focuses on generating the alternative strategies through the matching of key internal and external factors. Key techniques used in stage 2 include the Strengths-Weaknesses-Opportunities-Threats (SWOT) Matrix, the Strategic Position and Action Evaluation (SPACE) Matrix, the Boston Consulting Group (BCG) Matrix, the Internal-External (IE) Matrix, and the Grand Strategy Matrix.

The *SWOT Matrix* helps the strategists to develop four types of strategies, i.e. SO, WO, ST and WT strategies. SO strategies use an organization's internal strengths to take advantage of external opportunities. WO strategies aim at overcoming internal weaknesses to take advantage of external opportunities. ST strategies use an organization's strength to reduce the impact of external threats. WT strategies target to reduce internal weaknesses and avoid external threats.

The SPACE a Matrix a is matching tool. It presents a four-quadrant framework indicating whether aggressive, conservative, defensive or competitive strategies should be taken by a given organization. The four quadrants represent Financial Strength (FS), Competitive Advantage (CA), Environment al Stability (ES) and Industry Strength (IS), and the respective strategy types for each quadrant would then be the appropriate recommendations for the organization. The SPACE Matrix complements the SWOT technique by providing further qualifications to the SO, ST, WO and WT strategies.

The BCG Matrix graphically presents the differences in the portfolio of an organization in terms of relative market share position and industry growth rate: Business units with a high relative market share with high industry growth rate (*"Stars")* are the best long-run opportunities for growth and profitability, and therefore they should receive substantial investment. Units which have a high relative market share but compete in slow-growth industry generate cash in excess of their needs ("*Cash Cows"). Question Marks* units have a low relative market share but compete in a high-growth industry. Their cash needs are high and their cash generation is low, and the organization will need to consider either to invest to grow this business or to sell it. Units which have a low relative market share position and compete in a slow-growth industry (*"Dogs"*) might need to be liquidated, divested or trimmed down through retrenchment.

The *Internal-External Matrix* expands the concept of the BCG Matrix and provides a categorization of business development strategies into *„grow and build", „hold and maintain",* and *„harvest or divest"*.

Finally, the *Grand Strategy Matrix* applied in stage 2 is based on two evaluative dimensions: competitive position and market growth, and it allows for strategy formulation attaining market penetration/ market development and product development, or vertical/horizontal integration or concentric diversification, etc.

Stages 1 and 2 furnish a prioritized list of strategies. In stage 3, the *Quantitative Strategic Planning Matrix* determines the relative attractiveness of various strategies based on the extent to which key external and internal critical success factors are capitalized upon or improved. The relative attractiveness of each strategy is computed by determining the cumulative impact of each external and internal critical success factor.

This enumeration of techniques may suffice as a brief introduction for a reader who is not acquainted with the conceptions of strategic management. For an in-depth research the reader may be referenced to the "classical" texts by e.g. Mintzberg and Quinn (1998) and by Hamel and Prahalad (1994.) A more recent overview is Johnson, Scholes and Whittington (2008), and regular updates appear on http://strategicmanagement.net. In accordance with the purpose of this book chapter, the authors wish to advise that literature on strategic management to a large extent focuses on the marketing side of business. However, many rationales which embrace this end of an enterprise can easily be related to the supply side of an organization. If we take, for example, the Boston Consulting Group Matrix which originally applies to a product portfolio of an organization in terms of relative market share position and industry growth rate, the matrix perspectives may very well be versed to a "portfolio of supply items" or a "portfolio of technologies" or a "vendor portfolio". The terms for the correspondent analysis might remain <market share> and <growth rate>, but they might be altered into other criteria like <supply risk> and <product complexity> or <supplier capabilities> and <competitive position>. Which criteria to choose is a question of which result is expected from the analysis. Thus, portfolio analysis becomes a generally applicable tool that combines two or more dimensions into a set of heterogeneous categories for which different (strategic) recommendations are provided (Gelderman 2003). An example will be given in section 3.1.2 below.

So what can be accomplished by formulating strategies? We have seen that a broad array of informational input is used and selected for analysis and for filtering out the relevant impact factors. This in itself provides a broad set of determinants by which to guide (supply) decisions. Also, as can be seen from the three-stage model delineated above, strategy formulation creates awareness and provides systematic problem solving approaches for all levels of decision making. And, with regard to procurement, strategy formulation will help to secure that supply strategies always correlate to the overall business strategies of the organization.

1.3 Correlating supply strategies and overall business strategies: An example from the automotive industry

Strategy development for the supply function must be pursued in close association with other functions. For instance, market entry choices will affect procurement strategies, and the determinants would be market maturity, complexity of logistics, import tax tariffs, ability to develop suppliers, etc. Furthermore, when devising a strategy, the tactical and operational levels must be taken into consideration. This is best done by proceeding along a line of analytical inferences which set out from market criteria, resource allocation and process determinants: The strategic level designs the supply network, reflecting the investigation of broad based policies, corporate financial plans, competitiveness and the intensity of adherence to organizational goals. Connecting to resource allocation and process determinants in the design phase will secure stable implementation, and the range of strategic alternatives provided by the analysis will thus be rooted in what is achievable. Exhibit 2 gives an illustration of the procedure.

The column in Exhibit 2 which is marked “Criteria” lists some patterns which are exemplary for the automotive industry, but they can be generalized very easily; the column marked “Characteristics” shows a choice of values for each of the characteristics. The values which label the characteristics will determine the structure of a specific strategy. For example, in a fast growing market with low import tariffs and low logistics cost where the manufacturer may establish an import ownership, and customs clearance is efficient, the strategy will tend to set up a local assembly and ship the components completely knocked down (“CKD”) even if the requirement for local content is medium. This strategy design will then involve decisions on the levels of resource allocation and of business processes, and these must be apparent at the time of the strategic decision already. The analytical model presented here (Yu Song 2009) will warrant that the need for those decisions becomes apparent.

1.4 Implementation of strategies

Strategy formulation, whichever is their impact on creating awareness and providing systematic problem solving approaches, does not guarantee success. Managers and employees must be motivated to implement those strategies, and they must get technical support from top level executives. This would include establishing annual objectives, devising policies, allocating resources, altering an existing organizational structure, restructuring and reengineering, revising reward and incentive plans, etc. Strategies can only be implemented successfully in organizations which handle their goods and services production and marketing properly, which have access to the working capital they require, and which use an effective and efficient information system. These functional issues must also be addressed during the implementation phase.

The leading technique for implementing strategies is the Balanced Scorecard. While the Balanced Scorecard approach as developed by Kaplan and Norton (1992) was not specifically designed for the Supply Chain, the idea that metrics be closely aligned to a company’s strategic objectives does very well apply to the ambience of procurement: The central focus is on targets measured by key performance indicators that monitor if an objective has been reached. Thus the level of strategic decision-making and day-to-day business results get intrinsically interconnected. The metrics to be set will help to measure the performance of supply processes, warehousing and delivery from various viewpoints (“perspectives”), including customer satisfaction and financial outcomes, giving the key managers a guidance for optimizing the overall supply chain and the business unit procurement. A typical metric pack includes such Key Performance Indicators as Defects Per Million Opportunities, Inventory Months of Supply, Claims percentage for freight costs, On-time pickups, Transit time, On Time Line Count, Customer Order Promised Cycle Time, etc.

<table>
<tr><th>Criteria</th><th colspan="10">Characteristics</th></tr>
<tr><td>Market trend for the end product</td><td>Introduction</td><td colspan="3">Development (fast growth)</td><td colspan="2">Stable growth</td><td colspan="3">Maturity</td><td>Introduction</td></tr>
<tr><td>Local content ratio</td><td colspan="2">No requirement</td><td colspan="3">Low</td><td colspan="3">Medium</td><td colspan="2">High</td></tr>
<tr><td>Import tax tariff</td><td colspan="2">No requirement</td><td colspan="3">Low</td><td colspan="3">Medium</td><td colspan="2">High</td></tr>
<tr><td>Local logistics costs</td><td colspan="3">Much cheaper than export country</td><td colspan="4">More expensive than export country</td><td colspan="3">No big difference to export country</td></tr>
<tr><td>Import OEM ownership structure</td><td colspan="3">Wholly Foreign Owned</td><td colspan="4">Joint Ventures</td><td colspan="3">Independent 3rd party</td></tr>
<tr><td>Customs clearance efficiency</td><td colspan="3">Low</td><td colspan="4">Medium</td><td colspan="3">High</td></tr>
<tr><td>Factory organization</td><td colspan="3">Controlled by the parent company</td><td colspan="4">Controlled by the export company</td><td colspan="3">Controlled by the import company</td></tr>
<tr><td>Integrated logistics chain control</td><td colspan="3">Centralized by the parent company</td><td colspan="4">Centralized by the export company</td><td colspan="3">Centralized by the import company</td></tr>
<tr><td>Autonomy of the planning</td><td colspan="3">Locally independent</td><td colspan="4">Centrally coordinated</td><td colspan="3">Centrally controlled</td></tr>
<tr><td>Manufacturing technology</td><td colspan="3">Parent company</td><td colspan="4">Export company</td><td colspan="3">Import company</td></tr>
<tr><td>Product variants</td><td colspan="3">Few</td><td colspan="4">Medium</td><td colspan="3">Many</td></tr>
<tr><td>Target market for finished products</td><td colspan="5">Domestic only</td><td colspan="5">Domestic and export</td></tr>
<tr><td>Frozen period (time in which plans remain unchanged)</td><td colspan="3">Short</td><td colspan="4">Medium</td><td colspan="3">Long</td></tr>
<tr><td>Complexity of product shipped by exporter</td><td colspan="2">Vehicle</td><td colspan="3">Module structure</td><td colspan="3">Component structure</td><td colspan="2">Single items</td></tr>
<tr><td>Packaging from exporter</td><td colspan="3">Vehicle oriented</td><td colspan="4">Module oriented</td><td colspan="3">Component oriented</td></tr>
<tr><td>Warehousing before export</td><td colspan="5">Consolidation</td><td colspan="5">No Consolidation</td></tr>
<tr><td>Inventory transparency</td><td colspan="5">Transparent</td><td colspan="5">Not transparent</td></tr>
</table>

Exhibit 2. Determinants for correlating supply strategies and overall business strategies
Source: Song, Yu 2009.

The use of a well designed and balanced "metric pack" often leads the applicant to just install a measurement system (which is definitely a valuable intent) instead of also connecting each of the metrics to a strategic goal. So, for instance, if the metric is "Defects Per Million Opportunities", the strategic goal behind the metric must be to reduce the defects, and it must be connected to an approach of how to achieve this reduction. Similar contexts can be shown for each and every of the various indicators. The following four tables (adapted from Bhagwat and Sharma 2007) display which indicators can be applied to a supply chain's four perspectives "Finance", "Customer", "Internal Business" and "Learning". This should serve to guide the reader towards contemplate which objectives and which approaches they represent.

Performance metrics for the financial perspective
Customer query time
Net profit vs. productivity ratio
Rate of return on investment
Variations against budget
Buyer–supplier partnership level
Delivery performance
Supplier cost saving initiatives
Delivery reliability
Cost per operation hour
Information carrying cost
Supplier rejection rate

Performance metrics for the innovation and learning perspective
Supplier assistance in solving technical problems
Supplier ability to respond to quality problems
Supplier cost saving initiatives
Supplier's booking in procedures
Capacity utilization
Order entry methods
Accuracy of forecasting techniques
Product development cycle time
Flexibility of service systems to meet particular customer needs
Buyer–supplier partnership level
Range of products and services
Level of customer perceived value of product

Exhibit 3. Supply Chain Metrics fitted into the perspectives "Finance" and "Innovation & Learning" of a Balanced Scorecard. Source: Bhagwat and Sharma 2007.

Performance metrics for the internal business perspective
Total supply chain cycle time
Total cash flow time
Flexibility of service systems to meet particular customer needs
Supplier lead time against industry norms
Level of supplier's defect free deliveries
Accuracy of forecasting techniques
Product development cycle time
Purchase order cycle time
Planned process cycle time
Effectiveness of master production schedule
Capacity utilization
Total inventory cost as:
Incoming stock level
Work-in-progress
Scrap value
Finished goods in transit
Supplier rejection rate
Efficiency of purchase order cycle time
Frequency of delivery

Performance metrics for the customer perspective
Customer query time
Level of customer perceived value of product
Range of products and services
Order lead time
Flexibility of service systems to meet particular customer needs
Buyer–supplier partnership level
Delivery lead time
Delivery performance
Effectiveness of delivery invoice methods
Delivery reliability
Responsiveness to urgent deliveries
Effectiveness of distribution planning schedule
Information carrying cost
Quality of delivery documentation
Driver reliability for performance
Quality of delivered goods
Achievement of defect free deliveries

Exhibit 3a. Supply Chain Metrics fitted into the perspectives "Customer" and "Internal Business" of a Balanced Scorecard. Source: Bhagwat and Sharma 2007.

These tables are shown here not only to illustrate the wide range of performance metrics in a supply chain; they shall also demonstrate the wide range of strategic objectives that supply chain management may entail. If we take just one metric out of each perspective: Customer query time, which appears in the "Finance" and in the "Customer" perspectives, would certainly measure how far a numeric goal, e.g. "Reduction by 20 %" has been met, i.e. if there is progress on the way to reach this goal (the "strategy"). There is a financial outcome as there is less cost involved with solving queries, and there is an outcome in customer satisfaction. And when we look at "Supplier assistance in solving technical problems": there will as well be an underlying strategy, e.g. early supplier involvement, which also carries financial effects. Lastly, "Total Supply Chain Cycle Time" in the internal business perspective has cost effects, cash flow effects and definitely customer satisfaction effects. So we can see the "cause and effects" chain that protrudes the set of objectives and of strategies. Each of them contributes to the overall objective. We will now examine this further; section 4.4 will come back to the use of the Balanced Scorecard for strategy implementation.

2. Dissecting the overall supply chain objective

Establishing a supply chain provides better procurement of inputs and better use of resources as compared to standalone solutions. But what is meant by "better"? The Supply Chain Council has estimated that most companies and organizations can realize the following performance benefits from improved supply chain management [Supply Chain Council, 2000 (http://www.supply-chain.org)]:

- Increase forecast accuracy by 25-80%
- Reduce inventory levels by 25-60%
- Reduce fulfillment cycle time by 30-50%
- Lower supply chain costs by 25-50%
- Upgrade fill rates by 25-30%
- Improve delivery performance by 16-28%

In the essence, what is accomplished is an elimination of what is called the „bullwhip effect“: The amplification of order variability as one goes upstream in the supply chain is drastically reduced.

But we have to go beyond the "visible effect". In order to achieve the improvements outlined above, an institutional achievement has to be effectuated. Thus, the overall supply chain objective is made up by a set of determinants which may be divided into two groups: Defining scope and attributing tasks.

2.1 Defining scope (determination of width and of tiers)

Defining the scope of the network will be a primordial task and it should start with the end-customer requirements and work back through each element of the chain, assessing the value-added activities and the resources required at each stage of goods transfer (or service activity). This analysis should look at the alternatives for redeployment of resources to better optimize the value chain and thereby reduce overall costs and build up speed. This optimization will often include plans for insourcing/outsourcing, inventory management plans (e.g., supplier-managed inventory), supplier management and partnering, e-procurement strategies, and third-party logistics providers.

The traditional arms-length, win-lose approach that many companies have taken with their suppliers will simply not deliver the required results. What has to be called for is a more integrated, win-win relationship, taking a more sophisticated and segmented approach to buyer-supplier relationships. There will always remain some suppliers with whom a traditional buyer-seller relationship will suffice. However, for more critical commodities and services, higher-level relationships will be required. These could range from conventional preferred supplier agreements to sophisticated, multi-year partnering arrangements with value-added activities included, such as inventory management systems, technical support, and even technology co-development programs. For a better understanding of the various arrangements, and following Pyke and Johnson (2003), we categorize the supplier relationships into five different types:

Buy-the-market relationship. Buy-the-market relationships are transaction-based relationships with a focus on price. They are often used to choose the low-cost seller of reliable, standard products, where little variations in performances between different sellers are expected.

Ongoing relationship. When the product performance, such as the quality, may differ among competing sellers, ongoing relationship is the type of relationship with a deeper and broader interaction that provides experience about the performance and, thus, is the better relationship in such situations.

Partnership. A partnership is an even closer relationship than an ongoing relationship with the aim of choosing the best performance of the product via closer interaction and improving the performance of a product through information sharing.

Strategic alliance. Beyond the goal of improving product performance, strategic alliances provide a sharing of risk and trust at a level that allows extensive cooperation in strategic business areas and product development - from engineering and marketing to production planning, inventory and quality management - without the fear of negative effects of information sharing such as espionage.

Backward integration. Buyers integrate the production of bought product components back into their production process, if relationships are extremely complex, uncertainty is high, and the products have key strategic significance. This is actually no relationship in the classical meaning anymore and only mentioned here for the matter of completeness.

Each of these relationships[1] will require an adequate supply strategy. There are four parameters which shape the design of any of the strategies. They are

- Contract: The type of contract used, its length, and the specification detail.
- Information sharing: The intensity sharing of information about supply chain and buyer characteristic, such as actual demands and forecasts.
- Interaction and culture: The interaction between buyer and seller and the difference in company cultures.
- Trust: From the many definitions of trust we might choose Hagen and Choe (1998): „...the expectation that the promise of another can be relied on and that - in unforeseen circumstances - the other will act in a spirit of cooperation with the trustor". Trust is hard to measure in terms of numbers, but, with regard to supply chains, we might see some determinants for trust. One would be the strategic importance of the purchased component: If the component is critical to competitive differentiation or involves proprietary know-how, a close alliance will only be entered with highly reliable sellers. Another determinant is the number of sellers (suppliers) that can provide the component or service: A low number of sellers (extreme: only one seller) will drive the firm towards closer relationships, and it will have to check on trustworthyness. A third

[1] Another aspect of the relationships in a supply chain will be dealt with in section 3.4.2.1

determinant would be the complexity of the interfaces of the component to be acquired with the rest of the final product(s) and of the logistics involved. Complex interactions between components can be better handled in trusted alliances.

All these parameters and determinants will induce the composition of the supply chain. The next step would be to decide on which tasks will be attributed to which member.

2.2 Attributing tasks and performance objectives

A crucial definition in modeling a supply network is about which tasks would have to be performed by which of its members, how those tasks would be performed and how they would interconnect. One criterion is effectiveness, the other one is costs. Costs should be evaluated on a basis of total cost of ownership (TCO) of the tasks being performed. TCO, in this meaning, goes beyond the price paid for materials and services at each stage and includes all other meaningful elements of cost involved in acquiring, transforming, and delivering the materials or services to the next stage in the chain: inventory carrying costs, quality costs, late delivery costs, warranties, and other factors.

One other part of supply chain planning is the information systems required to integrate all the partners in the chain. From first-generation dedicated EDI systems the way would lead to web-based tools and portals for forecasting, demand balancing, inventory replenishment, order entry and tracking, account management and other information to execute a supply chain. "Execution" here means putting the agreed-upon plans into action and establishing the management-review- and tracking-systems which ensure that cost goals and operational requirements for the chain can be met. In this context, the following reasoning has been laid down, interestingly enough, by the US Department of Defense which is part of one of the largest supply chains in the world (Department of Defense Reliability Analysis Center 2004):

"This division of work requires some non-traditional thinking in terms of the relationships between an organization and its suppliers. In the extended enterprise model, suppliers and distribution customers become the arms and legs of the product or service provider. The extended enterprise model requires a well advanced operational integration of the value chain. Information flow is especially critical to the success of the supply chain. Consequently, a well-planned, integrated information system strategy is a critical element, and the SCM software industry has gone aggressively after this market requirement.

Fully integrated suppliers can support a variety of lean manufacturing activities, such as kanban and automatic replenishment systems, vendor-managed inventory systems, and outsourced subassembly operations. A further, logical development of these concepts is the recent rise of third-party logistics (3PL) or lead logistics providers (LLPs) who offer a fully integrated logistics outsourcing approach that can include inventory management, warehousing, freight & transportation, cross-docking, kitting & kanban, and outbound distribution services on an optimized basis.

Supply chain partners are also frequently engaged in technology co-development and new product development activities. In this context, integration of supplier reliability, maintainability, and supportability capabilities into the new product development process becomes a key enabler and should occur in the earliest phases of the product development program.

Key suppliers should be members of the cross-functional product development team in order to best leverage their organizations capabilities to reduce costs and cycle times. In most cases these key suppliers can contribute effective ideas and capabilities for reducing materials costs, design fabrication costs, logistics costs, and manufacturing cycle times."

What we have here is nothing less than an appeal to change the mindset. And this holds true for governmental and for business organizations: "The biggest obstacles to achieving optimized supply chain management solutions will likely be overcoming traditional mindsets concerning buyer/supplier relationships and cost-effectively establishing the required information systems networks between different organizations in the chain" (Miller 2002). So when the minds of managers have grown into what is implied by a "collaborative mindset" and when the appropriate objectives have been mounted, the next step will be to fine-tune into the pertinent strategies.

3. Procurement strategies: Classifications in a "standalone" perspective

Strategists in any business will always set out from a perspective that positions their organization in a situation of independence. This is a natural starting point, as it allows them to develop coherent plans and actions for penetrating and skimming markets, for product research and design, recruitment and humans resource management, manufacturing and purchasing patterns etc. Incorporating inter-organizational relationships into the deliberations would at first sight disorder the coherence of business planning, because one may very rightly presume that the plans and actions of third parties lie beyond the reach of corporate planning. The changes in scope and impact of procurement which took place in the last 30 years have contributed to alter this way of thinking, and relationship management has moved into the focus of how businesses can improve performance. Still, procurement strategies can best be understood if we set out from a "standalone" perspective. Collaborative issues and the issue of interconnecting the tiers of a supply chain will be examined afterwards.

3.1 Traditional procurement strategies classification

Procurement strategy development can be distinguished along three lines (Soellner, Mackrodt 1999). They represent the objectives of

- achieving total cost leadership
- positioning the company favorably in the value chain
- creating growth opportunities.

From there, four streams to deal with the strategy problem in supply management can be identified (Hess 2004): Sourcing concepts, portfolio approaches, process approaches and task-focused approaches. These concepts will be further described within the following paragraphs.

3.1.1 Sourcing concepts

Sourcing concepts are providing combinations of sub-strategies. The goal of the combination is to find a suitable procurement strategy that provides the most beneficial target contribution with utmost synergetic effects (Koppelmann 2004). A typical example of a sourcing concept can be found in Arnold (1996) who has developed the so-called sourcing toolbox. The sub-strategies are defining elements like: number of suppliers, configuration of sourcing object, sourcing area, etc. All sub-strategies are consisting of at least two alternatives. The selection of the most suitable alternative and combination of all sub-strategies' alternatives can be done case by case or representative for typical repeatable sourcing decisions. One advantage of the sourcing-toolbox ist the possibility to add or delete elements to adapt it to a specific purpose of strategic decision-making.

3.1.2 Portfolio approaches

Kraljic (1983) was the first to develop a comprehensive portfolio model for procurement. Together with his matrix, which is exhibited below, he proposed an approach for defining the supply strategy with four steps: Phase 1 is intended for classification of the supply item by using the dimensions profit impact and supply risk. Phase 2 focuses on market analysis with an evaluation of the bargaining power of the suppliers in comparison to the own strength as a customer. During the strategic positioning of phase 3 the purchasing portfolio matrix is created by positioning the strategic items defined during phase 1 alongside the two dimensions of company strength and supplier strength. Result of phase 3 is an allocation of the item and supplier combination within one of three risk categories to be found in the purchasing portfolio matrix. For all three risk categories Kraljic (1983) recommends specific strategic thrusts. Phase 4 is dedicated to the development of detailed action plans to address the risk and all strategic concern appeared during strategy development.

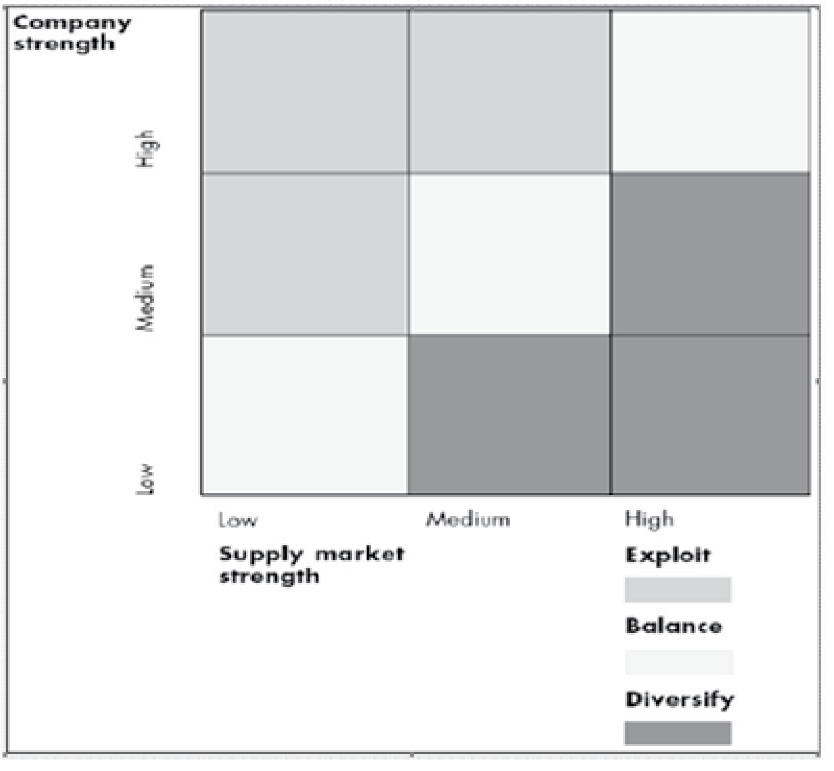

Exhibit 4. The Purchase Portfolio Matrix. Source: Kraljic 1983.

Extensive research work has been conducted in the field of purchasing portfolios both on further developing the portfolios with different dimensions and on analyzing the practical applicability of Kraljic's model. Geldermann, Van Weele (2003) investigated cases and experiences of practicioners with application of portfolio analysis and recommended to see the filling of the matrix not as the main scope of work. In their conclusions they identified Kraljic's model as providing a basis for strategic discourse during a strategy formulation process and pointed out that these in-depth discussions are the most important part of the analysis. There are critics also which exhibit that the reality differs from the model, e.g. Hess (2008). But he also admits that the portfolio approach is a common practice, due to its usefulness for first orientation purposes.

3.1.3 Process approaches

A typical characteristic of the portfolio analysis is the development of generic strategies once the supply requirement has been positioned within the portfolio. Process approaches should provide an alternative to this method of using standardized recommendations or generic strategies. The main focus of process approaches lies on defining the required activities to identify and structure internal and external potential for success. The alignment to superordinate strategies has to be assured. A thoroughly established method includes decision field structuring, effective arrangement of process steps, estimations for time durations and it would consider the required approval steps. To support analysis and decision making it will make use of analytical frameworks, checklists, decision-making tools, means to coordinate the different instruments, etc.

As strategic processes do not consist of automated workflows, accomplishments do not come automatically. Executives will have to watch the motivation level of employees and prepare means to monitor compliance. Motivation and compliance gain importance with increasing requirement of cross-functional coordination as goals and objectives of the various functions involved are in many cases naturally opposing. A sophisticated process approach will therefore address the requirement of cross-functional coordination from the outset. Even the most sophisticated method can not overcome challenges inherent to strategic planning processes. We know that cost estimations related to strategic measures are often difficult to impossible and that the valuation of strategic measures' impact is not feasible immediately and directly.

Among the many different process approaches spanning from strategic alignment up to implementation guidelines the authors want to mention the examples of Koppelmann (2004), Appelfeller, Buchholz (2005) or Laseter (1998). Hess (2008) intended to provide a systematic framework by combining methods for particular procurement tasks, sourcing concepts, portfolio approaches and a Procurement Balanced Scorecard and called it the "15M-Architecture". It turns out to be the most comprehensive process method consisting of 4 strategic building blocks with 15 modules.

3.1.4 Task-focused approaches

Methods focusing efforts on specific tasks are providing sets of activities in the majority of cases for a dedicated team for a pre-defined timeframe. The rationale behind this way to handle a problem can be seen in the different requirements of strategic problem solving compared to the standard operational workload in procurement. Additionally the specific tasks are often related to extensive cross-functional coordination and are not fitting into existing lines of responsibility. We find among the topics in task-focus examples like supplier relationship management, global sourcing or e-procurement.

Successful completion of tasks are often requiring dedicated teams with special training that can operate with organizational autonomy towards this single objective. Thus, an immediate reorganization can be avoided as the additionally required capacity is provided by the team members. Arnold, Morgan (1994) state that for a similar strategic question the main design challenges to be addressed would be:

- the type of vision to dominate the design of the project
- project's extent of separation from or integration into the existing system
- assurance of sustainability of the approach.

Among the disadvantages that might come along with these approaches are potential narrow views within the team that lead to short-term measures without considering long-term effects and sustainability. Other weaknesses can be found in organizational aspects, as the relationship with the existing organization may not evolve positively and conflicting goals might lead to hostility. In general, separation of activities does not foster synergy creation and can lead to discontinuities in information flow.

A common way to benefit from a task-focused approach led by a dedicated project team and to additionally create a sustainable implementation is to start with the project and to perform organizational changes based on experiences from the pilots (Arnold, Morgan 1994).

3.1.5 Value-focused approaches

From a competitive standpoint, it may seem to the market leaders that he widespread use of competitive sourcing techniques and tools has eroded the major advantage that it gave pioneers in the 1990s. A.T. Kearney's 2008 "Assessment of Excellence in Procurement Research" (A.T. Kearney 2008) found that the savings gap between leader- and follower-companies had shrunk by half just since 2004. So, since value derived from sourcing cost savings will not be enough in the coming years, a new approach is required. This would be to use the supply base as a resource to both supplement and complement the company's resources and to employ this combined capability to improve overall company competitiveness by creating additional value for both customers and shareholders (Monczka, Blascovich, Parker and Slaight 2011). Increased emphasis is to be laid on value goals (i.e. beyond cost) and the supporting data/information collection and analysis. These include the requirements of the ultimate customers that will impact what is purchased, the dynamics of the supply market and specific supplier capabilities. Overall, the breadth and depth of the data collection and analysis increases significantly. For example, the linkage between customer and company business, product and technology strategies must be clearly understood. Understanding where value is created in the supply network is critical as is the detailed application of value mapping tools, supplier and network optimization, supplier needs analysis, product design complexity and so forth.

3.2 Connecting the procurement strategy approaches to synergy creation

The very nature of procurement strives to accomplish advantages through acquiring goods and services for which the supplier possesses a competence which is higher than that of the buyer. The goal, thus, is increased performance, and it is achieved through synergy. Synergy and performance objectives are closely interrelated. Stahl/Mendenhall (2005) name four basic categories of synergy: cost reduction, revenue enhancement, increased market power, and intangibles. The most relevant strategic objectives in a buyer-supplier relation in this regard will lie with avoiding the build-up of fixed cost and fixed assets elements by increased utilization of existing assets, with distribution optimization, and with overall economies of scale. Investment synergies and management synergy will also get a high rank, as will transfer and balancing of assets. Closer to performance, standardization and techniques of know-how-transfer will play a major role in target setting. Hence, the process-focused and task-focused approaches for formulating and implementing procurement strategies will gain momentum.

The following exemplary procurement strategy frameworks are appropriate to support requirements of synergy enhancement. Among the concepts to be exhibited are: Strategic sourcing, commodity strategy, supplier management, supplier relationship management, supply chain management or co-development with suppliers. Coming back to the categorization of Hess, the sourcing concepts are described here with components originating from Koppelmann (2004), with a model of process approach that was developed by Laseter (1998), and with the Global Sourcing concept of Trent/Monczka (1991).

3.2.1 Introducing the commodity level

According to Koppelmann (2004), there are certain elements which have to be employed on both the level of the overall purchasing strategy and the commodity level and which are based upon the following set of generic strategies:

- Product strategies
- Sourcing strategies
- Communication strategies
- Service strategies
- Cost strategies

For synergy creation, the following elements are to be considered in Product strategies:

- Co-development
- Platform concepts / standardization
- Zero-defect concepts

The following elements are to be considered in Sourcing strategies:

- Insourcing vs.Outsourcing,
- Supplier Concepts (multiple vs. single),
- Object Concepts (system-modular-unit),
- Replenishment Concepts (stock vs. just in time delivery),
- Area Concepts (global-domestic-regional),
- Subject Concepts (individual vs. collective)

The following elements are to be considered in Communication Strategies:

- Information exchange acceleration
- Intensifying of competition
- Know-how-transfer

The following elements are to be considered in Service Strategies:

- Support
- Outsourcing services
- Outsourcing waste management
- Intensifying inspection

The following elements are to be considered in Cost Strategies:

- Minimum price
- Fair price
- Average market price

This enumeration of elements should serve to illustrate the wide range of considerations that are intrinsic in shaping an individual set of strategies for an organization. The decisión-makers will have to carefully select the proper elements and to reach an adequate balance.

3.2.2 "Balanced Sourcing"

The term "Balanced Sourcing" has been introduced by Laseter (1998) based upon practical cases and research of Booz Allen Hamilton. The model considers a broad perspective as the procurement function and the supply base are considered to have connections to almost all business processes. The method suggests to establish a balance between cost savings initiatives and cooperative relationships with suppliers.

Applying "Balanced Sourcing" to the entire extent defined by Laseter (1998) would mean to transform the organization from the transactional approach to a cross-functional strategic management. This transformation comes in parallel with the development of six organizational purchasing capabilities. Three of these capabilities are universally applicable to any company and represent core processes of the procurement strategy: (a) Modeling total cost, (b) Creating sourcing strategies and (c) Building and sustaining relationships. The other three capabilities have been defined to be different ways towards competitive advantage: (d) Integrating the supply web, (e) Leveraging supplier innovation, and (f) Evolving a global supply base.

The "universal" capabilities are core processes of general practicability in supplier management and strategic sourcing, and Laseter (1998) advises that companies should select from the other three capabilities the most suitable one or two. Due to the scope of these three, application of all three would remain for the largest companies with most advanced strategic procurement organizations. But all the capabilities resonate throughout any supply chain. The capacity of evolving a global supply base has been refined in many ways. If properly applied, the synergy potential of global sourcing ranks highest amongst all as will be seen from what follows.

3.2.3 Global sourcing

Evolving a supply network into a global supply base, in the perspective of Laseter (see above), is certainly a differential capability as it will eventually lead to competitive advantage. Adding another perspective will bring us back to the strategic issue. This is about the motives to evolving a global supply base. Wildemann (2006) enumerated the following motivations to start global sourcing:

1. Realization of cost savings by capturing factor cost differences
2. Securing availability of purchased goods
3. Reduction of existing dependence on suppliers or supply markets
4. Natural hedging of revenues and currency fluctuations
5. Addressing local content requirements
6. Spreading sourcing risks like insolvency risk or risk of shortfalls in production
7. Optimization of deliveries within the international manufacturing footprint.

If we investigate motivations not only from a procurement standpoint but with the supply chain view we can distinguish between the two main intentions (1) Following an overall expansion strategy of the firm into new global markets and supporting it with procurement activities and (2) pursue global sourcing to improve competitiveness of domestic operations. If we further investigate item (1) we find that especially in businesses with a high requirement for variety and volatile demands localized sourcing to reduce in-bound lead-times represents the means to sustain supply chain agility (Christopher 2010). The localization of components should focus primarily on those items that generate the differentiation of the final product. An adaption of the product to changing customer needs is more easily achievable as adjustment of delivery schedules for the differentiating components can be realized within shorter periods of time. In case no. (2), if procurement motivations are dominant, the selection of commodities for global sourcing will depend primarily on the selected source of competitiveness the company intends to improve. Bogaschewsky (2005) summarizes the drivers more general into: cost reduction, quality improvement, increased flexibility and shorter development times.

At this point the authors want to emphasize their understanding of global sourcing and refer to the definition of Trent, Monczka (2003, p. 26): "Global Sourcing involves proactively integrating and coordinating common items and materials, processes, designs, technologies, and suppliers across worldwide purchasing, engineering, and operating locations". The Five-Level-Model as per Exhibit 5 below positions global sourcing in comparison to international purchasing approaches. We can observe an international approach at level III already, but what makes the difference to a global sourcing initiative is the organizational integration. A level IV strategy is characterized by a global coordination and integration of all procurement organizational units and top management supports and promotes the global approach. A real cross-functional integration across global locations is the main differentiator in a level V strategy. One of the most challenging tasks to accomplish on the global scale is the integration of R&D together with new product development activities (Trent, Monczka 2003).

Exhibit 5. The Five-Level Model of Global Sourcing. Source: Trent and Monczka (2005), p. 28

Trent, Monczka (2005) identified seven broad characteristics of global sourcing excellence in the most successful companies within their empirical research. The detailed description of these characteristics has been delivered and provides insight to the correlation of opportunities for purchasing synergy creation and global sourcing excellence factors. If we refer to the model of Rozemeijer (2000) whose dissertation concentrated on synergy creating activities in purchasing, we recognize the following correlations:

Benefits from an integrated, cross-locational and cross-functional approach will not only be found at the most successful companies. Positive effects will materialize if an organization is

Opportunities for Purchasing Synergy	**Characteristics of Global Sourcing Excellence**
1. Jointly negotiated contracts	Rigorous and well-defined processes
	Methodologies of measuring savings
	Executive commitment to global sourcing
2. Frequently shared functional resources	Supportive organizational design
	Availability of needed resources
3. Frequent exchange/sharing of information 4. Frequent exchange/sharing of knowledge	Integration through information technology
	Structured approaches to communication

Exhibit 6. Correlation between opportunities for purchasing synergy and characteristics of global sourcing excellence. Source: authors' design based upon Rozemeijer (2000), p. 231, and Trent/Monczka (2005), p. 30.

prepared to recognize that a global sourcing approach has to integrate all core functions of the enterprise. The following list (from Trent/Monczka 2003, p.32) gives an overview of the main benefits where an influence has been observed:

- Better access to product technology
- Improved supplier relationships
- Common access to process technology
- Improved sharing of information with suppliers
- Lower purchase price/cost
- Shorter ordering cycle times
- Better management of total supply chain inventory
- Higher supplier responsiveness to buying unit needs
- Standardization or consistency to the sourcing process
- Early supplier involvement during new product/service/development
- Higher material/component/service quality
- Improved delivery reliability
- Improved environmental compliance
- Greater appreciation of purchasing by internal users
- Lower purchasing process transactions costs
- Higher user satisfaction with the purchasing process

The main characteristic of this list is that most of its elements not only refer to advantages for *all* members of a supply network (unlike many other lists which only cover benefits for a single firm), but that they can also be expressed in measurable targets. Still, what we need up on that, is an outlook which focuses on the collaborative perspective of a supply chain. This will be given in the following section. The outset would be that true supply chain superiority does not come by emulating the best practices of others. Rather, it flows from leveraging a strategic framework and deeper set of guiding principles that lead to competitive advantage (what has been called the "competitively principled" supply chain by Lapide (2006)).

3.3 Collaborative procurement strategies: Setting upon uncertainty, complexity, and free riders

3.3.1 Reducing uncertainty

For a systematization of strategies that appertain to the whole of a supply chain, it is useful to remember that collaboration in a supply chain generally reduces uncertainties. With regard to the sources of the uncertainties and the ways to reduce them, we can again set out from demand-side and supply-side strategies: The first type of uncertainty reduction strategies aims at reducing the demand uncertainties, such as avoiding the bullwhip effect, by using, among others, collaborative replenishments. Supply uncertainty reduction strategies aim at reducing or even avoiding uncertainties concerning the continuous upstream. Examples of such strategies are the exchange of information (starting with product development and continuing with the mature and end-of-life phases of the product life cycle) and the use of supplier hubs (in order, e.g., to reduce the risk of break-downs in manufacturing lines). We can match this perspective with two other viewpoints (Lee 2002). One is the character of the goods channeled through the supply chain: they can either have long life-cycles and satisfy needs that do not change much over time ("*functional products*"); these products will be fast movers and produce low inventory and stock-out cost and low profit margins. Or they can have short life-cycles and an unpredictable demand ("*innovative products*"); these produce high inventory and stock-out cost and (possibly) high profit margins. The second viewpoint is that of supply process stability: We may distinguish between a *stable process* and an *evolving process*: The first one is based on a mature technology and on mature manufacturing techniques, in the other one those characteristics change rapidly and experience is limited. Putting all this into a grid we get four quadrants (Exhibit 7):

Each of the quadrants represents a distinctive composition of a supply chain. Lee (2002) connects these compositions to four distinctive collaborative strategies:

Efficient Supply Chains utilize strategies aimed at creating the cost efficiencies in the supply chain. All these strategies aim at minimizing non-value- added activities, deploying scale economics and optimization techniques, and establishing information linkages for demand, inventory, and capacity exchange.

Risk-Hedging Supply Chains utilize strategies that hedge the risks in the supply chain. These are strategies aimed at pooling and sharing resources in a supply chain so that the risks in supply disruption can also be shared.

Responsive Supply Chains utilize strategies aimed at being responsive and flexible to the changing and diverse needs of the customers, such as mass-customization (with order accuracy) and build-to-order techniques.

Agile Supply Chains utilize strategies aimed at being responsive and flexible to customer needs, while the risk of supply shortages or disruptions are hedged by pooling inventory or capacity resources. The strategies that are used here range from the risk-hedging to the responsive supply chains.

Due to the differences in the goals and strategies of the four models, the value and competitiveness of a supply chain different must be determined by a diverse set of measures. Generally speaking, for efficient and risk-hedging supply chains, measures such as plant capacity utilization and inventory turns of the whole supply chains may be adequate. For responsive and agile supply chains, a measure, such as the product availability, may be more appropriate (Paulitsch 2003). This aspect will be further evaluated in section 6 below.

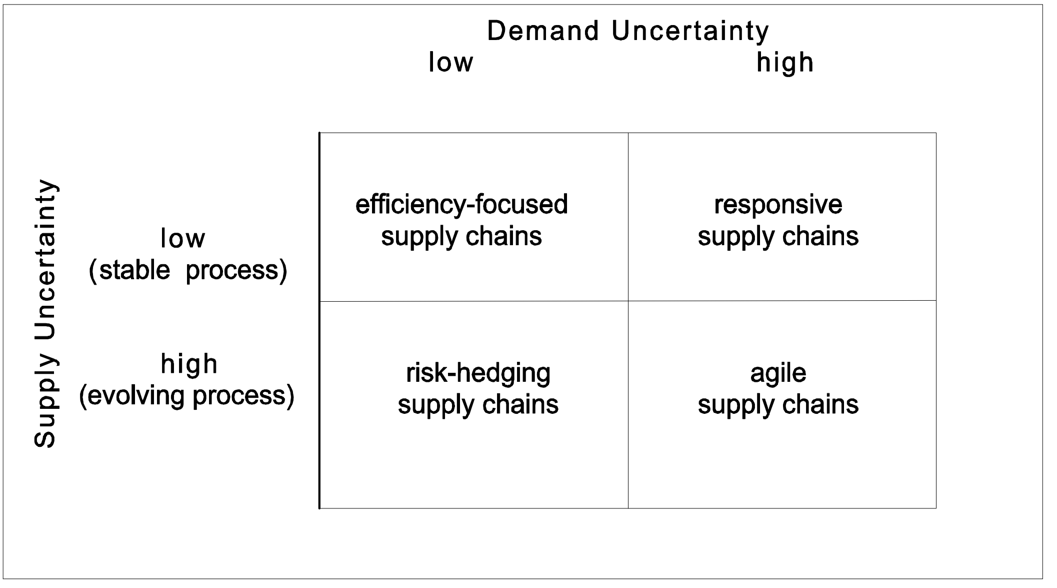

Exhibit 7. Supply chain strategies for different products and process types. Source: Lee 2002.

There is another aspect deriving from the classification into "efficiency seeking", "risk-hedging", "responsive" and "agile": The stronger members have to assist those members whose resources are limited, and altogether they will defend the objectives against "pirates" who want a free ride without providing any contribution. Those opportunists often hide behind the complexity of the system, so providing transparency is one means to fight them.

3.3.2 Overcoming complexity

Supply chains are complex systems. Their complexity is expressed in volatility, uncertainty, numerousness, variety and a dynamic environment. These complexity parameters determine the structural configuration and the relationship between the elements of the supply chain, and the effects resulting from the system's complexity are reflected in the indicators used to monitor network performance. There are five basic strategies for dealing with the effects of complexity: Accepting, managing, reducing, preventing and transferring. Two examples of complexity management will be given below (from Kersten 2010). One relates to effects on direct cost (Exhibit 8), the other one to effects on overhead cost (Exhibit 9).

According to Kersten (2010), the five different strategies would be characterized as follows:

- The "Accepting Complexity" strategy reactively adapts the organization to what is predetermined through external requirements. The complexity effects on the company are compensated by going back to traditional, less sophisticated supply chain management.
- The "Reducing Complexity" strategy objective is to simplify and optimize structures, products or processes, diminishing the numerousness of elements and their connectivity.
- The "Managing/Controlling Complexity strategy" proactively handles the existing structure of business processes in the most effective way to ensure their reliability. For this, the variety of process outputs and the predictability of process results are reconsidered.

Complexity Parameters	Area of cost impact	Type of Strategy	Actions
Variety	Procurement Warehousing Handling	Reducing	Centralizing supply requirements, supplier development and certification, consolidating international supplier base, reconfiguring warehouses regionally, focusing on fewer product types.
Numerous–Ness	Purchase prices, transportation Suppliers' finan- cial health	Reducing	Consolidating purchasing volumes, con-solidating suppliers, consolidating warehouse operations, using alternative modes of transportation based on volume requirements.
Volatility	Direct materials (including fuel)	Accepting/ Managing/ Reducing/ Transferring	Charging surcharges based on fuel prices and distances/ Improving reliability of operations Optimizing operational costs of procurement
Uncertainty	Labor Transportation Suppliers' financial health	Managing/ Reducing	Improving forecasts with suppliers, cooperating with suppliers to improve their operations Consolidating supplier base
Dynamic Environment	Global sourcing Shifts in customer demands	Accepting/ Reducing	Downsizing organizational structure / Cutting supplier base, closing facilities and offshoring operations.

Exhibit 8. Complexity management strategies for direct cost impacts. Source: Kersten 2010.

- The "Preventing/Avoiding Complexity" strategy anticipates future complexity within existing structures or processes by improving awareness of how complexity is generated.
- The "Transferring/Exporting Complexity" strategy sidesteps complexity by transferring them to other players in the market.

There is a similarity, at least in the denomination, of complexity strategies and risk management strategies: Accepting, managing, reducing, preventing and transferring also indicates the range in which risk is handled. As can be seen from the tables, quite a few of the actions which are listed here would also show up in a list of recommendations regarding risk management. A few other remarks on risk management will be given in section 5.

3.3.3 The "defensive" perspective: Looking inward

Transparency and a reduction of complexity will not alone suffice to defend the supply chain against free riders. The "real-term-solution" will have to start with securing access to and use of information. There is a wide consensus on the idea that the information systems integration is a must, and this makes it even more difficult to restrict access. The task

Complexity Origin	Type of Strategy	Actions
Organization	Reduce	Outsourcing of operations, reducing product lines, restructuring by regions, consolidating operations and purchase volumes.
	Prevent	Implementing new IT and other technologies; automation
	Manage	Setting supplier close to overseas production sites, increasing supplier base, global sourcing, standardizing parts catalog, increasing frequency of deliveries.
External Environment	Reduce	Cutting of operations and licensing of production.
	Prevent	Introducing model variety, implementing corporate responsibility standards
	Manage	Diversifying supplier base and developing suppliers' competitiveness.
	Accept	Charging fuel surcharges, downsizing organizational structure and diversify operations' location.
	Transfer	Conducting price increments in transportation and warehousing services and products.
Structural Interface	Reduce	Consolidating shipments, consolidating operations and technology improvements in transportation.
	Prevent	Using intermodal transportation, sourcing locally and expanding operations internationally.
	Manage	Diversifying supplier and customer base.
	Accept	Increasing inventory and order frequencies, delaying production phases, building buffer stock and shifting transportation modes.

Exhibit 9. Complexity management strategies for overhead cost impacts. Source: Kersten 2010.

requires sophisticated system administration, and it requires trust. When we look at the traditional vision of the supply chain, demand flows down the chain (from each "node" which represents a trading partner to the next "node", which is the downstream trading partner) and products are moved in the opposite direction (see Exhibit 10 below). The effect of free riders taking advantage of access to the system can be compared to what results form instability of information: Delay times, distorted demand signals, and poor visibility of exception conditions result in critical information gaps, including misinformation and, ultimately, leading to mistrust. When partners lose faith in the forecast they receive, they typically respond by building up inventory buffers to guard against demand uncertainty. This is aggravated when there are deficiencies in data security. The disruption that results from dramatic, sudden changes in forecasted demand is amplified as it travels up through the supply chain, and the chain gets a victim of the "bullwhip effect" like if the partners were just dealing on arms' length instead of collaborating in a supply chain.

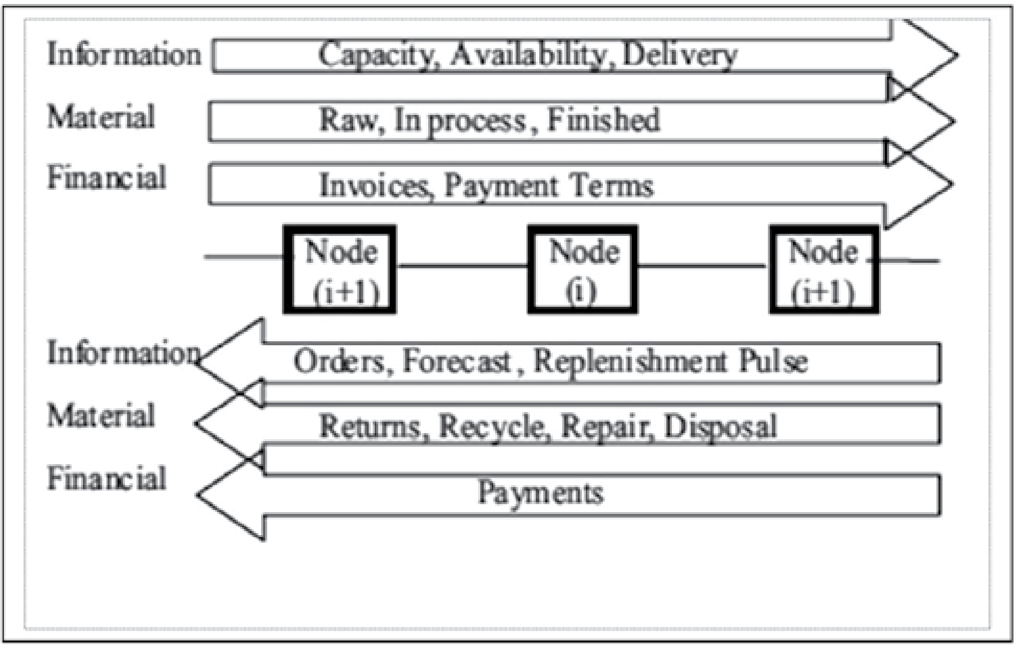

Exhibit 10. Flows of material, information and finance

The above exhibit demonstrates that a strategy is needed to guarantee a secure flow of material, information and finance, not to just eliminate free riders but, first and foremost to enhance performance. The main aspect here is connectivity and trustful collaborative practice. The relevant technicalities will be dealt with in section 3.4. Before getting there, we need to briefly look at what might be deemed the opposite of collaboration: offensiveness.

3.3.4 The "offensive" perspective: Competition between supply chains

There is a tendency to assume, from the way in which companies reconsider arms' length practices and competition, that, in the future, companies will no longer compete against other companies and instead, networks will compete against networks, and supply chains against supply chains. On the other hand, experience shows that supply chains use their competitive advantage in a completely different way: They create internal capabilities through integrating capabilities from upstream and downstream partners. Still, one may consider three scenarios, where actions take place that may be considered as competition between supply chains, and this certainly has an impact on strategic management. Rice and Hoppe (2001) demarcate three scenarios:

- Scenario (A)

Rivalry among groups of companies across the supply network, competing as one entity, formally or informally. This applies when the following conditions are present:

- The chain is a vertically integrated company, either competing against another similar vertically integrated company or against supply networks comprised of many companies;
- The supply network is a highly integrated company with no common suppliers;

- The supply network is comprised of companies that have sole-source relationships;
- The industry is fragmented in such a way that there are no common strategic suppliers represented in more that one supply network, and most strategic suppliers are dedicated to one supply network.

• Scenario (B)

Competing on supply network capabilities. Competition between individual companies competing on their internal supply network capabilities. Mainly competing on the effectiveness, efficiency and responsiveness of the network and on the network design used (for instance, applying innovative postponement production strategies, introducing new distribution channels, etc.). Network capabilities can be added or integrated (not copied).

• Scenario (C)

Competition centered on the single, most powerful company of a supply network (referred to as the "channel master"). This scenario is the most relevant and is commonplace in today's marketplace: The channel master uses its market power to exert strict unilateral coordination of processes among its suppliers and customers. Examples are Dell Computer, Procter and Gamble and Wal-Mart, and their exertion of power ranges from being benevolent for the entire network to being entirely company-focused and transaction-oriented (Christiaanse and Kumar 2000).

Above all, the "channel master scenario" is commonplace in today's practice. Daimler's supplier network serves as a good example. The auto-maker considers suppliers to be an integral part of its "extended enterprise" and works aggressively to refrain suppliers from providing their capabilities to other networks. Still, the present relationship of Daimler with its suppliers is far more constructive than it used to be a decade ago (Elmazi and Kordha 2009).

3.3.5 Co-opetition

Combining the "inward" and the "outward" (= offensive) perspectives we get to the paradigm of bringing together cooperation and competition into a third position that has been called co-opetition. Cooperation is characterized by autonomous entities in the supply chain which form a dynamic network with integration, coordination, collaboration, information sharing, common interests and mutual competitive advantage. Likewise, competition focuses on the need for development of competitive advantage between the actors; the network environment enables them to optimally allocate scarce resources, providing the impetus for innovation and entrepreneurship, and reducing transaction costs. This paradox proves livable when proper arbitration and sufficient balance is ensured between competition and cooperation in view of the various interdependencies in the network. From a theoretical standpoint, as it is given by transaction cost economics, it is these interdependencies which make the network livable: There are hierarchical interdependencies, as expressed in the tiers of the supply change or in the powers conferred to the central player of a focal network, and there are market interdependencies, but the members of the network stay legally independent, holding their identity, culture and capabilities and maintaining a structural flexibility.

Transaction cost economics roughly states that the optimal structure of market-relations is determined by finding an optimum for the "costs connected with using the market mechanism" (this definition for "transaction costs" was first discussed by R.H. Coase in 1937). In the context of supply networks, these transaction costs represent the summation of coordination costs between the actors, including cost to avoid risks relating to operations and risks arising from opportunism. Coordination costs reflect the costs of information exchange (on product qualities, on demand, inventories, production capacity, etc.), costs related to the integration of this information into the process of decision-making, and costs related to delays due to communication problems. La and Cooper (2000) distinguish between coordination risks that relate from operations (risks of misinformation or voluntary withholding of information), and risks that relate from opportunism including those which are connected to lack or loss of bargaining power.

In practice, there are not many cases where transaction costs are actually measured and reported, but it seems logical that the network will at least gradually arrive at a status and a structure where these cost are minimized. Nevertheless, this is not as obvious as one might think. Although integration between members may be the motive of a supply chain, it doesn't happen automatically. An excessive integration could be detrimental to the performance of the supply chain, and it is first necessary to identify activities and key members. In most cases, drivers for integration are situational and different from one process link to another, the degrees of integration differ from link to link and also vary over time. Finally, the integration of the supply chain also depends on certain organizational factors such as trust, commitment, interdependence, organizational compatibility, vision, leadership and top management support (La and Cooper, 2000). Consequently, the road to structuring the network becomes dynamic and non-linear. And, with each member's need to strive for its individual competitive advantage, we will find that they behave in ways so as to create more value by cooperating, but also to capture a large share of the created value by means of competitive actions. This is the outcome of what might be called "bipolar strategies".

There is an intrinsic bi-polarity in supply chains: Cooperation and competition represent an ago-antagonistic couple in the supply chain, since on one hand they are viewed as contradictory, yet on the other hand this paradoxical combination has positive effects. Also, there are two logics to the phenomenon. One is characterized by behavioral aspects (competitive action), and the second is characterized by strategic aspects (cooperative relations): With a view to long-term effectiveness and survival, the members of the network univocally recognize its strategic value. However, each one wishes to achieve short-term improvements individually. For this, the term "co-opetition" was coined in 1996 by Adam M. Brandenburger of the Harvard Business School (Brandenburger and Nalebuff 1998). The approach is towards a "win"-"win"-"win"-situation, where companies can create value by cooperation processes, and at the same time capture value by competitive processes. A case that illustrates co-opetion is Covisint, a venture which had been founded in 1999 by General Motors, Ford and DaimlerChrysler to serve as a common automotive exchange platform (see https://daimler.portal.covisint.com). The aim was to build a virtual marketplace in which partners would perform a certain number of a activities jointly. The platform performs several functions like networking between all the actors, coordinating and synchronizing processes, standardization of quality standards and of safety standards, and improved allocation of resources between partners. In 2001, Renault and Nissan joined the venture. This cooperative initiative between companies who compete in the market provides economies to each of them: lower product or service purchase prices, collective auctions, reduced transaction costs among members and pooled Research and Development activities. So as to not lose competitive advantages, the partners integrate private platform mediation which allows them to benefit from cooperation in a competitive environment.

3.4 Putting the collaborative perception into practice: control strategies

Inter-organizational control has three aspects: functional, institutional and instrumental. The "**functional**" would refer to the question if there is a dominant role of either accountability issues or purely (procedural) logistic issues. A system which ensures an accountability structure will definitely develop a closer collaboration based on the willingness to widely share information, to initiate problem solving and to adapt to changes; this would be accompanied by restraints from the use of power (Mahama 2006). The "**institutional**" would refer to the question who develops the strategic framework: The two main choices are that this is done either by one powerful supply chain member who has been conferred the leadership role ("focal network"), or by a team consisting of several equally empowered members ("polycentric network"). One determinant factor in this will be the complexity of the network, and, besides the distribution of power, the two alternatives involve the notion of trust. With the "**instrumental**", we get to the question of how to obtain the data for managing the network and for performance measurement.

3.4.1 Management control patterns

Management control in a network, like in a standalone firm, can be conceptualized and categorized in various ways: formal vs. informal controls, behavior vs. outcome controls, diagnostic vs. interactive controls, mechanistic vs. organic controls, and bureaucratic vs. clan controls (Langfield-Smith 1997). From a long-term perspective, management control in supply chains has to apprehend that

a. any network will develop along three phases of transactional relations (contact phase, contract phase and execution phase), for which either the market plays a dominant role (and, following this, specific control instruments are not required as they are substituted by market mechanisms), or bureaucratic means are required such as pre-defined norms, standards, and rules, or where trust is the dominant factor (control mechanisms are process-oriented and based on fairness as trust reduces goal conflicts);
b. the nature of outsourcing relationships will vary over time, and that, again, we may discern between market-orientation or the need for bureaucracy or a situation of elevated mutual trust. From there, the control pattern will either call for strict programmability of (repetitive) tasks, high measurability of output and low asset specificity, and high task repetition, or it will include rules of behavior and rigid performance targets which are captured in detailed contracts, or it will be mainly ruled by competence and goodwill.

Whichever of the above situations is prevalent in a specific case, accounting has to be used to monitor, control and influence the behavior of the network partners. The other determinant for control is market prices, but they must be seen here as an "input" to accounting. The pattern of monitoring may embrace

- -self-regulation mechanisms like transfer prices and pre-set fees which would serve to translate knowledge, complementarities and other intangibles into governable resources;
- -orchestration mechanisms which deal with the network as a resource and equip it with a common strategy, and enable and empower the partners to hold network relations.

This may best be illustrated through a model developed by Dekker (2004), who sets out from the strategic ("ex-ante") and connects it to the operational ("ex-post") mechanisms. Ex-ante mechanisms mitigate control problems in advance of the implementation of a partnership by aligning partners' interests and through reducing coordination efforts. Ex-post mechanisms deal with concrete control mechanisms by examining the achievement of certain performance goals as demonstrated in the following exhibit which shows the mechanisms that should be implemented both before and after the network has been set up and put into motion:

Ex ante mechanisms

Goal setting	Structural specifications	Partner selection
Strategic goals	Ordering and supply procedures	Long lasting joint history and cultural fit
Short-term goals,	Functional specifications	
cost reductions and ordering quantities	Program of innovations	Interactive goal setting
	Quality plans	Joint governance design
Incentive systems	Specification and division of	Short-term goals
Alliance fund	intellectual property rights	Reputation
	Organizational structuring	Trustworthiness for other alliances
	Alliance board	Trust
	Task groups	Long-lasting relationship
		Reputation
		Open book agreement
		Intentional incomplete contracting

Ex post mechanisms

Performance monitoring	Behavior monitoring	Shared decision-making and goal-setting
Open-book accounting (=> cost reductions)	Pre-action review of ideas for innovation	Joint alliance board
	Board monitoring	Joint task groups
Rewarding	Auditing use of quality plan	
Benefit sharing		

Exhibit 11. Management Control Pattern and Management Control Instruments in a Supply Chain (Source: Dekker, 2004, p. 43)

From a strategic view, the emphasis must be on how to organize the best interplay between the functional, the institutional and the instrumental elements. Therefore no attempt is made here to extensively enumerate the instruments for data management that are commonly applied. Instead, section 4 will elaborate on the issue of selecting appropriate metrics with a view to the prerequisites that must be in place. One such prerequisite will be dealt with right now as it constitutes the primary area of connectivity between the members of a supply chain: Collaborative planning, forecasting and replenishment.

3.4.2 Collaborative planning, forecasting and replenishment and its prerequisites

When it comes to combine the intelligence of multiple trading partners in the planning and fulfillment of customer demand, instruments are needed, and they must serve and be based on the process structure in the network. Again, as seen in the previous section, ex-ante considerations will be required. The outset must be way before determining the techniques: Following the idea of combining "the best" of all possible network partners, the overall strategy to become more efficient will have to focus on core competencies of the supply chain members. The capabilities of and the relationships among the supply chain members will have an influence on the type and reliability of the information exchanged. Also, requirements for a supply chain solution may comprise an objective to be followed by the supply chain as a whole, and this includes the notion of fairness.

3.4.2.1 Criteria for discriminating supply chain structures and relationships

Several criterion specifications should be considered when building a supply network. In order to define the structure of a supply chain, these would be (Stadtler 2009):
(1.1) the number of supply chain tiers,
(1.2) the number of supply chain members in each tier, and
(1.3) the business functions supply chain members fulfil.
The problem here is complexity resulting from the number of links to handle and pertinent decision-making. If we take, for example, a two-level supply chain (one supplier, various buyers) with a scarce resource on the side of the supplier, we may find a decision problem on allocating the scarce material in light of the (unfilled) demand from the buyers. Also, if decisions have to be linked within the same business function, e.g. capacity reservation, the question arises on how to harmonize the planning domains of the supply chain members. This is the reason why one of the structural criteria is the business functions supply chain members fulfill.
There would also be
(2.1) market- or technological or financial power of each supply chain member,
(2.2) the extent of self-interest governing a supply chain member's behaviour,
(2.3) learning effects and
(2.4) rolling schedules.
Let us pick out rolling schedules which play a role in collaborative planning. This not only involves updating and extending an existing plan by one supply chain member but also renegotiating all changes with all other affected members. One question here is, who will bear the cost resulting from these changes if there is already a previously approved plan? Closely related to rolling schedules is the notion of learning effects. If the negotiation procedure is repeated, then a party may make use of information gained in previous negotiations. This is especially true if there is an overlap of decisions in two successive plans (like in rolling schedules), because once the buyer has decided to choose a specific purchasing contract, all data are revealed to the supplier. Would then there be space for a new negotiation?
Similarly, criteria might be developed for the information status (degree of uncertainty, timeliness, etc.). As will be discussed in section 4.3, the quality of data is an important discriminator for supply chain performance.
When the criteria have been chosen, the structural decisions can be made for the supply chain in question. It should be well documented which members have made which commitment with regard to contributing which capability, which data, which systems, etc.

Also, rules should be set up as to how decisions be made in the case of circumstances beyond control. All this will form the framework for the implementation of the core processes to be moved in the supply chain. For these, the criterion will be how much they contribute to performance improvement.

3.4.2.2 Core processes

Nine general practices for supply chain management have been found in numerous studies that might influence performance (Lockamy and McCormack 2004):

- Planning processes
- Collaboration
- Teaming
- Process measures
- Process credibility
- Process integration
- IT support
- Process documentation
- Process ownership

Using factor analysis, Lockamy and McCormack (2004) found that "Planning processes" and "Collaboration" are especially important for supply chain performance within all process categories. In the denomination of the Supply Chain Operations Reference model, these would belong to the top level (selecting the process type) and the configuration level (selecting the core processes a business wants to employ). The Supply Chain Operations Reference (SCOR) model has been developed by the Supply Chain Council to provide a best-practice framework for supply chain management practices and processes with the goal to increase performance. A rough scheme of SCOR is shown in Exhibit 12 on the following page.

As can be seen in the Top Level Quadrant of Exhibit 12, the SCOR model consists of five major process categories: Plan, Source, Make, Deliver and Return. So, SCOR is about “what” (a strategic dimension). In contrast, collaborative planning, forecasting and replenishment (CPFR) is about “how” (operational decisions). But more than just a set of processes that enable planning and monitoring across corporate borders, the acronym, correctly spelled CPFR® with the trademark denomination, is an inter-industry standard of the US-based Voluntary Inter-Industry Commerce Standards organization (VICS). The reason for this is that, early on, supply chain managers have realized the importance of using uniformly adopted systems for data interchange among trading partners. CPFR begins with an agreement between trading partners to develop a collaborative business relationship based on exchanging information to support the synchronization of activities to deliver products in response to market demand. 2011 marks the 25th anniversary of the introduction of CPFR®, and the standard has since then spread into businesses all over the world (http://www.vics.org/committees/cpfr) which use it for interactions between processes. This allows them to improve the accuracy of plans and thus ease the flow of products in the channel. By focusing on the flow of supply to consumers, without the clouding effect of inventory, participants can discover and address previously hidden bottlenecks in the flow (by analyzing variances in actual from plan). In turn, by taking care of these inefficiencies, cross-process operational costs can be reduced and performance is enhanced. But this has to be “performance” seen from a supply chain context as per the definitions given in the following section.

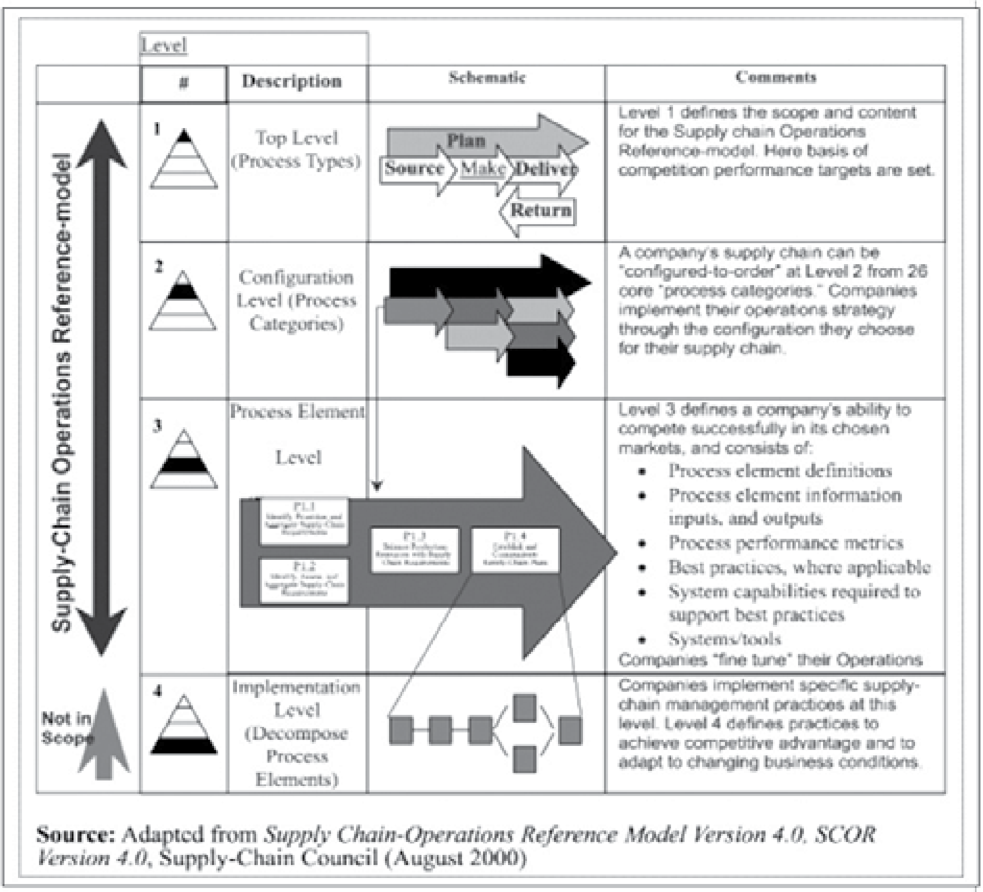

Exhibit 12. The SCOR model

4. Strategies for monitoring supply chain performance

Several approaches exist to transfer existing performance measurement issues into a supply chain context. For this, the objective of performance measurement would most accurately be defined as the *process of quantifying the efficiency and effectiveness of an action performed throughout the various layers and entities of the supply chain.* Based on this, the most common categorization of supply chain performance measures is into

1. *Service measures,* like cycle time, order fill rates, and perfect order;
2. *Cost measures,* like cost per order, logistics cost per unit, and cost per unit;
3. *Return on asset measures,* which measure the extent to which the capital tied up in the supply chain is earning the desired financial return;
4. *flexibility measures* which reflect the ability of the supply chain to respond to changing environments (e.g., range & response flexibility).

Performance measures may also be classified according to their strategic or operational usage (e.g. Soosay and Chapman 2006). For instance, strategic performance measures would comprise key metrics for leadership, strategic planning, human resource management, customer satisfaction, and process quality. Operational measures might include cost management, asset management, quality, productivity, and delivery issues. The metrics can be related to activities (“actions”) to be performed on the various levels within a supply chain relationship. In the level of direct inter-company activities, the metrics relate to the management of internal processes (e.g. internal cycle time, logistics-costs per company, etc.). On the level of relations which expand throughout the whole network, the focus would be on metrics for delivery time, cash to cash cycle time, etc. On the level which looks at the supply chain as an entity in itself, the metrics would relate to the cycle time in the whole chain, time to market, and flexibility within the chain.

4.1 Hierarchies of performance measures

From a strategic viewpoint, a performance measure “hierarchy” should be developed to concentrate on the relevant metrics for various classes of objectives (Hofman 2004). The *top-tier level* would deal with the purpose to "assess" supply chain performance and responsiveness, like demand forecast accuracy, perfect order fulfillment, and "SCM total costs". *The mid tier level* is built to "diagnose" identified strengths and weaknesses. It mainly deals with the measurement of the cash-to-cash cycle time and either supplier or customer payment time. The *ground level* provides measures that should enable the supply chain management control to "correct" identified weaknesses. Another approach would be to arrange the parameters along a classification of “tactical vs. strategic” and “internal vs. external”. This approach is pursued by IBM (Kleemann, Erling and Gräfe 2009). The concinnity of this arrangement in a coordinate system is visualized by Exhibit 13: All parameters are be sorted into one of the 4 quadrants, depending on which of the characterization fits best. E.g., if a parameter is very external oriented and strategic, it should be shown in the outer range of the upper right quadrant. If another parameter has a lower external and strategic impact, it should be shown closer to the center. In case any of the quadrants is empty after all parameters are entered, the area should be revised again to be sure it is either on purpose that there is no entrance or until the white spot area is filled.
The division into strategic and operational performance measures has been researched in field studies (Soosay & Chapman, 2006). They show that there is a disproportionate focus on costs (42%) over non-cost measures such as quality (28%), time (19%), flexibility (10%), and innovativeness (1%). Only a few measurement systems deal with activity-based cost and customer satisfaction. From there, we encounter three areas of deficiency:

- A lack of approaches which balance financial and non-financial measures.
- A lack of systems thinking, i. e. viewing at a supply chain as an entity in itself.
- A loss of the supply chain context which encourages sub-optimal outcomes by local optimization of each supply chain partner.

4.2 Inter-organizational metrics

Measures that relate to the entire supply chain must cross company boundaries. A set of metrics that fulfill this requirement would have to comprise service metrics, assets (inventory) metrics, and speed metrics as all these refer to the result of actions as specified above. At least one performance measure of these three dimensions should serve as “key indicator” (in addition to quality which may be often regarded as an issue that is separate from performance, see Hausmann 2003). Some metrics for the three dimensions

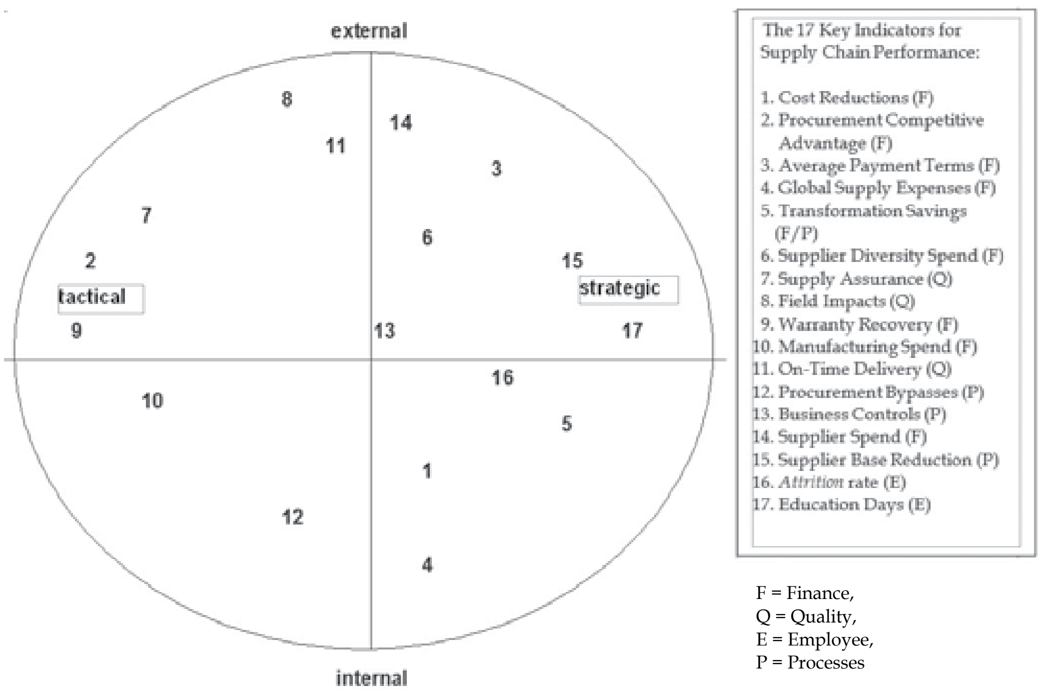

Exhibit 13. Positioning of SCM Performance Indicators. Source: Kleemann, Erling and Gräfe 2009.

service, assets (inventory) and speed will be listed below (from Paulitsch 2003). Otherwise, the measurement issue will not be covered here because it is operational and not strategic. But strategy formulation and strategy implementation is intrinsically conjoined with defining measurable targets:

Service Metrics: service metrics measure how well a supply chain serves its members. Since it is generally difficult to quantify costs of stock-outs or late deliveries, targets are usually set on member levels.

For service metrics, two different environments have to be accounted for: One is *"build-to-stock"*, and the other is *"build-to-order"*. Build-to-stock items are items that should be immediately available for purchase, (e.g. mechanical standard components), while for build-to-order the customer is willing to wait a certain time.

Some common service metrics for build-to-stock environments are:

- *Line-item-fill-rate* is the percentage of "lines" of all customer orders that are filled immediately.
- *Complete-order-fill-rate* is the percentage of which all lines of an order have been filled (the distinction between line item or complete order fill rate is important in case of a large number of lines per order).
- *Delivery process on time* is the percentage of the delivery processes that are on time. This metric is included - although it does not have a direct effect for the customer - because it is important for the (safety and cycle) inventory and subsequently for the cost of a product.

- *Costs of back-ordered/lost sales* are the costs of back-ordered and lost sales in a period.
- *Number of back orders* are the number of back orders in a period.
- *Aging of back orders* is the time it takes to fill a back order.

Some common service metrics for build-to-order environments are:

- *Quoted customer response time* (also *standard lead time)* is the time a customer is told to wait for order fulfillment.
- *Percentage on-time completion* is the percentage of orders completed on time.
- *Delivery process on time* is the percentage of the delivery processes on time.
- *Costs of late orders* are the costs that arise from late orders.
- *Number of late orders* are the number of late orders in a period.
- *Aging of late orders* is the time it takes to complete an order that is late.

Assets (= Inventory) Metrics[2]: these metrics measure the inventory involvement throughout the supply chain.

- *Monetary value* of the supply chain inventory (measured as an asset on the firm's balance sheet or as cost of goods sold per inventory value).
- *Turnover rates and "Time Supply".* The latter accounts for the time the supply chain can surf and relates to the inventory flow.

From a supply chain perspective, it is important to see these metrics in combination with the achieved service level the supply chain provides.

Speed Metrics: these are related to timeliness, speed, responsiveness, and flexibility.

- *Cycle (flow) time at a node* is the total time it takes to fulfill an order.
- *Supply chain cycle time* is the total time it would take to fulfill a new order if all upstream and in-house inventory levels were zero.
- *Cash conversion cycle* is the duration between paying for raw material or components and getting paid by the customers. An estimate of the cash flow conversion cycle is the sum of inventory and accounts receivable minus the accounts payable (measured in days of supply).
- *"Upside" flexibility* measures if demand is higher than forecasted, which is particularly interesting in high-tech industry. The metric refers to the requirement for a supplier to be prepared to deliver an additional percentage within specified time windows.

Paulitsch (2003), from whom we took this enumeration of metrics because it fits the practice very closely, does not mention the dimension of quality. For this, we will refer to a study by Mentzer, Flint, and Hult (2001). The study suggests that customers' perceptions of suppliers' service quality begin to form as soon as they try to place orders, and the perceptions develop until they receive complete and accurate shipments, in good condition, with all discrepancies addressed. When viewed as a process, suppliers can identify the drivers of various supplier service quality perceptions. The process view enables marketers to see the interrelationships among service quality components. Mentzer, Flint and Kent (2001) conceptualized and tested Logistics Service Quality (LSQ) as a second order construct, with nine dimensions:

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[2] Metrics that relate to fixed assets, like commonly used warehouses or software systems etc. are often neglected. They are an issue of partnership accounting which involves target setting investment, rules for cost- and profit sharing etc. (see Bardy 2006).

- Personnel Contact Quality (PQ),
- Order Release Quantities (OR),
- Information Quality (IQ),
- Ordering Procedures (OP),
- Order Accuracy (OA),
- Order Condition (OC),
- Order Quality (OQ),
- Order Discrepancy Handling (OD),
- Timeliness (TI).

Order placement

Receipt of shipment

As for the strategic perspective, Mentzer, Flint, and Hult (2001) found five parameters which influence the nine dimensions: „Commitment“ (info sharing and congruence of objectives), "Supplier development", "Conflict resolution mechanisms", "Logistics partner fit" and "Communication / joint projects". Even though numerical measures for these cannot be determined, and may sound theoretical, any practitioner will know how to rate the influence of these parameters.

4.3 Ascribing metrics and directing the data input

4.3.1 Another aspect of performance: The knowledge issue in sharing information

For any metric to be effective, two ingredients must be properly rendered: accurate definition and accurate capturing of data. This is where knowledge management comes into place: Mainstream research propositions suggest that it is three main attributes which enhance the capturing, organizing, and disseminating of knowledge throughout the aggregate of interactions between suppliers and clients (Desouza et al., 2003). Connectivity is the first attribute to allow the flow of knowledge. The second attribute is the communication of this knowledge in a fashion that allows all the users in the supply chain to make business decisions that maximize value while reducing costs and cycle times. The third attribute of supply chain knowledge management systems is the ability to collaborate in a real-time fashion, encouraging knowledge sharing and allowing the supply chain to adjust to market changes. In practice, this third attribute highly depends on how far higher management has got in establishing trust, power of decision-making and application skills on all levels from middle management down to the shop floor (Bardy 2010).

The performance metrics that have been pointed out in the previous section heavily depend on an appropriate data input. But data input itself is an issue of criteria fulfillment (we do not want to have "garbage out" from "garbage in"). So it becomes apparent that a two-way-definition of supply chain performance is needed: One way would refer to meeting the customer requirements, including product availability and on-time delivery ("downstream"), and the opposite way ("upstream") would refer to meeting the supplier expectations on data input and data handling. It is understood that the two-way performance is best if the mechanics of data exchange and the quality of information fully yield what both vendors and customers require for their day-to-day business. From there, the question arises if a better performance can be achieved by implementing more sophisticated tools for planning and co-ordination, or if there are other ingredients which affect the mechanics of data exchange and the quality of information. This shall be examined further on.

From the outset – definition and target setting – to the evaluation of results, the metrics to be chosen in a specific supply chain are the product of information sharing between the members. Even if a metric is applicable only on the level of one specific member, it will nevertheless have nevertheless to be communicated throughout the whole chain together with comments on its objectives and content. This would include inventory, sales, demand forecast, order status, product planning, logistics, production schedule, etc., and can be summarized as three types: product information, customer demand and transaction information, and inventory information. These are outlined in the next section.

4.3.2 Product information, demand and transaction information, inventory information

Product information*:* Going back to when exchange of product information among the supply chain partners was done by paperwork, such as paper catalogue, fax, etc., we had delays in information sharing and miscommunications among the trading partners. With today's IT-technology, entering the product information into an information system, a supply chain member still has to check on the data, which may or may not come along with the product, for consistency and accurateness. Keeping the data updated is an additional task. For example, if some information has been changed since its last release, all the supply chain members retailers in the industry have to check the data individually. According to UCCnet[3] (Trost 2009), 30 % of data exchanged between suppliers and retailers doesn't match up due to the inefficiencies of manual data entry and convoluted processes. This is an enormous problem for the industry, because incorrect data translates into an erroneous understanding of what retailers actually have on their shelves and what suppliers actually have in their warehouses. This means that often data have to go through a long-winded manual, error-prone procedure before being re-entered into the IT systems.

Customer Demand and Transaction Information*:* Customer demand and transaction information is as a critical source of information about future business. It is here that the advantages of working with a CFPR standard enables supply chain members to forecast demand and schedule production jointly and on a rolling forecast scheme. Capacity planning, labor availability planning and related activities are all dependent on exact and reliable data inputs for customer demand throughout the levels of a supply chain.

Inventory information: Deploying inventory status and inventory decision models in a network directly affects the amount of orders placed to the upper stream supply chain partners. Often, trading partners are less willing to share inventory information than customer demand and transaction information. So, manufacturers may not only be unwilling to divulge their true inventory situation but even portray false inventory levels to discourage competitors from building additional capacities. They may fear that customers may use inventory and sales data to get a better bargaining leverage. But when trading partners convene to share a vendor-managed inventory facilitation, they must be absolutely sure of trustworthy data, because in a vendor-managed inventory system it is the manufacturer who generates the purchase order, not the customer.

Subscribing to a supply network, thus, obligates the member to feed a broad array of reliable information and resources into that network. But there is more: Forming a partnership with its suppliers and/or customers may mean for the entrant to change jobs and job descriptions. One the other hand, a division of work to be established with regard to evaluating and handling inventories, systems, processes, new technologies, training, work methodologies, equipment utilization, etc. may also provide access to procedural resources

[3]UCCnet, a non-profit subsidiary of the Uniform Code Council, is a standards organization that provides an Internet-based supply chain management data registry service.

like, e.g., instruments for preparing strategic decisions that will be exhibited in the next section.

4.4 Strategic instruments: balanced sorecard, activity based management, target costing, total cost of ownership

4.4.1 Supply chain balanced scorecard

The balanced scorecard (BSC) connects strategic objectives with operational metrics, both financial and non financial, for the traditional financial and three further perspectives. This was shown in section 1.4. Adaptations of this concept have been made to the supply chain context to capture its inter-organizational complexity. This can be done by either replacing the perspectives by new ones or by adding more perspectives. In any one of these perspectives, objectives ("goals") must be set. As per the following exhibit, each of the goals is to be expressed in a strategy:

Exhibit 14. Six perspectives of a BSC: Drivers and Stakeholders. From: http://www.fin.gov.on.ca/en/bpssupplychain/documents/perf_meas_framework.html

Subsequently, numerical targets must be set for each of the goals. The organization will thus not only be able to monitor how a strategy performs, the BSC technique will also enable it to promote organizational effectiveness (Chia, Goh and Sin-Hoon Hum 2009).

An example for an additional supply chain perspective in a BSC would be *partnership management* and *management of information flows* expressed in a cooperation perspective. This is shown in the following Exhibit. The table shown in the upper right with "Objectives", "Metrics", "Benchmarks" (= Targets) and "Initiatives" applies to all perspectives. For the cooperations perspective, one of the objectives might be "Improve Order Accuracy!", the metric would be "Number of order queries", the target would be "Reduce by 50 %!" with the corresponding initiative being "Elaborate new order entry system together with suppliers". This example might look simple, and practice has shown that the most prominent obstacle for the implementation of a BSC throughout a supply chain may be the simple fact that the supply chain partners' individual goals and objectives cannot be integrated into one BSC. Still, Supply-Chain BSCs have been reported to be in use e.g. in the automotive sector for the tire business and in the chemicals sector (Zimmermann 2005).

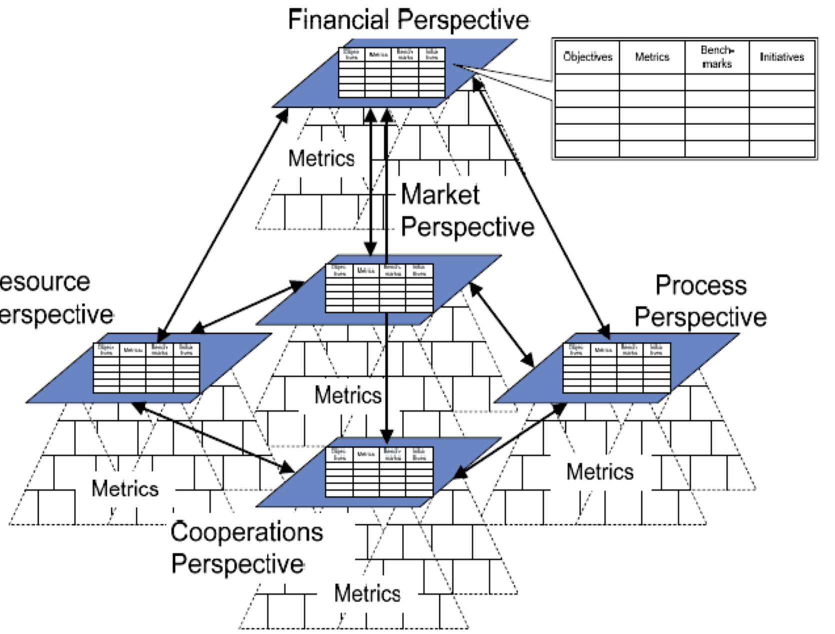

Exhibit 14. Adding a co-operations perspective to the BSC. Source: Von Haaren and Malyshko 2007.

4.2.2 Activity-based management and target costing in supply chains

As with the BSC, activity-based costing (ABC) seems to lend itself easily to a supply chain environment as it focuses on activities and processes (for a general overview and recent developments see Gosselin 2007). Transferring the ABC method into the processes and collaborative activities of a supply chain would mainly lead to optimization through analyzing process structures, identifying and eliminating redundant activities and pointing at alternative channels and sourcing structures. However, the ABC method is not strongly supported by practitioners because it involves a considerable amount of time-consuming groundwork, and there are many pitfalls and caveats (Bardy and Hartgraves 2002). Still, a well-focused effort that is restricted to previously identified problem areas will definitely achieve a result. And, when used as a strategic tool for preparing decisions e.g. on how to deal with redundant activities, ABC comes closer to activity based management as it avoids the setbacks caused by implementing routine activity cost reporting. Furthermore, ABC in its strategic adoption, can easily be combined with target costing. First implemented in Japanese firms, the target costing approach uses collaborative principles to establish a cost target that is connected with the desired functional outcome of the cost object, breaks down the cost target into its components and finally optimizes both outcome and cost. Transferring this into the supply chain environment would firstly connect to customer requirements and consider product- or service-functionalities. Suppliers are often involved in target costing projects, however, sometimes only as recipients of rationalization targets set by a focal company. From there, depending on the relationship with the supply chain partners, a wider approach of target costing seems feasible. In line with this, special inter-organizational cost management initiatives should also be implemented (see below).

The core concept of target costing is very straightforward. It is based on the logic that a company should manufacture the products that yield the desired profit. If the product is not yielding the desired amount of profit, the design of the product should be changed to obtain the desired profit. The design issue incorporates early supplier involvement, beginning, mostly, in the research and development phase. This is where the concept of “strategic purchase” comes in: The procurement function is to be included at this stage of buyer-supplier relations already. By including R&D in the scope of supply chain management, cost, quality and time objectives can be affected positively and with a lead-time that enables well founded decision-making. Up on that, the involvement of supply chain partners allows companies to connect heterogeneous sources of expertise. However, this type of collaboration involves risks of unintended leakage of knowledge and competencies, since the range of inter-organizational activities is broadened. This can certainly be avoided by all sorts of secrecy agreements, but, from a strategic point of view, the first choice would be to determine where to position the type of inter-company relations to be chosen.

The *following* graph (Source: Schmidt 2010) illustrates that there are nine basic options of combining “make”, “cooperate” and “buy” in R&D and in, e.g., manufacturing (with all feasible analogies in service providing etc.).

The unintended leakage as specified above will occur if the decision is made to opt out of the position that has been in use so far. Thus, if a corporation within an existing supply chain switches either to "make" (quadrants 1-3) by terminating a long term contract with a supplier in favor of an in-house production or to "buy" (quadrants 7-9) by introducing an independent supplier on the basis of a short term contract, the cooperative relationships in the supply chain will run the risk of being decomposed and knowledge will start to leak.

The leakage-risk is mitigated if the pertinent decisions encompass two classes of safeguards: One relates to the “secrecy agreement” issue mentioned above (legal protection rights and contractual agreements), the other one relates to mechanisms which factually prevent an unintended knowledge transfer. The major device here would be to prevent that an imitator does not get an opportunity for product modification. Teece (1986) gives the example of microelectronics, where selecting designs is dictated by the need to meet certain compatibility standards so that new hardware can interface with existing applications software, and designs become locked in when the circuitry is chosen. Product modification is then limited to debugging or software modification. In industries with large developmental and prototyping costs and hence significant irreversibilities, one would expect that the probability that the imitator would commit a substantial amount of capital to build the same structure anew is low. Another factual device to prevent imitators from using wrongfully appropriated knowledge would be to heavily control the specialized assets of the overall business such as distribution channels, specialized manufacturing capacity. No efforts should be made to protect generalized equipment and skills, since they are, almost by definition, available in an industry at all times (Teece 1986).

R&D / Manufacturing	**Make (internal R&D)**	**Cooperate (vertically, horizontally)**	**Buy (external R&D)**
Make	Internal R&D and in-house production 1	R&D cooperation and in-house production 2	External R&D and in-house production 3
Cooperate (vertically)	Internal R&D and cooperative supply chain relationships 4	R&D cooperation (with supply partners or others); cooperative supply chain relations 5	External R&D (by supply partners or others); cooperative supply chain relations 6
Buy	Internal R&D and pure supply relations 7	R&D cooperation and external procurement 8	Both R&D and procu-rement are external 9

Exhibit 15. R&D and manufacturing cooperation choices. Source: Schmidt 2010.

4.2.3 Inter-organizational cost management and total cost of ownership (TCO)

The concept of supply chain costing or inter-organizational cost management (IOCM) can be seen as an extension of traditional cost management, adding the notion of information asymmetries as it eliminates differences in access to data and to data analyses. It is thus based on the transaction cost economics (TCE) approach (see section 3.3.5). But while TCE looks for the lower of cost of either network- or standalone conditions, the main objective of IOCM is to find ways to reduce costs which are beyond the own companies' boundaries; for this, cooperative actions of the supply chain members are needed. In conclusion, the IOCM approach extends the scope beyond the boundaries of a firm towards synchronized processes and similar definitions of process steps and key performance indicators (KPIs) across the supply chain. The prerequisite for this is coordination and cooperation and the willingness of sharing the relevant data. Inter-organizational cost management systems, in this way, contribute to several supply chain management issues: (1) they provide support for the implementation of inter-organizational teams, (2) they allow the negotiation of modifications within product and process specifications along the supply chain to reach cost objectives, and (3) they support in identifying ways to make the relations between the supply chain partners more efficient and to help members to improve their cost structures.

Conducting IOCM-practices requires profound knowledge about internal processes in a member firm and partner-specific processes. The pertinent analysis can be handled with the help of value chain analysis approaches which deliver maps that reflect the process-structure of the supply chain. Based on that, an inter-firm planning system must be configured. This must be supported by what has been called "open-book accounting", i.e. complete cost transparency for all the members of the network (see. e.g., Mouritsen, Hansen and Hansen 2001). This creates new space for cost management within a supply chain, as more information from each of the supply chain members can be taken into account during the planning procedures.

Some of the techniques associated with IOCM would be easily recognized as an inter-organizational application of traditional internal cost management practices (e.g. budgeting and performance, investment appraisal, target costing, and open book accounting), while other techniques may not be related to conventional management accounting, like target costing, kaizen costing and total cost of ownership studies. However, all of the IOCM techniques are similar in that they are cooperative activities that have a common goal to create value for all partner firms through modification of interorganizational cost structures. For organizations to engage in IOCM activities, a set of institutional and dynamic capabilities are required (Fayard, Lee, Eitsch and Kettinger 2006):

a. the organization's information technology integration (electronic integration among supply chain members),
b. the organization's existing internal cost management capabilities and practices, and
c. the management's inter-organizational absorptive capacity (i.e. the ability to acquire, assimilate, transform, and exploit knowledge in order to create and utilize organizational capability).

In other words, the organization should be nearing the state of the art in accounting and EDP, and managers should be willing to learn and to cooperate.

The remainder of this paragraph will focus on kaizen costing and total cost of ownership (TCO) since the other instruments have already been dealt with. Kaizen costing is similar to target costing in that both techniques aim at cost reduction, but while target costing focuses on the design and development phases of a product, kaizen costing is used to reduce costs in the manufacturing and delivery phases. Originating from quality improvement practices in Japanese firms, kaizen costing is a system of incremental and continuous cost reductions of the product manufacturing process. So, other than target costing, kaizen costing may be deemed to be short term and more operational than strategic. But the mere decision to involve supply chain partners into target or kaizen costing initiatives is of strategic importance as it determines the structure of interrelations in a supply network.

The principle of TCO has impacted commercial negotiations by expanding the narrow confines of price to a larger field of opportunities for attaining win-win results in a buyer-supplier relation. Simply put by a consultant: "Anyone can get a lower price". The object of business is to attain the lowest TCO" (Menard, 2010). It is definitely true that good negotiation will contribute to attain a low TCO, as all purchase officers will know. They have been trained to conceive cost as being constituted by Quality, Service, Delivery and Price, so TCO would be the sum of those cost elements, or TCO = Quality + Service + Delivery + Price. And negotiation practices should follow along this line. Another approach would be to set out from an internal perspective like inventory costs, where each of the elements (holding cost, damage cost, cost of obsolescence, handling cost etc.) is susceptible to be influenced by a prudent buyer-supplier relation, or to set out from life-cycle analyses where TCO is the sum of acquisition cost and lifecycle cost like maintenance, spare parts and discharging cost. There are some strategic constituents in all these considerations: One is about long-term supplier selection, another one is about choosing the format of contracts, impact ("Does it make sense to analyze the cost of a cow farm if I only want a glass of milk?"). What is meant here can be illustrated by the following graph (Exhibit 16). The (strategic) decisions to be made relate to the extent of analyses and of supplier negotiations, regarding the phase and the level in which cost improvements can be sought (acquisition, reception, etc. phase and supplier, product etc. level.). This will provide a framework for how TCO should be deployed.

Similar frameworks like the one for how TCO should be deployed are also useful for the other strategic instruments: Target and kaizen costing, for example, will as well require a set of pre-conditions; otherwise the "cost of cost saving" may get too high.

		Acquisition	Reception	Possession	Utilization	Elimination	Total Cost
Supplier Level	Cash						Σ Level 1
	Non cash	Quotation Contract Follow-up Change					
Product Level	Cash				Replacement		Σ Level 2
	Non cash				Personnel training Adaptions		
Order Level	Cash		Transportation				Σ Level 3
	Non cash	Order	Reception Invoicing Litigation				
Product Order Level	Cash						Σ Level 4
	Non cash		Quantity test Quality test				
Unit Level	Cash	Price and discounts Price evolution Payment delay			Intrinsic efficiency	Waste valorization	Σ Level 5
	Non cash	Service cost Product testing		Inventory holding	Production failure Product failure Maintenance Installation Quality control		
							TCO

Exhibit 16. A TCO Decision-Matrix. Source: Degraeve, Labro and Roodhooft, 2005.

5. Risk management and business continuity planning

The interdependence of all members which is a constitutive characteristic of a supply chain provides an array of chances, as was exposed in this chapter, but it also bears risks – from small operational accidents that may occur at any level of the various tiers to a catastrophic breakdown throughout the whole supply chain. Exhibit 17 on the following page depicts the areas of risk (analysis), the types of risk and the instruments of risk and business continuity management. The “Unit of Analysis” axis in the graph demonstrates where risks may occur. The risk avoidance strategies are shown in the vertical axis, and from there one may guess how far the measures could go. Displaying all the possibilities would definitely exceed the limits of this chapter. So much can be said: What is required is a well-orchestrated and harmonized common risk management strategy (which will very often be difficult to reach because of varying interest and powers within the partnerships). We will constrain ourselves to an observation that is not covered by the graph:

One risk avoiding strategy would certainly be to reduce the number of the supply chain members. This would also reduce the cost of coordination (which stem from complexity; see section 3.3.3 above). But this approach is ambiguous. Limiting the partnership to a few efficiently connected "value partners" can end up in unintended dependencies and risks. Up to the logistical risk of replenishment, there is the risk of loosing the control on purchasing prices as they are dictated from the (powerful) tier two-supplier who himself skims the market and gains competitive advantage. The leverage effect of purchase prices on the overall company performance is a menacing indication of the limitation that might result from this strategy. So alternative strategies have to be evaluated. This would mostly lead to an asymmetric strategy, where the buying company takes the lead by using a supplier relationship management platform. So instead of symmetric equal-level-cooperation, the buyer asymmetrically selects, defines and implements its concepts of collaboration per partner.

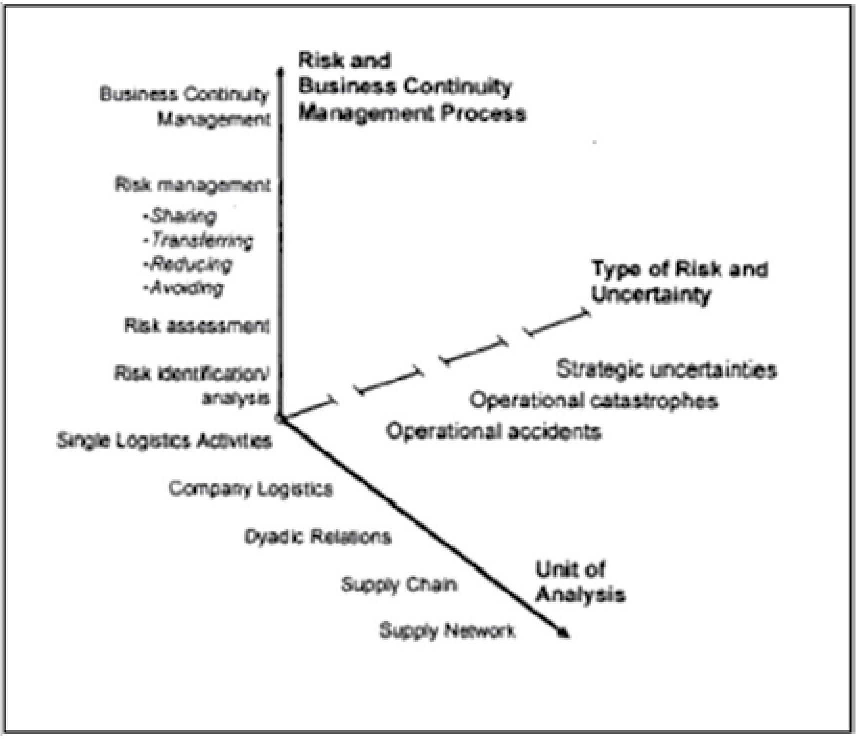

Exhibit 17. The three dimensions of supply chain risk management. From Norrman and Lindroth, 2004.

This type of riskavoidance has led to quite a few supplier-relationship management platforms, e.g. in the automotive industry, and there is wide support for this from application service providers like SAP, Cascade Works or Actuate. They provide IT-support for supplier selection, performance management, relationship management and collaborative management, among others, but the decisions are made by the lead-firm which thus dominates the mode of collaboration with a large number of network partners (Ortner and Schweiger 2010).

6. Summary and conclusion

Procurement strategies in a supply network must above all aim at stable and long-term partnerships, standardisation, consolidation of the procurement volume, assurance of supplies based on re-positioning after disruptions and well-balanced procurement procedures. Determinants will be procurement market complexity and the strategies‘

influence on product success. Total cost orientation, functional integration and a harmonized and reliable flow of information are the prime ingredients.

To conclude, here are five best-practice recommendations given by John Evans, Managing Partner with Denali Group, who has has consulted in the supply chain and strategic procurement space since 1989, beginning with A.T. Kearney:

1. Use of a single, consistent and formal savings tracking methodology, based on total cost of ownership (TCO).
2. Formation of a cross-functional financial steering group comprised of financial representatives from impacted organizations that review, approve and make budgetary reductions for all supply chain improvement initiatives.
3. Expansion of the roles of strategic sourcing and supply chain improvement project teams beyond an analysis- and recommendation-role into implementation responsibilities.
4. Utilization of broad unit-based cost metrics, balanced by service and quality metrics, to track savings at the spend category and initiative level.
5. Linkage of savings realization targets to supply chain departmental goals and personal development plans.

Improving corporate financial performance is certainly not the only strategic role for supply chain organizations, but it is inarguably a very important one. Most corporate supply chain organizations have the ability to impact 50 to 70 percent of their corporation's total cost structure, so creating a model that can optimize this lever is critical to any supply chain organization's success. The biggest obstacles to achieving optimized supply chain management solutions are traditional mindsets concerning buyer-supplier relationships. When these are overcome, and the partners have cost-effectively established the required information systems networks between different organizations, performance will increase. Those companies and organizations that succeed in achieving this level of supply chain integration will be richly rewarded. Those that do not will get the crumbs (Metz 1998).

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Part 2

The Role of Cooperative Relationships

6

Collaboration and Exceptions Management in the Supply Chain

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1. Introduction

A supply chain is a network of companies that performs the functions of procurement of materials, transformation of these materials into intermediate and finished products, and the distribution of these finished products to customers. Over the past few decades companies have been forced to react to a multitude of changing market dynamics:

- The increasing size of companies for attending global markets results in complex, longer and costly logistics infrastructures.
- The trend towards outsourcing and off-shoring has caused a fragmentation of the supply chain.
- Globalization means companies will have to face global managerial risks: financial crisis, environmental tsunamis, political risks, terrorist attacks.
- Environmental sustainability is a key consideration in the development of future globalization strategies.

To sum up, a company is no more going to behave like an island. All companies are interconnected and the final service to the customer is the result of the participation of a set of companies. Therefore, it is necessary to adopt a holistic view in order to make good decisions.

The objective of Supply Chain Management (SCM) is managing the entire flow of information, materials and services from raw materials suppliers through factories and warehouses to the end customer (Burt et al., 2002). SCM adds value to the customer when inventory is correctly positioned, thus facilitating sales. Besides, it helps organizations to build a suitable balance between differentiation through superior customer service and cost (Christopher, 2005).

In order to manage a supply chain in a successful way, it is necessary to reduce both lead times and inventory levels, since they contribute to increase the global cost of the supply chain and harm customer service. Moreover, any delays related to a mismatch between supply and demand may cause excess of inventories and stock-outs that must be avoided. Demand variations and possible supply problems are inevitable, so it is necessary to ensure that the supply chain is responsive and flexible. Therefore, a fluent information exchange and collaboration between members of the supply chain is desirable. SCM is intrinsically linked to collaboration: not only material, information, or money flows must be managed, but also relationships that are located both upstream and downstream the chain.

The purpose of this chapter is to provide an approach for collaborative dynamic scheduling that tries to coordinate different echelons of the supply chain in order to reduce inventory, backorders and ensure production orders visibility to the customer. This approach handles exceptions that could invalidate a production plan using a wide perspective to include suppliers and customers so as to obtain feasible and optimized plans, as well as better customer service. Therefore, it analyzes the implications of disruptions affecting production schedules that occur at a certain point of the supply chain for other nodes and takes proper actions to minimize the effects.

2. Literature review

Considering the volatility of market dynamics, it is paramount that supply chains are agile in order to provide a fast response to changes. A key aspect of agile supply chains is a fast information exchange across the enterprise networks. Besides, the visibility of demand changes and disruptions throughout the supply chain is crucial if we want to obtain effective and efficient solutions.

As regards commercial solutions, Manufacturing Resource Planning (MRP II)/Enterprise Resource Planning (ERP) systems are recognized as successful solutions to integrate different functions of a company, e.g. production, purchasing, sales, accounting, etc. But at the same time, they are focused internally and do not support information exchange, let alone collaboration with either suppliers or customers. Later on, the so-called Advanced Planning Systems (APS) appeared to avoid some limitations of the MRP II/ERP systems such as infinite capacity or fixed lead times. The APS systems provide a centralized management of the supply chain activities and processes in real time. In recent years, the ERP II concept emerged in order to support the idea of integrating both internal and external business processes, enabling a direct data interchange between companies. But most commercial solutions have an important limitation, i.e. they are not affordable for SMEs.

The basic operational problem that causes disruptions in the supply chain is the difficulty to match supply and demand. On the demand side, changes may derive into excess of inventories and stock-outs. Unplanned demand oscillation can cause distortions in the supply chain when the different nodes do not interchange information. These distortions are commonly known as the "bullwhip effect" (Forrester, 1961). This effect has been extensively analyzed and has been a key issue of many scientific publications due to the negative implications it has in terms of excess of inventory, shipping cost increase and quality problems. There is a common agreement that information sharing is a crucial factor in order to obtain global benefits in the supply chain level. Therefore, a fluent flow of information throughout the supply chain is necessary. The CPFR model offers a general framework by which a buyer and a seller can use collaborative planning, forecasting and replenishing processes in order to meet customer demand. Buyers and sellers are involved in four collaboration activities: Strategy and planning, Demand and Supply Management, Execution and Analysis.

On the supply side, late deliveries and quality problems often incur an interruption of the manufacturing processes. In order to implement the just-in-time philosophy (JIT), new collaboration concepts arose such as vendor-managed inventory (VMI) where orders disappear and vendors have access to real demand information, thus reducing costs and enhancing service. This means that the supply network must be responsive to these demand and supply variations (Hu, 2010).

Furthermore, the so-called CO-OPERATE project (Azevedo et al., 2005) aims at improving the overall goal of the supply chain by creating a communication infrastructure between companies. This infrastructure enables a collaborative production planning, multi sourcing coordination, process visibility and exception handling reducing the "bullwhip" effect thanks to information sharing. But some authors (Viswanathan et al., 2007) showed, that in order to enjoy the full benefits of collaboration, practitioners should focus more on synchronization than just on information visibility. Therefore, the SCOR and CPFR models provide suitable tools to reduce the bullwhip effect and best meet customer demand. Besides, the CO-OPERATE project enables collaborative production planning and exception handling by means of a common information infrastructure in the supply chain. But despite all the contributions in this research area, there is a lack of studies that focus on synchronizing local scheduling solutions in real time in order to improve the decision-making processes.

2.1 Problem scope

Managing information in an inter-organizational context has become critical and it is necessary not only to exchange information but to synchronize the production plans at the different echelons of the SC.

The system works with the following assumptions:

- Information is only exchanged with immediate suppliers and customers, this means that a basic supply chain will be considered rather than an extended one (Hugos, 2006).
- The company has several plants that are independent in the sense that they are not connected through assembly operations. But they have alternate resources at different plants that can opportunistically be used in case of unavailability problems. In Fig. 1, a representation of the entities included in our research is shown.

The control system is distributed and decisions are made at each node but taking into consideration information exchanged with other nodes. This means that each plant will

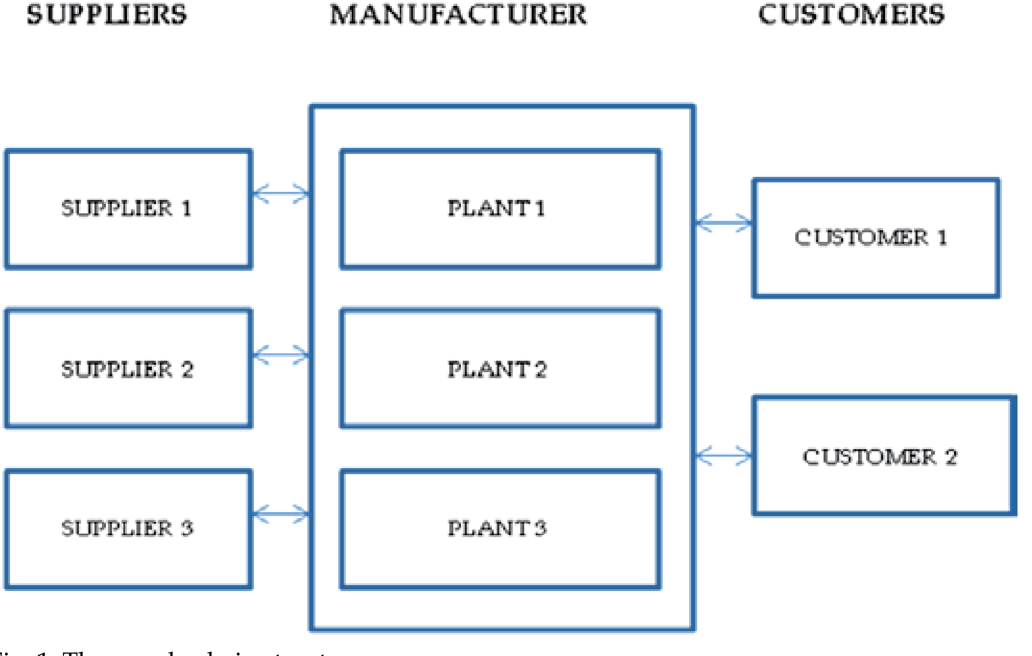

Fig. 1. The supply chain structure

be autonomous as regards decision making in terms of production management but, at the same time, will take advantage of information coming from other nodes in order to allow a dynamic collaboration and a better global solution.

2.2 Description of the model

The model of the industrial factory that has been selected for our research corresponds to a discrete manufacturing environment that is often subject to disruptions. An entity-relationship semantic model has been used in order to represent the elements of the industrial factory.

The main components of the database are the following (Álvarez & Diaz, 2010):

1. *Plant*. The company can have several plants. Each production plant has its own production schedule that has been generated independently.
2. *Reference*. A product reference is related to an end product that can be manufactured at a specific plant. Some attributes of the product reference are the code, batch size, cost and unitary manufacturing time.
3. *Work order*. It is related to the orders the system has and refers to only one reference, for which there can exist one or more process plans.
4. *Material*. Each reference needs a set of raw materials that must be transformed into end products (references).
5. *Operation*. The operation types are the different possible operations that can be performed by the machines of the plant. Besides, each machine can perform several operations at different individual speeds.
6. *Characteristic*. They are related to the possible product features of the company. In addition to that, they define the sequence-dependent set-up times.
7. *Customer*. Entity that receives the end products of the company.
8. *Supplier*. Entity that provides materials to manufacture end products of the company.
9. *Operator*. Human being that is in charge of executing jobs at a plant.

3. Software architecture

It is very important to preserve the necessary level of autonomy of each node when they belong to different companies. Therefore, we consider that a distributed approach is more suitable than a centralized one, where the exceptions that occur at a certain node can be solved in a collaborative way with other nodes of the network.

Most decentralized planning solutions use agent-based models. An agent is a software system that communicates with others in order to solve a problem that exceeds the capacity of each individual software module. Agent-based technology is considered a suitable approach for the development of distributed planning and scheduling systems (Hao et al., 2006). Lu et al. (2005) propose a collaborative production framework based on agents, where production orders, subassemblies, production lines and cells are represented as agents that interact among them in a collaborative way. A supply chain is composed of several agents, such as vendors, wholesalers, manufacturers, retailers and customers. These agents must share information and coordinate the physical execution of their operations to ensure a smooth flow of materials, services, information, and cash through the chain.

The general framework of the system is based on a decentralized multi-agent architecture that will be used in order to coordinate the different production plans, where each agent will represent a node of the supply chain. Production will be scheduled at each plant, independently from other nodes. But when exceptions arise, other nodes will also be at stake. For example, when new orders arrive at a plant and there are not enough raw materials available at that plant to manufacture them, the affected node will ask for materials to one or several suppliers, which might have to communicate with their own suppliers. Whenever an exception arises, the affected node will reschedule all the affected operations taking into account the capacity available at the active production schedule and will also check the feasibility of the solution externally. The solution will then be transmitted to the customer who generated the new order. Possible interactions between nodes of the supply chain will be analyzed and relevant information will be communicated to the affected ones.

In fig. 2 the software architecture with all the modules of the system is shown, as well as the relationships among them. The modules are the following: Data Capture (DC), Internal Events Manager (IEM), Plant Scheduler (PS), Suppliers Module (SM), Customers Module (CM), Plants Coordinator (PC) and Events Monitoring and Management (EMM). The exchange of information among agents is mainly represented by three subsystems of information: (i) a communication subsystem inside the plants (IEM module), which will manage the unforeseen events that may lead to a rescheduling of part or the entire production plan, (ii) an inter-plants communication subsystem (PC module), which will manage the events produced in a plant that may affect other plants and (iii) a supply chain communication subsystem (EMM module), which will manage events occurred in a plant that can affect suppliers and/or customers (Álvarez & Díaz, 2011).

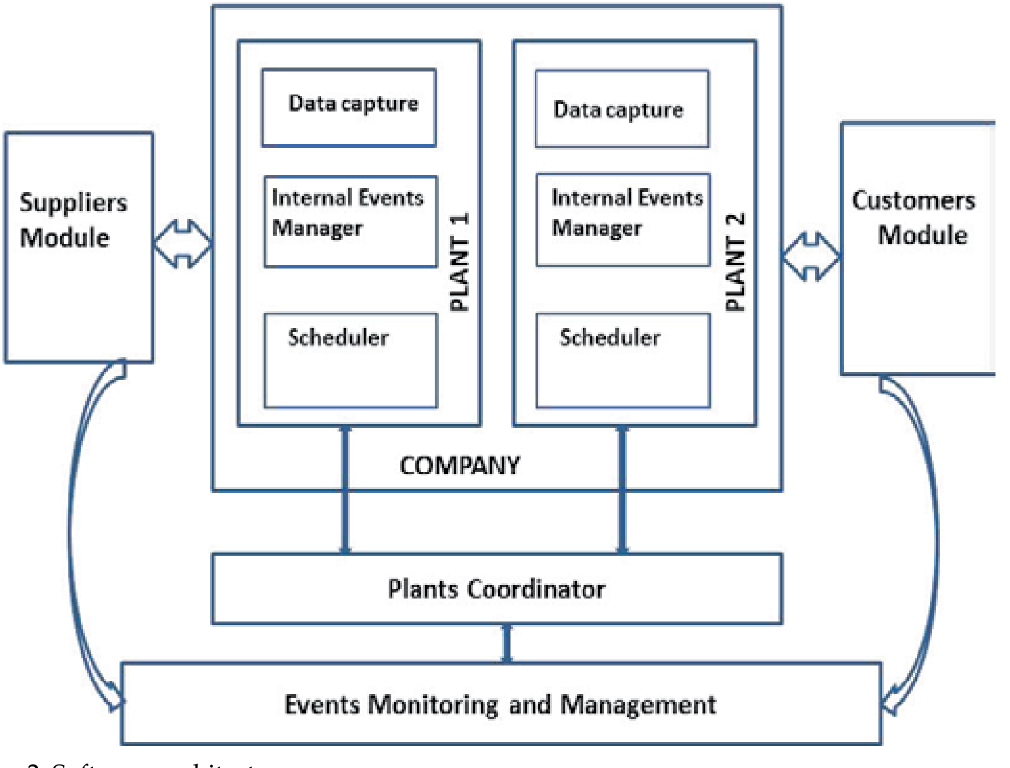

Fig. 2. Software architecture.

4. Exceptions

Exceptions can be classified into two main groups: internal and external. The latter can also be divided into two subgroups: exceptions related to customers and exceptions related to suppliers (see table 1).

Exceptions		
Internal	External	
	Related to customers	Related to suppliers
Repeat parts Machine failure Machine recovery Material shortage Arrival of material Absence of operator Presence of operator	Shortening due date Extension of due date New urgent order Order quantity increase Order quantity reduction Order cancellation	Return of materials Partial materials delivery Delayed delivery Defective delivery Cancelled delivery

Table 1. Types of exceptions

4.1 Internal exceptions

Main internal exceptions are related to the availability of machines, operators and auxiliary resources, as well as quality related events. If an exception occurs at a shop floor, the affected operations at the current production schedule will be identified and the feasibility of the solution will be verified. Nevertheless, these internal exceptions can generate external exceptions if they affect either suppliers or customers. These exceptions will contribute to synchronize and optimize the entire supply chain.

Here is a list of all the possible internal exceptions that are going to be managed by the system:

- *Repeat parts*: whenever there is a quality reject that can be repaired through reprocessing, the user will introduce this event.
- *Machine breakdown*: this event can be manually introduced through the user interface, or automatically by the shop floor Data Capture module, and will allow the system to know that this machine is out of order. Besides, if possible, an estimated duration of the unavailability interval will be input to the system.
- *Machine recovery*: this is the opposite event of the previous one, informing the system that the broken-down machine has been repaired and is fully operative again.
- *Material shortage*: through this option, the user can specify a single lack of material affecting only one order, or a global lack of material affecting each order consuming that material.
- *Arrival of material*: this is the opposite event of the previous one, meaning that the orders affected by the material shortage can be processed.
- *Absence of operator*: this event informs about an unexpected temporary absence of a needed operator.
- *Presence of operator*: this is the opposite event of the previous one, meaning that the absent operator is available again.

4.1.1 Absence of operator

The absence of operator event is handled according to the process described in fig. 3. When the Data Capture module of a plant detects that an operator is missing, the Internal Events

Manager module will calculate the percentage of operations affected, and based on that percentage it will assess the severity of the event.

If the absence of the operator is not serious, the event will finish. Otherwise, this module must check whether there are other operators in the plant that could replace him/her. Sometimes, in multi-plant environments, it may happen that some operators work in different plants (e.g., one week in one of them and the next week in another). When this kind of situations happens, we should look at the possibility that an absent operator is replaced by another that is working at the same plant or at a different one on condition that

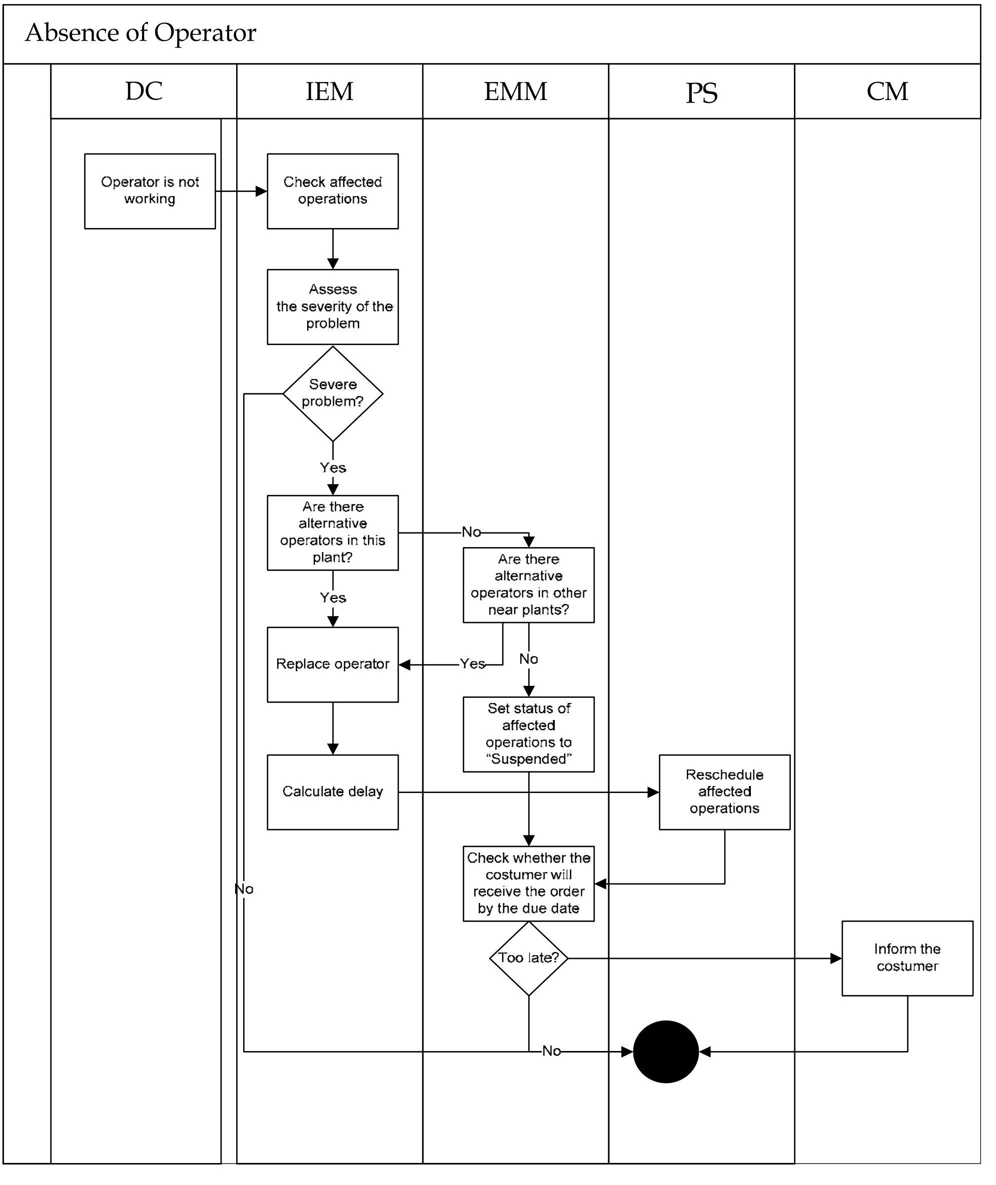

Fig. 3. Flowchart of an unexpected absence of operator event.

he/she has enough time to travel from one plant to the other and to make these operations.This event could launch a re-planning process, caused by an operator who is not in his/her place. The field Available_Flag, in the table OPERATOR, indicates the availability or not of and operator in real time. When a non-programmed unavailability of an operator happens, this flag would be set to 'N'. This means that it would not be possible to consider any operator whose flag is 'N'.

In principle, since every plant is going to have a scheduler (PS), it will be necessary to determine the compatibility between machines and operators. So, if an operator is free during a certain period of time and is compatible with the machines that must be used for the affected operations, he/she will have to move through the plant or even to come from another plant. In this case, we should also consider an estimation of the travelling time between plants.

In order to see whether there are other operators available, it is necessary to search for workers that could operate that machine and are free. If so, the operator will be replaced, else the same search will be done in other plants. If there are no operators available in any plant, the flag of the affected operations will be set to "Pending" until the operator returns to his/her place.

Finally, the Event Manager Module will check whether the modification of the plan affects the client, mostly because of the delays. If so, the client will be informed about that modification, otherwise the event will finish (dot symbol).

4.2 Exceptions related to suppliers

Here is a list of possible exceptions that are generated at the suppliers' side:

- *Return of materials*: If the supplier has delivered defective parts that are detected during the manufacturing process, the affected batches will be taken away.
- *Partial materials delivery*: It means that the supplier is not able to deliver the total amount requested, but just a part of it. Problems will arise if there is not enough level of on-hand inventory to replace it.
- *Delayed delivery*. It means that the supplier informs the company that a certain order will arrive late. An explanation of how this event is handled by the system is provided in the next section.
- *Defective delivery*. A supplier detects a defective lot once it has already reached the customer.
- *Cancelled delivery*. This means that a supplier is not be able to make a delivery at all, not even partial. This may imply that some manufacturing orders cannot be produced due to lack of materials.

4.2.1 Delayed delivery

The process associated to a delayed delivery event is described in fig. 4. Firstly, the Internal Event Manager module will change the order status as "delayed" by modifying that field of the database. Then, the level of inventory will be checked. If there is enough inventory to compensate for this delay, the event will end (dot symbol). Otherwise, the Internal Event Manager module will check whether the event is severe or not, considering the delay interval indicated by the provider and the impact on the current production schedule. If the impact is small, the plan will be changed and the event will finish (dot symbol). Then, if this change affects any order, the affected clients will be informed. However, if the impact is big,

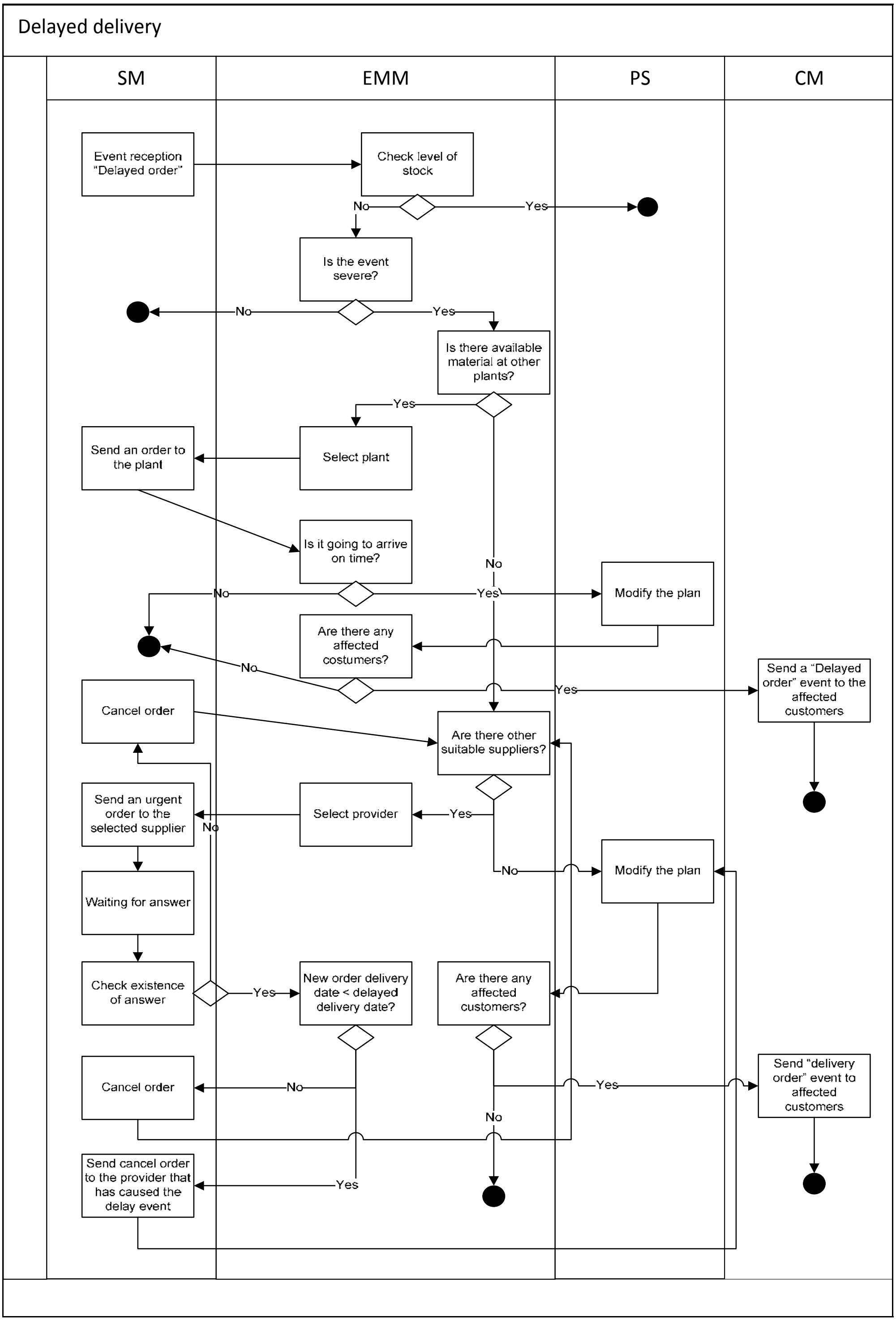

Fig. 4. Flowchart of a delayed delivery event.

the module must check in the database whether any other plant has the materials that are needed. If so, a request will be sent to the plant that is going to provide the material.
If the estimated arrival date of the material (to do that, the matrix of distances between plants must be checked) is earlier than the date of the first operation affected by the delayed order the event will finish. Else, the plan must be modified and customers must be informed by sending to them a "Delayed order" event and then the process will finish. In case the raw materials cannot be moved from another plant, a negotiation process with the suppliers will start, following a repetitive structure. Firstly, the table Material Provider of the database will be checked, regardless of which supplier generated the exception that is being handled. Then, the most suitable provider will be selected, if there exists one.
Since the system will be working in real-time, when it is necessary to search for a different supplier, only a small set of suppliers will be considered for selection. This set of suppliers should have shown a sufficient level of quality, price and service in the past. The candidate that accepts the order and offers the best combination of cost and service will finally be selected. Next, the Suppliers Module will take the control and will send an urgent order event to the provider. Later, the SM will wait for a certain interval, defined by a constant. If the provider does not answer before the time expires, the iteration will start again. Otherwise, the SM will send a reply to the Internal Event Manager module, which would compare this new delivery date with the delay date of the provider that generated the exception. If the delivery period is shorter than the delay period, the Suppliers Module will send a confirmation message to the new provider and a message to cancel the order will be sent to the provider that caused the delayed delivery event.
Consequently, the database must be updated, setting the delayed order status to "cancelled", and adding the new order. Then, it will be checked whether the delivery date of the new order is earlier than the initial delivery date of the delayed order. If so, the event will finish, else the plan will be modified by adding the new delivery date. Once the plan is made, the Internal Event Manager module will check the orders that do not fulfil the due dates and the Customers Module will inform those clients affected by the delay. Then the process will end.

4.3 Exceptions related to customers

The most important events in this category are the following:

- *Shortening due date*. This means that the manufacturing operations of the work order must be moved backwards in time.
- *Extension of due date*. This is the opposite situation meaning that the manufacturing operations must be moved forwards in time in order to comply with the new due date.
- *New urgent order* or *order quantity increase*. This event will involve an order promising process in order to check material limitations or real-time capacity in the active schedule to include the added units. This event will include an ATP (Available to Promise) check and possibly a CTP (Capable to Promise) check. The ATP information is based on the on-hand inventory or planned production of the MPS available for commitment to customers' orders. On the other hand, the CTP information refers to the resource time available that can be used to meet customer demand over a certain time interval (Viswanathan et al., 2007). Consequently, the urgent unplanned demand coming from customers will often mean an availability check of the supplier network. With this information, it will be possible to promise a realistic due date to customers.
- *Order quantity reduction*. If the customer decides to cancel a part of the order, it will request a reduction in the materials order quantity to the supplier, else the whole

purchasing order will be received. Furthermore, the plant will reduce the work order to the exactly quantity required and therefore, some slack times will be introduced in the schedule.

- *Order cancellation*. The jobs of the order will be eliminated and the corresponding capacity will be released at the assigned resources.

5. Plant Scheduler (PS)

Exceptions management usually implies rescheduling operations in the affected plant or plants. This task is done by the Plant Scheduler module. We have developed a finite-capacity scheduling system that operates in different plants and works with multiple optimization criteria, and besides, it can generate both static and dynamic schedules. It allocates jobs to machines in order to minimize production cost, delivery delays, machine idle time and, in case of rescheduling, maximize similarity with original schedule.

5.1 Main features of the scheduler

The job-shop scheduling problem on manufacturing environments presents the following general features:

- An industrial plant (shop-floor) has as main objective the production of a set of different parts. The manufacturing of every part is done by means of a process plan composed by one or more processes, which can be sequential or take place in parallel.
- The plant has a set of material and/or human resources to do the manufacturing processes of the parts.
- There exists a set of production orders of the different parts, each one referred to a single part with its corresponding quantity. The production orders can either be make-to-order or make-to-stock.
- The production of every order generates as many manufacturing operations as processes in the process plan of the corresponding part. Precisely, the resolution of the problem consists of obtaining a schedule that specifies the necessary resources and time intervals to do these manufacturing operations.
- There exists a number of constraints that must be satisfied totally or partially in order to achieve a valid schedule. This way, there can be constraints related to the process plan of any part (precedence in the accomplishment of the processes), constraints related to the resources (limitations in the operability and capacity of the machines, availability of operators and tools), and constraints related to the orders (release dates and due dates).
- The aim of production scheduling is to decide the assignments of resources to the different operations of the production orders with their corresponding time intervals, preserving the constraints, optimizing the use of resources, and minimizing costs and times.

Formally, the problem can be described with the following elements:

- Set of problem variables, $X = \{(x_{11}, x_{12}), (x_{21}, x_{22}), ..., (x_{n1}, x_{n2})\}$, where each variable pair (x_{i1}, x_{i2}) represents a job/machine combination.
- Solution space, $S = (OP \times M)^n$, being $\#S = (nm)^n$.
- Set of feasible solutions of the problem, $S' \subseteq S$.
- Objective function, $f : S' \rightarrow \Re$, where four main goals are included in terms of cost:

$$\sum_{i=1}^{n} Cm(OP_i) + \sum_{i=1}^{m} \left(Cdd(OR_i) + Chd(OR_i)[+Cjit(OR_i)] \right) + \sum_{i=1}^{q} Cid(M_i) + \left[\frac{k \cdot w}{n} \sum_{i=1}^{n} Cm(OP_i) \right]$$

where:

- n is the number of manufacturing operations scheduled.
- m is the number of work orders.
- q is the number of operative machines in the plant.
- $Cm(OP_i)$ is the manufacturing cost of operation i. It is equal to the unitary manufacturing cost of a part at the assigned machine multiplied by the number of parts to be manufactured in the operation.
- $Cdd(OR_i)$ is the delay cost with respect to the due date of order i. It is equal to a delay cost per day multiplied by the number of days the order is delivered late.
- $Chd(OR_i)$ is the delay cost with respect to the scheduling planning horizon of order i. It is equal to a delay cost per day multiplied by the number of days the order is finished late.
- $Cjit(OR_i)$ is the cost due to early completion of the order i with regard to the due date (in case of JIT scheduling). It is equal to an early completion cost per day multiplied by the number of days the order is finished before the due date.
- $Cid(M_i)$ is the idle time cost of machine i.
- k is the number of manufacturing operations in the schedule, whose machine or sequence in the machine has changed with respect to the original plan.
- w is an influence factor that is decided by the user.

Apart from this basic definition, some important information related to the plant model must be considered to start the calculations:

- Alternative process plans for every manufacturing part.
- Standard batch size for every part.
- Preference levels for machines.
- Sequence-dependent set-up times for machines.
- Maintenance plans for machines.
- Priority levels of the work orders.
- Critical auxiliary resources (operators and tools).
- Working calendar for each plant.
- Weekly working shifts for every resource (machines, operators, tools).

5.2 Evolving algorithm

The algorithm designed for this job-shop scheduling problem is based on the general procedure of an evolving algorithm, EA, combined with a specific heuristic adapted to the problem. This heuristic is applied in the generation process of organisms at the initial population, as well as in the recombination of genes to build new organisms at the successive generations. The aim is to generate feasible organisms, that is, solutions that satisfy all the problem constraints. This means that all the production schedules obtained can be applied to the actual plant situation, since they satisfy all the existing constraints.

5.2.1 Basic structure of the evolving algorithm

The input information of the EA is composed of all the entities integrating the model of the industrial plant (parts, machines, processes, part characteristics for set-up times calculation, work orders, jobs, calendars, etc.). In particular, starting from all the operations in the system, the EA schedules those operations that have not yet been assigned to any manufacturing resource, but keeping the machine and time assignments of the scheduled operations.

The EA is not affected by the origin of non-assigned operations to be scheduled, i.e., non-assigned operations can be all the operations in the system, or just a subset of them that must be rescheduled due to an unexpected event or exception. As previously explained, the dynamic exceptions that are supported by the system (machine failure, return of materials, new urgent order, etc.) are processed before the execution of the EA. This process implies selecting the operations to reschedule, and changing the plant information affected by the exception. This independence and generality of the EA makes it suitable to build both static and dynamic production schedules.

Firstly, we implemented a configurable software application to support a general-purpose genetic algorithm using an object-oriented methodology, and later we transformed it into an evolutionary heuristic algorithm adapted to the problem. The general procedure of this algorithm is the typical one of the genetic and evolving algorithms.

In order to carry out the tests of the proposed EA in the job-shop scheduling system, we have chosen the following characteristics and configuration parameters:

- The number p of organisms in the population (50), as the main goal of the tests is to check the optimization quality of the solutions with the different evolving selection criteria.
- The fitness function f of every organism $\mathbf{x}_k$ ($k = 1,...,p$) used by the EA is calculated as the inverse of the objective function described in section 5.1:

$$f(\mathbf{x}_k) = \frac{1}{\sum_{i=1}^{n} Cm(OP_i) + \sum_{i=1}^{m}\left(Cdd(OR_i) + Chd(OR_i)[+Cjit(OR_i)]\right) + \sum_{i=1}^{q} Cid(M_i) + \left[\frac{k \cdot w}{n}\sum_{i=1}^{n} Cm(OP_i)\right]}$$

- The selection of reproductive organisms is done using a deterministic criterion that allows the reproduction of all organisms in the current population.
- The generation of new organisms is done only by mutation of existing organisms (no crossover), i.e. the proposed algorithm is of evolving type.
- The selection of surviving organisms is done by means of fourteen evolving selection criteria: a deterministic elitist scheme, a mixed elitist - random scheme, three schemes of proportional selection, three schemes of hierarchical selection, three schemes of selection by tournament, and three schemes of disruptive selection.

5.2.2 Solution coding

We use the typical structural model of genetic and evolving algorithms to represent the problem: population, organisms (feasible solutions of the problem), chromosomes (homogeneous groups of variables in a solution) and genes (variables of the problem). Every organism of the problem is formed specifically by n+m+q chromosomes, where n is the number of open and in-progress operations that exist in the system, m is the number of open and in-progress work orders, and q is the number of machines at the plant.

To support the scheduling information of operations, relative to machine and time interval assignments and to objectives and constraints, every operation-chromosome possesses 17 attribute-genes:

- *Genes[0]*. It indicates the number of the operation in the list of operations of the plant.
- *Genes[1]*. It indicates the number of the machine assigned to the operation in the list of machines of the plant.
- *Genes[2]..Genes[6]*. They indicate the scheduled starting date of the operation in the format *Year-Month-Day-Hour-Minute*.
- *Genes[7]..Genes[11]*. They indicate the scheduled finishing date of the operation in the format *Year-Month-Day-Hour-Minute*.
- *Genes[12]*. It indicates the previous operation-chromosome in the batch/order.
- *Genes[13]*. It indicates the following operation-chromosome in the batch/order.
- *Genes[14]*. It indicates the previous operation-chromosome in the assigned machine.
- *Genes[15]*. It indicates the following operation-chromosome in the assigned machine.
- *Genes[16]*. It indicates the production cost in cents of the operation in the assigned machine.

To support the scheduling information of work orders, relative to time interval assignments and to objectives and constraints, every order-chromosome possesses 14 attribute-genes:

- *Genes[0].]*. It indicates the number of the work order in the work orders list of the plant.
- *Genes[1]..Genes[5]*. They indicate the scheduled starting date of the work order in the format *Year-Month-Day-Hour-Minute*.
- *Genes[6]..Genes[10]*. They indicate the scheduled finishing date of the work order in the format *Year-Month-Day-Hour-Minute*.
- *Genes[11]*. It indicates the due date delay cost in cents of the work order.
- *Genes[12]*. It indicates the scheduling horizon delay cost in cents of the work order.
- *Genes[13]*. It indicates the due date advance cost in cents of the work order (valid only in case of JIT scheduling).

To support the scheduling information of machines, relative to objectives and constraints, every machine-chromosome possesses 4 attribute-genes:

- *Genes[0].]*. It indicates the number of the machine in the list of machines of the plant.
- *Genes[1]*. It indicates the maximum working time of the machine in the scheduling horizon.
- *Genes[2]*. It indicates the effective working time of the machine, i.e., the total duration of the jobs assigned to the machine.
- *Genes[3]*. It indicates the idle time cost of the machine in cents.

6. Tests

6.1.1 Description of tests

We have designed a set of tests on an instance of limited size of the industrial plant, with the main goal of testing and showing in a simple and clear way the performance of the production scheduler and of the evolving algorithm that sustains it in the collaborative system of exceptions management in the supply chain. This instance of the plant has the following components:

- Number of parts: 3.
- Number of machines: 6.
- Number of processes: 3.
- Number of part characteristics: 3.
- Number of work orders: 4.
- Number of batches: 6.

- Number of operations (jobs): 18.

The tests have been done considering three different scheduling situations:

- *Static Scheduling*. A complete schedule is generated for a scheduling horizon of 15 days in which machines and time intervals are assigned to the 18 operations.
- *Rescheduling due to a machine failure*. A machine failure exception has been simulated, which forces a rescheduling of the subset of manufacturing operations that were assigned to the damaged machine during the foreseen unavailability period.
- *Rescheduling due to a new urgent order*. A new urgent order event is simulated, which forces a rescheduling.

For every described situation the evolving algorithm has been executed on a population of 50 organisms using binary tournament survival selection operators, and the corresponding statistics and performance measures of the best found solution have been calculated, i.e., the organism with the best fitness value obtained as a result of the evolving optimization process. With regard to the execution efficiency of the algorithm, the generation of the complete static program takes less than one second, so it looks promising for instances of the industrial plant with hundreds of manufacturing operations to schedule. In these cases, an execution time that would range from some seconds and a few minutes is foreseen.

6.1.2 Analysis of tests

With regard to the static schedule, table 2 shows the set of assignments done by the production scheduler, whose schematic representation corresponds to the Gantt chart of fig. 5.

Order	Batch	Operation	Machine	Starting date	Starting time	Finishing date	Finishing time
ORD-1	1	OP-1	M1	2011-1-2	19:0	2011-1-3	11:40
		OP-2	M4	2011-1-5	14:50	2011-1-7	8:30
		OP-3	M5	2011-1-8	20:50	2011-1-12	8:10
	2	OP-4	M1	2011-1-2	9:0	2011-1-2	19:0
		OP-5	M4	2011-1-2	19:0	2011-1-3	20:0
		OP-6	M5	2011-1-3	20:0	2011-1-5	22:0
ORD-2	1	OP-7	M1	2011-1-3	12:25	2011-1-4	13:25
		OP-8	M4	2011-1-4	13:25	2011-1-5	14:25
		OP-9	M6	2011-1-5	14:25	2011-1-9	1:45
ORD-3	1	OP-10	M2	2011-1-2	9:0	2011-1-3	13:0
		OP-11	M3	2011-1-3	13:0	2011-1-5	0:0
		OP-12	M5	2011-1-5	22:25	2011-1-8	20:25
ORD-4	1	OP-13	M1	2011-1-4	14:0	2011-1-5	23:20
		OP-14	M4	2011-1-7	9:5	2011-1-9	19:25
		OP-15	M6	2011-1-9	19:25	2011-1-13	6:45
	2	OP-16	M1	2011-1-5	23:20	2011-1-6	12:40
		OP-17	M4	2011-1-9	19:25	2011-1-10	18:45
		OP-18	M6	2011-1-13	6:45	2011-1-14	16:5

Table 2. Static schedule

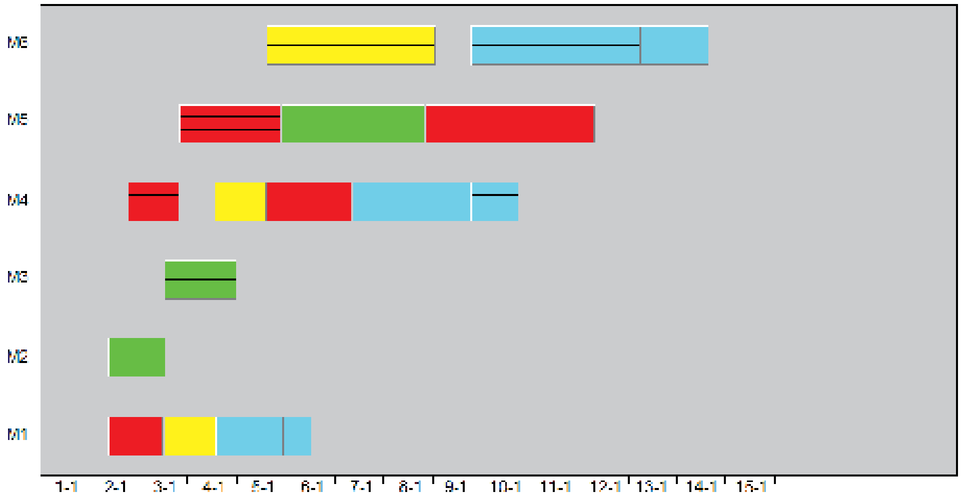

Fig. 5. Gantt chart of the static schedule

In the Gantt chart the operations corresponding to the same order are represented by blocks of the same colour (order 1 red, order 2 yellow, order 3 green, order 4 cyan). Likewise, the number of horizontal lines drawn in the interior of the block that represents every operation indicates the number of the work order batch to which the operation corresponds. The white vertical line to the right of the diagram indicates the limit of the planning horizon of the fixed scheduling time interval (15 days).

Table 3 contains the performance measures obtained for the previous static program, which will be used as reference for the comparison of results in the different cases of rescheduling. As it is observed, the work load of the plant is not excessive, and only one order (ORD-3) presents a due date delay. Besides, no order has been scheduled late with regard to the end of the planning horizon of the plant. Precisely, the due date delay of order ORD-3 relative to its foreseen manufacturing interval is 6.76 %, with an associate cost of 607.63 Euro. Note also that the average percentage of occupation of the machines is 34.17 % with a total cost derived from machine idle time of 2504.39 Euro.

With regard to the rescheduling due to machine failure, table 4 shows the set of assignments of machine and time interval calculated by the production scheduler for every order/lot/operation of the system in response to the exception. Likewise, in fig. 6 and 7 the Gantt charts of the operations appear before and after the rescheduling process respectively.

As it is observed in fig. 6, the machine that generated the failure exception is M4, which remains inoperative during a foreseen period of 3 days (5-1, 6-1, 7-1). Therefore, the three affected operations (OP-2, OP-8, OP-14) are initially eliminated from the schedule. In this case, the exception manager checks the existence of an available alternative machine (M3) that can execute these operations, so that they can be rescheduled and not remain pending. In the rescheduling process, the assignments of machine or time intervals of the operations started before the current date (event date) are not modified. Likewise, the machine assignment of the remaining operations is not changed, though these operations can be moved forward in time, as a consequence of the optimization process. Indeed, other operations might be considered, apart from the three directly affected by the event, for

STATIC SCHEDULE - GLOBAL PERFORMANCE IN TERMS OF COST	
Total cost (objective): 105412.02	**Production cost:** 102300.00

PERFORMANCE RELATED TO WORK ORDERS					
	throughput time	**due date delay**	**due date delay cost**	**horizon delay**	**horizon delay cost**
Order 1	14350	0	0	0	0
Order 2	8000	0	0	0	0
Order 3	9325	625	607.63	0	0
Order 4	14525	0	0	0	0
Maximum	14525	625	-	0	-
Average	11550	156.25	-	0	-
Σ	-	-	607.63	-	0

PERFORMANCE RELATED TO MACHINES			
	allocated operations	**usage percentage**	**idle time cost**
Machine 1	5	27.31	418.66
Machine 2	1	7.78	553.33
Machine 3	1	9.72	780.00
Machine 4	5	48.15	448.00
Machine 5	3	56.48	131.60
Machine 6	3	55.56	172.80
Average	3	34.17	-
Σ	-	-	2504.39

Table 3. Static schedule performance

relocation during the rescheduling process (by simply annulling the machine assignment of the operation before the scheduler is launched), but this possibility has been avoided taking into consideration the general aim of minimizing the changes with respect to the previous schedule.

Table 5 contains the performance measures for the schedule obtained after the event of machine failure. As it is observed, after the rescheduling process three orders (ORD-2, ORD-3, ORD-4) present a due date delay, with an associate cost of 16489.57 Euro. Even one of them (ORD-4) is scheduled late with respect to the end of the planning horizon of the plant, with an associate cost of 272.36 Euro. Note also that the average percentage of occupation of the machines is 35.32 % with a total cost derived from machine idle time of 2444.39 Euro.

Order	Batch	Operation	Machine	Starting date	Starting time	Finishing date	Finishing time
ORD-1	1	OP-1	M1	2011-1-2	19:0	2011-1-3	11:40
		OP-2	M3	2011-1-7	3:20	2011-1-8	4:20
		OP-3	M5	2011-1-8	4:20	2011-1-11	15:40
	2	OP-4	M1	2011-1-2	9:0	2011-1-2	19:0
		OP-5	M4	2011-1-2	19:0	2011-1-3	20:0
		OP-6	M5	2011-1-3	20:0	2011-1-5	22:0
ORD-2	1	OP-7	M1	2011-1-3	12:25	2011-1-4	13:25
		OP-8	M3	2011-1-5	0:40	2011-1-7	2:40
		OP-9	M6	2011-1-7	2:40	2011-1-10	14:0
ORD-3	1	OP-10	M2	2011-1-2	9:0	2011-1-3	13:0
		OP-11	M3	2011-1-3	13:0	2011-1-5	0:0
		OP-12	M5	2011-1-11	16:5	2011-1-14	14:5
ORD-4	1	OP-13	M1	2011-1-4	14:0	2011-1-5	23:20
		OP-14	M3	2011-1-8	4:45	2011-1-11	7:45
		OP-15	M6	2011-1-11	7:45	2011-1-14	19:5
	2	OP-16	M1	2011-1-5	23:20	2011-1-6	12:40
		OP-17	M4	2011-1-8	0:0	2011-1-8	23:20
		OP-18	M6	2011-1-14	19:5	2011-1-16	4:25

Table 4. Schedule obtained after rescheduling due to machine failure

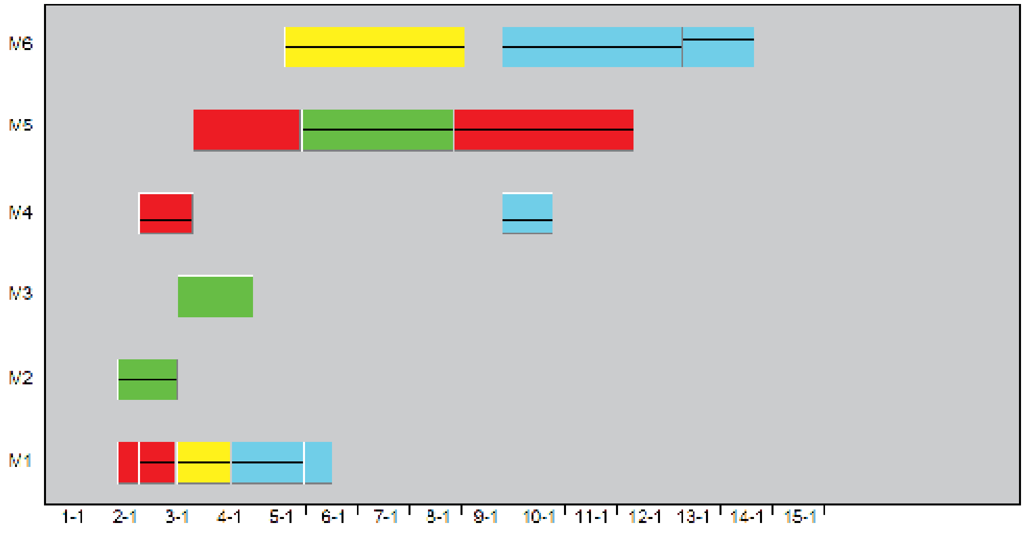

Fig. 6. Gantt chart of the schedule affected by a machine failure event before rescheduling

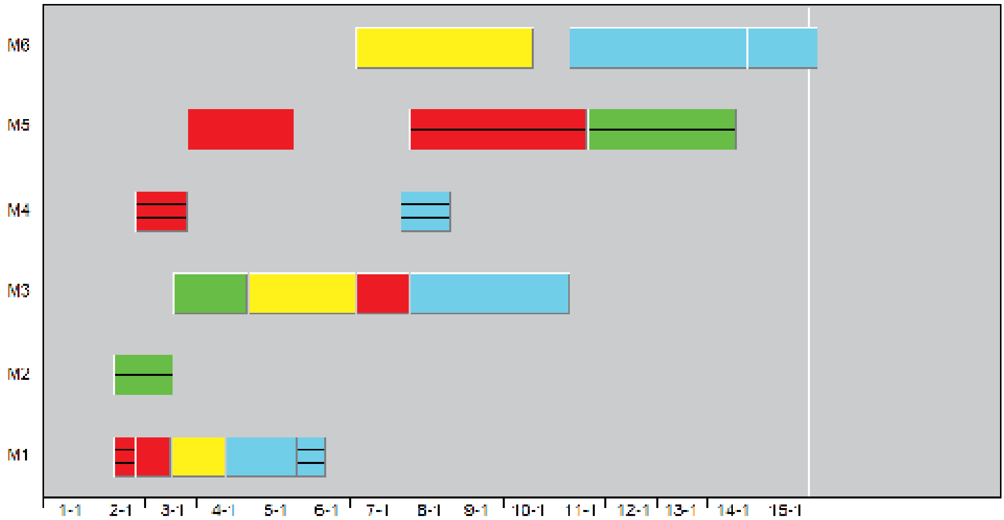

Fig. 7. Gantt chart of the schedule affected by a machine failure after rescheduling

RESCHEDULING DUE TO MACHINE FAILURE - GLOBAL PERFORMANCE IN TERMS OF COST	
Total cost (objective): 127506.32	**Production cost:** 108300.00

PERFORMANCE RELATED TO WORK ORDERS					
	throughput time	**due date delay**	**due date delay cost**	**horizon delay**	**horizon delay cost**
Order 1	13360	0	0	0	0
Order 2	10175	1680	5950.00	0	0
Order 3	17585	8885	8638.19	0	0
Order 4	16705	925	1901.38	265	272.36
Maximum	17585	8885	-	265	-
Average	14456.25	2872.5	-	66.25	-
Σ	-	-	16489.57	-	272.36

PERFORMANCE RELATED TO MACHINES			
	allocated operations	**usage percentage**	**idle time cost**
Machine 1	5	27.31	418.66
Machine 2	1	7.78	553.33
Machine 3	4	51.39	420.00
Machine 4	2	13.43	748.00
Machine 5	3	56.48	131.60
Machine 6	3	55.56	172.80
Average	3	35.32	-
Σ	-	-	2444.39

Table 5. Rescheduling performance due to machine failure

Order	Batch	Operation	Machine	Starting date	Starting time	Finishing date	Finishing time
ORD-1	1	OP-1	M1	2011-1-2	19:0	2011-1-3	11:40
		OP-2	M4	2011-1-4	9:0	2011-1-6	2:40
		OP-3	M5	2011-1-10	10:45	2011-1-13	22:5
	2	OP-4	M1	2011-1-2	9:0	2011-1-2	19:0
		OP-5	M4	2011-1-2	19:0	2011-1-3	20:0
		OP-6	M5	2011-1-3	20:0	2011-1-5	22:0
ORD-2	1	OP-7	M1	2011-1-3	12:25	2011-1-4	13:25
		OP-8	M4	2011-1-6	2:55	2011-1-7	3:55
		OP-9	M6	2011-1-7	3:55	2011-1-10	15:15
ORD-3	1	OP-10	M2	2011-1-2	9:0	2011-1-3	13:0
		OP-11	M3	2011-1-3	13:0	2011-1-5	0:0
		OP-12	M5	2011-1-13	22:30	2011-1-16	20:30
ORD-4	1	OP-13	M1	2011-1-5	10:20	2011-1-6	19:40
		OP-14	M4	2011-1-7	4:30	2011-1-9	14:50
		OP-15	M6	2011-1-10	15:25	2011-1-14	2:45
	2	OP-16	M1	2011-1-6	19:40	2011-1-7	9:0
		OP-17	M4	2011-1-9	14:50	2011-1-10	14:10
		OP-18	M6	2011-1-14	2:45	2011-1-15	12:5
ORD-5	1	OP-19	M1	2011-1-4	14:10	2011-1-5	10:10
		OP-20	M3	2011-1-5	10:10	2011-1-7	2:10
		OP-21	M5	2011-1-7	2:10	2011-1-10	10:10

Table 6. Schedule obtained after rescheduling due to a new urgent order

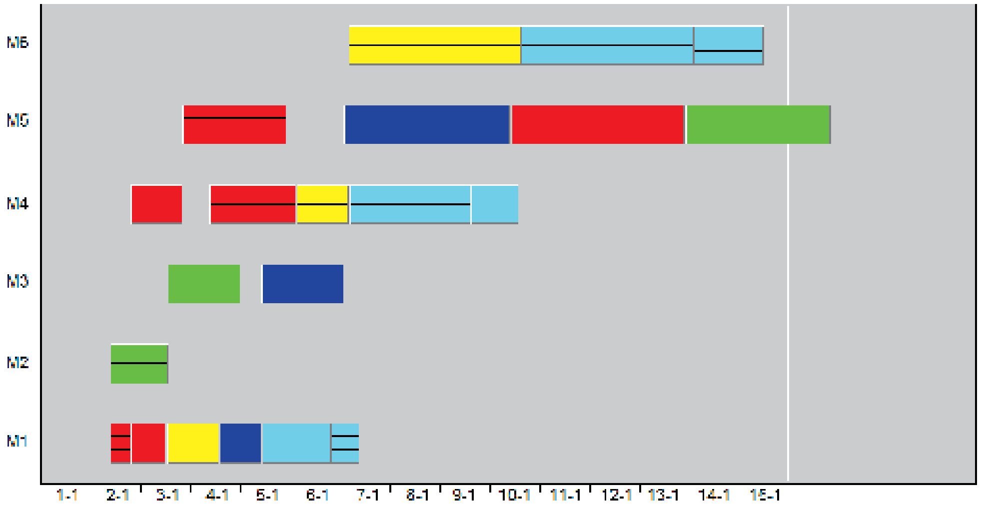

Fig. 8. Gantt chart of the schedule affected by a new urgent order after rescheduling

With regard to the rescheduling process due to a new urgent order, table 6 shows the set of assignments of machine and time intervals calculated by the production scheduler for every order/lot/operation of the system in answer to the exception. Likewise, in fig. 8 the Gantt

chart of the operations after the rescheduling is presented. In this case, the Gantt chart previous to the rescheduling is that of the static schedule (fig. 5).
As it is observed in fig. 8, the new urgent order (ORD-5) is represented by blocks of blue colour and only comprises one batch and three operations to be scheduled. In case the new work order has a high priority level, its operations are allocated as soon as possible so that they could finish before the due date, moving forward in time other operations if necessary.
Table 7 contains the performance measures for the program obtained after the exception of a new urgent order. As it is observed, after the rescheduling process three orders (ORD-1, e

RESCHEDULING DUE TO NEW URGENT ORDER - GLOBAL PERFORMANCE IN TERMS OF COST	
Total cost (objective): 142717.85	**Production cost:** 118300.00

PERFORMANCE RELATED TO WORK ORDERS					
	throughput time	**due date delay**	**due date delay cost**	**horizon delay**	**horizon delay cost**
Order 1	16625	1325	3238.88	0	0
Order 2	10250	1755	6459.37	0	0
Order 3	20850	12150	11812.50	1230	597.91
Order 4	14505	0	0	0	0
Order 5	8400	0	0	0	0
Maximum	16625	12150	-	1230	-
Average	14126	3046.00	-	246	-
Σ	-	-	21510.75	-	597.91

PERFORMANCE RELATED TO MACHINES			
	allocated operations	**usage percentage**	**idle time cost**
Machine 1	6	32.87	386.66
Machine 2	1	7.78	553.33
Machine 3	2	20.83	684.00
Machine 4	5	48.15	448.00
Machine 5	4	78.70	64.40
Machine 6	3	55.56	172.80
Average	3.50	40.65	-
Σ	-	-	2309.19

Table 7. Rescheduling performance due to a new urgent order

ORD-2, ORD-3) present a due date delay, with an associate cost of 21510.75 Euro. Even one of them (ORD-3) is scheduled late with regard to the end of the planning horizon of the plant, with an associate cost of 597.91 Euro. On the contrary, the new urgent order fulfils all the time constraints and does not generate any delay costs. Note also that in this case the average percentage of occupation of the machines is 40.65%, with a total cost derived from machine idle time of 2309.19 Euro.

7. Conclusions

In this chapter a proactive tool that manages unforeseen events in different plants of the same company is described, using a wide perspective that includes suppliers and customers. The study helps to reach a competitive advantage in the extended enterprise, since it analyzes the implications of the changes happened in a specific point of the supply chain for other nodes. This means, for example, that in case demand increases and there are not enough materials in the plant, the possibility of urgently requesting orders to suitable suppliers is explored, in order to generate a feasible production schedule. In addition, if a disruption affects the customers, these are warned early about possible service problems, and this way they will be able to take correct decisions that will benefit both their companies and their own customers.

This research proposes to incorporate collaborative capabilities to real-time production scheduling. This way, the objective of SCM is better met by a dynamic and fluent coordination of the different organizations that produce value to the customer. Therefore, this tool not only allows for information exchange with other nodes but it also contributes to collaborative production scheduling and synchronized production, thus leading to globally optimized solutions that reduce costs and increase customer satisfaction.

A description of the problem is provided identifying the key assumptions used in the model. Besides, the different exceptions supported by the system are categorized and explained. Finally, the software modules are identified, and a wide description of the Production Scheduler module of the plant is provided.

With respect to this Production Scheduler module, the study shows the possibility of successfully applying an advanced technique of optimization, the genetic and evolving algorithms, to the job-shop scheduling problem, working with a complex model of a multi-plant company and obtaining always feasible solutions that verify the constraints of the problem. The latter characteristic is achieved thanks to the incorporation of a specific heuristic of the problem in the generation process of the initial organisms and in the mutation of organisms in successive generations. This heuristic consists of supporting the operations to schedule in a sequential list that respects the precedence restrictions between processes, to assign them in the order marked by this sequential list, first the machines and then the dates. Thus, the search procedure of time intervals for the operations is done forward and without undoing previous assignments, which gives the joint algorithm an outstanding rapidity of execution.

The characteristics and complexity of the developed system can be extended in different directions, which can become condensed briefly in the following lines of development:

- Analyze the behaviour of the system on JIT scheduling environments, which are also supported in the developed software.

- Realize a rigorous analysis of the evolving algorithm of production scheduling from the point of view of the quality of the solutions, with plant instances of big size, and contrasting the different implemented techniques of survival selection, as well as other basic techniques of combinatorial optimization, such as taboo search and simulated annealing.
- The elements of the supply chain that can be most affected by decision variables subject to dynamic constraints are production and distribution. Due to that, it would be very interesting to develop an approach that aims to integrate these elements of the supply chain (manufacturing and distribution) into a single model of optimization that would simultaneously act on the decision variables of several objective functions.

8. Acknowledgement

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7

Strategic Approaches to Domination in Supply Chains

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1. Introduction

Dominance in the supply chain has shifted throughout history. Dominance or power in supply chains concern the extent of influence one participant in the chain has over one or more participants. The recognition of such dominance in any industry has long been recognized. Raven and French (1958) were among the first to explore inter-firm power. They developed five different bases of power which can still be useful to perceive reasons why one supply chain participant may hold authority over another. Emerson (1962) defined power as the ability of one firm (the source) to influence the intentions and actions of another firm (the target). Whilst Butaney and Wortzel (1988) related power to supply chains by demonstrating that distributors have power in supply chains when industry sales are approximately equally distributed among manufacturers and the overall competition within the industry is strong. Since these early days it appears that all participants along the supply chain including their second and third tier suppliers within a network, can hold some extent of dominance over some or all participants within the supply chain.

This chapter analyses the changing nature of such domination in supply chains and incorporates the supply chain management strategies that may encourage or inhibit domination of the dominant participants. There are various types of power that can be exercised in supply chains that impact on supply chain participants. These types will be delineated to show how some supply chain participants exert their power so successfully. Further power can extend to different parts of the supply chain. The main power centric types of supplier power, manufacturing power, and retail power will be explained. The fourth power centric regime is a recent addition to the domination in supply chain literature. It relates to distributor centric power which has recently evolved with the globalisation of supply chains.

The main purpose of this chapter is to address the various sorts of power that the dominant supply chain participant exerts on its followers. The strategies that the dominant player uses to expand its regime as well as the various strategies that it puts in place to retain its existing power base is provided. In conclusion the changing nature of the dominating influences in supply chains and their associated networks is emphasised.

2. Types of power in supply chains

This first section delineates the types of power that can occur with supply chains. Total supply chain dominance is rare but sections along the supply chain are regularly dominated by one participant whose influence extends upstream or downstream or in both directions to varying lengths along the supply chain and varying depths within the supply chain impacting on second and third tiered suppliers.

Mentzer in 2001 defined supply chains as consisting of a leader and two or more other participants operating upstream or downstream from the dominant member. These participants of the supply chain were directly integrated by flows of products, services, finance and information. They had common goals of giving a level of performance of operations that would provide benefits and profits to all members of the supply chain, not just the dominant participant.

According to Cox (1999) the relative use of resources needed in supply chain operations and exchanges between supply chain participants will determine the power base of the dominant player. Emerson (1962) began this research with the argument that the dependency of other market players is directly proportional to the motivational investment goals of a firm. Applying this concept to the total supply chain management the hypothesis would be that if the goals of firms along the total supply chain are similar then the dominant player can strongly support those goals and retain dominance. If the goals of the other participants along the supply chain are not similar then the level of dependency on the dominant player is fractured.

Buyer dependency is another way of interpreting the power regimes in supply chains. Cox (2004) classified power into buyer dominance with the buyer having an adversarial arm's length with suppliers' non adversarial arm's length compared with supplier dominance with the supplier having the adversarial role and the buyer the non adversarial role. At the other end of the spectrum Cox showed that there can be adversarial and non adversarial collaborative roles for both the buyer and supplier. The way certain players exert their power, whether it be collaborative or coercive, will in most instances impact on the retention of their domination. Similarly, the way the dominant player exerts power can determine the extent of market share. Types of power can extend the similar and consistent use of technology across different supply chain participants. The extent of product brand power along the total supply chain will depend on the type of power the dominant player exerts. The degree to which participants strategically collaborate with its partners and the extent of collaborative management of the intra and inter-organizational processes will depend on the collaborative or coercive use of power by dominant players.

A comprehensive review of buyer-supplier relationships from 1986 to 2005 by Terpend et al. (2008) found that research focused initially on operational improvements and later the focus shifted to financial performance of the participating firms. The four main improvements that buyers and suppliers typically seek from their collaborative relationships are: operational improvements; integration-based improvements; supplier capability-based improvements and financial performance. Their research indicated that the strategic approaches for integration in supply chains must incorporate their given operating environment and associated constrained resources. Their strategic approaches must consider wisely which relationships require greater attention and closeness. Furthermore their strategies must focus on the activities which are most likely to yield the greatest value.

Participants, according to Skjott-Larsen, (2006) can possess a dominant position either because of purchasing power, market power, access to proprietary technology and knowledge. Power can affect the elements (trust, co-operation, and commitment, conflict and conflict resolution) critical to effective supply chain integration. These findings support Maloni & Benton' s (2000) contention that power plays a crucial role in the formation and maintenance of productive supply chain relationships.

The concept of total interdependence (total power) can indicate the intensity of the relationship and is often an indicator of a strong cooperative collaborative arrangement between participants in the supply chain. According to Caniels & Gelderman (2007) these relationships have mutual trust and commitment and are commonly characterized by healthy profits for both parties.

The role of the leader or holder of power in supply chains gained academic attention during the 1990s but only recently has any level of attention been directed to the followers in supply chains. Supply chain leaders and followers according to Defee et. al. (2009) can be identified by the behaviours they exhibit. Follower characteristics have been described as the style of the relationships, the scope of responsibilities, the desire for collaborative and integrative relationships and commitment orientation. The notion and importance of followers compared with leaders was expanded by Poirier, Swink & Quinn (2008) who further separated the supply chain participants into three sections, namely, leaders, followers and laggards. They found that the leaders aligned with corporate strategy well and that strategic customer integration was an integral part of their strategic plan. Followers consciously and deliberately followed the leadership whilst laggards did not explicitly integrate.

Thus in conclusion of this brief summary of the current literature on domination, for the purposes of this chapter, domination of supply chains will be measured in terms of net dependence of one participant compared with the dependence of another participant and how a participant influences the operations of the other participant/s. The balance of dependence and inter-dependence within supply chains are not in perfect symmetry and this chapter demonstrates how the levels of power fluctuate and change over time. The academic debate to date shows the changing uses of power and the changes to domination that occur depending on a number of different strategic approaches both from the dominant participant's perspective as well as from the following participants along the supply chain. These strategic approaches will be analysed to show that integration of the various participants operating along the total supply chain requires well developed strategic supply chain management skills.

3. Power centric regimes in supply chains

The analysis of domination is now further broken down into the four domination sections along the supply chain, namely, supplier, manufacturer, distributor and retail. Alliances along supply chains can become very strong. The supply chain participant can obtain a positional advantage by filling some critical resource or service linkage in the chain. The level of dependency of other members on this critical aspect will either lead to a dominant position or a level of independence for the participant holding the positional advantage. If there exists a level of interdependency between a few or large number of supply chain participants then the dominant player will hold a strong degree of domination. Some firms in positional advantage can hold an efficiency advantage by providing similar services at a lower cost. Other firms in positional advantage can hold an effectiveness advantage by providing a better service at a similar or lower cost. The optimal advantage to be held in a supply chain occurs when a participating firm holds both an efficiency and effectiveness advantage. (Wittmann, Hunt & Arnett, 2009)

3.1 Manufacturer-centric dominance

Over a general time line manufacturers roles and dominance has grown and waned. Since the Henry Ford era of the 1920s the manufacturing sector entered a mass manufacturing age which was predominantly cost oriented. The supply chains aimed for economies of scale with the final products pushed forwards from the manufacturing stock piles to the customer. The aim was to achieve industrial integration and economies of scale to gain dominating power in the supply channels. The quality focused era emerged during the 1950s as manufacturers shifted their focus and resources to quality management embracing reliability, safety, durability and strict specifications of products. During this stage the Deming cycle gained prominence. The Japanese manufacturers gained from these quality control approaches substantially as their product image was rebuilt and consolidated. From the 1980s the manufacturing environment changed markedly and although still retaining cost and quality requirements it also entered the flexibility era. Three aspects were required for flexibility, namely;

- Production change requirements – different modifications or innovations of part configurations developed;
- Production system changes – different and new machinery, production methods and new computerized operating systems were added;
- Demand variations led to unexpected fluctuations which meant that manufacturers had to become flexible to adapt to these demand uncertainties.

Due to the volatile demand situations coupled with severe competition from Japanese manufacturers on the quality enhancement and innovation front, other global manufacturers reacted to 'best practice' situations where time became the competitive differentiator. JIT came into its real meaning and manufacturing entered a multi-dimensional stage that moved from economies of scale (mass production) to economies of scope (lean and flexible manufacturing) and economies of space and time (responsive to demand or time oriented). (Sethi & Sethi 1990)

Today's manufacturer is an agile player in supply chains relying on pull systems and postponement strategies to respond to variations in consumer demands. As manufacturers have overcome the trade-off of cost and quality efficiencies the various stages moved from cost, quality, assembly flexibility and time issues to total customer responsiveness and agility in production.

The 'lean' supply chain model indirectly advanced the concept of manufacturing dominance. Womack's examination (1990) of Toyota's supply chain showed how a powerful manufacturer can work closely with a limited set of suppliers to reduce waste and inefficiency. In the related sphere of supply chain 'networks', and building on resource dependency theory, Provan (1993) argued that interdependences, established through routine transactions and information sharing, provides a disincentive to opportunism, since sub-performance by one member of the network impacts on all members and prompts punishment. Although these theories are logically sound, they failed to recognise their hidden assumptions regarding the distribution of power within the supply chain. Toyota might be somewhat dependent on its suppliers to supply high quality products on time, but those suppliers were almost certainly more dependent on Toyota, since the loss of this customer would probably spell financial ruin. It is thus difficult to see how such a supplier could realistically punish an opportunistic Toyota. The domination of manufacturers in the automobile industry is sustained by long term strong relationships with their suppliers.

In the mid-1990s, these assumptions of 'lean' and 'integrated' supply chain 'networks' began to be questioned, and increased focus was placed upon the operation of the manufacturer's power in supply chain relationships. Lamming (1996) (Lamming 1996) observed that crude commercial power – the 'buyers market' versus the 'sellers market' ultimately has more of an impact on relationships than possible benefits of more competitive final products. The 'win-win' models were questioned based on the findings of concealed unequal distribution of costs and benefits. Christopher's promotion of the 'agile' supply chain model with the example of Dell Computers, which continued the 'lean' conception of a dominant manufacturer, pushed the notion of achieving competitive advantage through cooperation and strong relationships with suppliers. (Christopher and Towill, 2000)

Cox (1999) argued that dominant manufacturers like Toyota achieved the benefits of lean supply models not through cooperation but rather through their ability to control the cost, quality and innovation of the product of its dependent 'supplicant' suppliers, i.e. the coercive approach to domination. Dominant firms can drive innovations in its suppliers, but more importantly, they can control the flow of added value arising from those innovations, whilst placing less powerful competitors on an 'innovation treadmill to oblivion.' (Cox, 1999, p.169).

Cousins and Menguc (2007) did not view the manufacturer as being in the middle of the supply chain and in a position of dominating the backward or downstream integration of suppliers to match the manufacturing scheduling requirements. They viewed the forward integration as the flow from the supplier through the manufacturer onwards to the customer. The backward type of integration involves the coordination of information from the customer to the manufacturer and through the various postponement stages. The traditional view of manufacturer dominance related to the traditional concept of material management from suppliers to manufacturers. Thus through the development of customer demands and postponement as a value adding service as well as the information technology enabling the coordination of information downstream from the customer or retailer through the manufacturer to the main suppliers; the manufacturers in some supply chain types lost their dominant position or changed their strategies and patterns of domination.

Indeed, mainly due to globalization, different manufacturing strategies such as postponement and make to order (MTO), and advanced information technologies, have changed the blends of power between manufacturers and suppliers. It appears that the combined strength of manufacturers and distributors are changing their domination patterns, not necessarily their level of domination.

Innes and Hamilton (2009) shows that dominant manufacturers can price competitors out of the market, tempering intra-brand business stealing and encouraging inter-brand business stealing, by using retail price maintenance (RPM) cross-market controls in retail contracts, to discourage retailers from discounting competitor products. It demonstrates that powerful manufacturers such as oil companies will sell weakly-substitutable products at below cost (loss-leading), in order to extract rents from competing supply chains, and also extract rebates when their dependent buyers' make profits on other items. This complex paper claimed that "a vertical restraint by a manufacturer of one good can be used to simultaneously control the retail pricing of another good, resulting in the extension of monopoly power to a second market" (p.136) by the manufacturer. Brand power arising from manufacturers is seen in the automobile industry but a study by Lindblom and Olkkonen (2006) looked at the fast moving consumer goods industry. Their Finnish study showed that food manufacturers seem to have more control than non-food manufacturers over promotional activities but less influence over pricing where the retailer seems to be gaining dominance.

3.2 The retail-centric domination

A number of key debates occur in the contemporary literature concerning dominance of the retailers in supply chains. It is argued that retailers (operating in a pull supply chain) have now taken the power from the manufacturers who operated in push supply chains. These arguments are often based upon empirical examinations of 'big-box' retailers such as Wal-Mart, and related anxieties about market consolidation, and the loss of small and medium sized retailers.

During the 1990s it became evident that manufacturers, suppliers and retailers became more interdependent on each other.(Provan, 1993; Skjott-Larsen, 2006) In customer responsive supply chains the opportunistic behaviour of individual manufacturers and suppliers relative to dominant retailers declined with their increasing levels of embeddedness and dependency on their key retailers. Overall the total transaction costs dropped along the total supply chain. This was also due to the visibility that modern integrated technology provided for the information flows and the financial flows within the chain. In turn such visibility increased reliability of services and trust between collaborating participants.

The grocery industry in the United Kingdom was studied by Duke (1989) who undertook a structural analysis. His findings showed that the market was dominated by a small number of large retailers who were largely stocking the same branded products. In order to differentiate from their competitors these retailers sought to develop themselves by brand association. During the 1980s these grocery retailers had supplanted the manufacturers and their brands in the domination of the grocery supply chains. This analysis provided the foundations for a stream of further analyses in domination of supply chains. The original analysis was limited to providing insight of the major players. It covered the efforts of other supply chain participants such as the manufacturers who became vertically associated participants as well as the horizontal players. In this way they became the smaller niche grocery competitors, to counteract the growing domination of the larger retailers. This power in the supply chains of the grocery industry was further researched by Hogarth-Scott and Dapiran (1997, 1999) who explored the issues of trust in maintaining the power relationships in the grocery industry. Gassenheimer (1996) supported this work in the retailer centric grocery industry by analysing the impact of the use of power on long term supply chain relationships with a group of manufacturers. The work in this industry became substantial and the definition of a dominant player in supply chains took on a decided bias towards retail dominance. For example Govil (2002) defined a dominant player as: "*the partner in the supply chain that can understand the consumer demand and fulfil it in a timely and cost effective manner.*"(Govil, 2002, p.55)

As consumers became less loyal to manufacturing branding and global consolidation and competition emerged from the late 1990s, the giant retailers such as Wal-Mart, Toys R Us, McDonalds and Home Depots became economically more powerful. Retailer dominance increased because they were closest to the consumers and they well understood the demands and requirements of consumers. Since the late 1990s the retail business merged into large scale retail supermarkets and enterprises. The speed of the growth of the global retail industry was phenomenal. Furthermore the global reach and complexities of information networks enhanced their control backwards along their supply chains. (Wang, 2006; Wang & Lui, 2007; Wang & Lau, 2008)

Their competitive strategies are usually based on pricing and differentiation of products. Retailers began to rationalise logistics and distribution on a global scale. Coupled with the new sophisticated technologies the retailers became more dominant over their downstream partners. The retailers provided information to the downstream participants regarding the quantities of orders required. Strong interdependencies grew and more opportunistic behaviours emerged. (Choudhury, et. al., 2008)

Goval & Proth (2002) suggest that the dominant power is generally taken by the retailer or the manufacturer. The retailer will gain dominance and focus on standardised consumer products which are simplistic in design, high volume, reduced lead times and reduced manufacturing processes. They cited examples of Tesco, IKEA and Kmart. On the other hand heavy equipment manufacturers such as Caterpillar and John Deere gained global manufacturing dominance due to their focus on complex and lengthy manufacturing processes of their brand products and the long lead time requirements. Wang & Lau (2008) also suggested ways that the retailer can manipulate the manufacturer to produce according to the retailer-led strategic goals.

3.3 Supplier-centric dominance

The failure to manage suppliers or for suppliers to manages its own second or third tier suppliers can directly increase upstream costs. Supplier dominance can be a result of resource dependence, institutional aspects or cost factors. The ownership of critical resources, the limiting of the number of suppliers and the extent of outsourced suppliers in the industry will impact on supplier dominance. Suppliers can have dominance over raw materials; semi finished goods, components and parts as well as finished goods. Theoretically the identifying factors leading to supplier dominance are based on resource based theory; transactional cost theory and institutional aspects. From an institutional perspective there are the formal institutional laws and regulations as well as the informal institutional relationships. The electricity industry is a prime example of formal institutional arrangements determining the dominance of power along the supply chain. The transaction cost theory is based on the assumption that costs incurred by transactions among firms are significant and thus those firms designed to minimize transactions gain some dominance.

Overall where there are few competitive substitutes, lack of any threats of backward integration in supply chains and lack of threats from disintermediaries; suppliers tend to have power in supply chains. (Cox, 2001) Sources of supplier dominance according to Cox et. al. (2003) include: legal property rights, economies of scale, information impactedness, and reputation effects such as branding, buyer switching costs, buyer search costs and collusive cartels.

Attributes of supplier dominance indicate that there has to exist less suppliers than buyers, greater independence for supplier than buyers, more information control than buyers and less switching costs than buyers. When suppliers are small in numbers it indicates that there exist some relatively high barriers of entry. These barriers could be in the form of holders of scarce resources or geographic isolation. Regulations and/or government policies may also provide forms of protection to suppliers. Other forms of supplier dominance rest with knowledge and innovative abilities. When suppliers are in possession of critical technology which is constantly improved and renewed the entry barriers are high for potential entrants. In strong pull supply chains the suppliers can hold dominant positions due to the dependence of their abilities to supply the right amount on demand.

From the supplier's perspective, a dominant position will give the supplier extensive powers that permit them to continuously improve the product quality. As their materials become scarce suppliers can also use or abuse their power to price the materials at higher levels which in turn will add to the cost structures all the way upstream along the chain. (Cox, 2004)

Supplier dominance can be unfavourable to upstream participants because they may experience higher purchasing costs, uncertainty or unpredictability of supply. This means that upstream participants need to hold higher inventory buffer stocks. Suppliers can also damage upstream competitive positions. Suppliers can misuse information relating to competitors orders and their demand information. Suppliers can enforce 'tied' sales and bundling of products. This means that sales will occur based on restrictive conditions made by suppliers to enforce other purchases to be made in conjunction with some product or material sales.

Industries where supplier dominance exists include the oil industries due to the oil reserves being restricted. Alternate energy sources such as natural gas, solar, hydrogen continue to weaken this oil dependency. The automotive industry was revolutionised with the famous keiretsu relationships of the Japanese Toyota manufacturer dependency on their component and part suppliers. In the computer industry the prevailing trend has been to reduce the supplier base leaving the remaining competitive suppliers with huge market shares. The aviation industry was deregulated in the United Stated in 1978 and since then forward and backward integration along the supply chains have accelerated. Synergistic networks developed in which new aircraft models are designed, built and sustained over the life of the aircraft with suppliers of parts upgrading the designs, assemblies and deliveries of fully tested components for the aircraft over a thirty year projection. (Trunick, 2007)

3.4 Distributor-centric dominance

Fisher (1997), one of the first of many authors to categorize supply chain types, based his dual classification on product type, namely functional and innovative. The innovative products use responsive supply chains and within this chain the distributors play a major role in getting the products to the customer in a quick and responsive manner. According to Selldin & Olgaher (2007) who followed on the work of Fisher a decade earlier, the responsive supply chain type can be viewed as similar to the agile supply chain type of categorized by Christopher and Towill (2000). Thus a perceived dominant role of distributors in agile, responsive supply chains emerged. Refinements to this general dichotomy of supply chain types developed. Distributors can provide the flexibility of delivery. The MTO approach combines well with rapid response distributions. Truss, using the automobile industry, showed how distributors can offer consolidation services and build strong relationships with their customer bases. (Truss et.al., 2006)

Distributors act like a semi mobile warehouse for the retailers. In the fast moving goods industries, distributors track products and their life cycle use by dates to provide tailored and quick response distribution services. Dedrick and Kraemer (2005) demonstrated distributor's importance in providing customer service requirements in the personal computer market. Value adding benefits that distributors can provide include tracking of stock, reducing retail inventory stock holdings, being a high tech information conduit and gaining cost advantages via bulk purchases. They also provide geographic scope. Distributors play a vital role in short life products.

Geographic complexity is based on the complexities associated with the transactional costs involved in the linkages along the supply chain. The geographic distance, schedule integrating capabilities, security and risk, reliability of the transportation and related services as well as the probability of damage free flows impact on geographic complexity which in turn is related to the degree of the international buyer-supplier relationships. Distributors who position themselves to be indispensable to manufacturers to move their goods forwards through the supply chain or distributors who position themselves so that the retailers have a high degree of dependency on their services will hold some degree of dominance in supply chains. Global distributors who can perform efficiently and effectively in a geographically complex supply chain will also gain some degree of domination.

3.5 Reverse logistics dominance

A recent successfully emerged strategy in supply chain management is that of the green supply chain in which reverse logistic distributors play a dominant role. Their role is more important in the extended rather than the closed loop reverse cycles. The collection, testing, redistribution to product manufacturers or component and parts manufacturers and disposal and waste management are all done by distribution operators. Within reuse and remanufacturing cycles, distributors play a minor role but they play a dominant role in the recycling processes. Distributors control the material flow deciding on extraction, recycling and disposal of materials. The strategic position of the distributor adds value with the technical knowledge concerning the products so that they can undertake the process of inspection, testing, redistributing and even making the decisions relating to recycling within the closed loop system or to recycle only materials into an extended recycle loop. (Sangwan 2006)

4. Strategic supply chain management

Strategic approaches include the efficiency and effectiveness strategies which Christopher (2002) termed the 'lean' and 'agile' strategies. Strategies that differentiate a supply chain from its competitors were initially seen as the customer responsive or 'agile' strategic approach but the basic concept of differentiation strategies is for the supply chain capabilities to have distinguishing features to gain a competitive advantage. Differentiation strategies in supply chain management typically include time-based strategies, such as speed, timeliness, reductions in cycle times and other time reduction initiatives that technological collaborative can provide. Financial strategies are slightly different from the traditional economic based efficiencies strategies. Financial strategies include focusing on operational efficiency and performance metrics such as return on assets and investments. It also includes improving productivities in transportation and inventory management, facilities and equipment utilisation. Sourcing and outsourcing strategies are sometimes included with financial strategies. Technology based strategies focus on using the tools currently available to value add along the total supply chain. Global and relationship based strategies link the domination elements of the supply chain.

Strategies that extend beyond the competitive advantage strategies include growth, environmental, risk and security strategies. Growth strategic goals in supply chains can be achieved via partnering, mergers, takeovers, alliances, outsourcing, and geographic or product expansions. Diversification, e-commerce and e-logistics are definitive strategies that assist growth. The ecological, 'green' or environmental strategies used in supply chain include packaging, recycling, reusing, reverse logistics and environmentally friendly waste management practices. The deliberate inclusions of environmentally friendly facilities, transportation, e-commerce, organisational culture are definitive strategies that assist the implementation of environmental strategies within supply chains. Some supply chains use environmental strategies to differentiate their product, for example, Body Shop. Risk strategies include both avoidance of risk by moving premises or moving away from high risk areas and transferring of risks where risks can be transferred up or down the supply chain to rest on the supply chain participant that is most capable of handling the particular risk. Transfer or sharing of risk is a well used risk strategy in supply chain management. Outsourcing is a form of transferring risks in supply chains as it means that the outsourced company is more capable and more efficient of handling the particular operation. All supply chain participants will implement their own risk mitigation strategies but the risk mitigation strategy that is prevalent along the total supply chain tends to incorporate security issues.

Strategic issues relevant to supply chain domination will depend on where the source of domination arises. As shown above domination can occur at the supplier end of a very complex network where its strategies reach upstream to the end consumers or it can be dominated by the retailers whose strategies can reach downstream to the tiered suppliers and manufacturers. Strategic reach will also depend on whether the supply chain is partially or totally dominated. Another approach to analysing the effectiveness of various strategies implemented by dominant firms will depend on the type of supply chain.

Fisher (1997) looked at functional and innovative product based supply chains which in turn led to the two main strategies of efficiency for the functional based chains and responsiveness strategies for the innovative product based chains. This was extended to the lean vs customer responsive supply chain typology of Christopher and Towill (2002). The lean and agile strategies were further developed by Christopher. It was initially thought that the agile strategies would be implemented by retail dominated firms in supply chains and that manufacturer dominated supply chains would implement the efficiency and lean strategies. The functional and innovative product typology was revisited a decade later by Selldin (2007) and combined the innovative product type supply chain with the agile and customer responsiveness strategies. It was argued that these types of supply chains had strong strategic alliances with upstream and downstream participants. Distributors, especially distributors involved in global supply chains, became the natural supply chain participant who could integrate these strategies effectively. Finally the competitiveness of supply networks led to participants using strategies that combined both the efficiency and responsiveness strategies, ie the le-agility strategies purported by Christopher.

Perhaps most importantly their extensive research led them to conclude that logistics strategy has been stable over the last few decades. This is very interesting given the dynamic supply chain business environment. They also found that logistics strategies focus on efficiencies, coordination within supply chain participating firms and between the participating firms and risk mitigation. Risk mitigation strategies focused on achieving efficiencies through managing the complexities of the total supply chain and the uncertainties that the participating firms face in doing normal business.

Year	Authors	Strategic Approach
1987	Bowersox & Daughtery	Process Strategy involved the traditional approach of controlling costs. Market Strategy involved reducing the complexities for customers Information Strategy (otherwise referred to as Channel Strategy) involved achieving coordination and collaboration along the supply chain.
2008	Autry, Zacharia & Lamb	Functional Logistic strategies Externally Oriented Logistics strategies

Table 1. McGinnis, Kohn and Spillan (2010) summarised the following logistics strategic orientations.

There are power imbalances in all supply chains as the buyer-supplier relationships change their dependence on each other upstream and downstream along the total supply chains. If the power imbalance is too extreme then the buyer-supplier relationship can erode into an unproductive partnership in the long term. Although it seems intuitively possible there is little evidence in the literature at present showing that imbalances of power automatically involve actual misuse of power. Indeed Maloni & Benton (2000) found power asymmetry can promote supply chain integration and provide incentives for higher levels of performance. In 2007 Crook and Coombs suggested that dominant participants would use their bargaining power to benefit their own profits. When domination was gained through task independences and contractual arrangements preventing locked in partners disrupting product flows dominant players could and would use their power for their own gain. Crook and Coombs classified the task independences into the three types, namely, pooled, sequential and reciprocal. They found that with sequential interdependencies the followers were permitted to retain their profits. The dominant firm used this profit retention as an incentive to maintain their followers' co-operation. In situation of reciprocal task interdependences there would tend to be strong alignments of strategic goals. They concluded that in situations of pooled interdependencies the followers could hold different strategic goals; in sequential interdependencies limited strategic goal alignment would occur with weaker participants and in situations of reciprocal interdependencies there is stronger strategic alignments and closer working relationships and sharing of profits.

When a dominant firm forms alliances with its immediate upstream or downstream participants the domination effect becomes stronger. This occurs where there are strong competitive issues between supply chains. For example there are strong alliances and partnerships with manufacturers and suppliers in the Boeing and Lockheed Martin aerospace supply chains. In the recent Joint Strike Fighter contracts both these entities and their partners are collaborating to develop a best of practice supply chain where both competitors are working together to build and maintain these super fighter jets over the total life cycle of these planes. In this instance the tight collaborative practices and interdependence has reduced the domination effect of any participant of the duopoly supply chain.

5. Dissipation of domination in supply chains

With the increasing customer demands, stronger competition and rising development costs faced by B2B (business to business), B2C (business direct to customer) and even C2C (customer direct to customer) retailing over the internet could dissipate the dominant player roles in supply chains. Multinational firms are facing tightening lead times, higher customer expectations and reductions in design cycle times. These factors lead to closer collaborations along the supply chain which in turn lead to closer alignment of strategies.

Shifts in consumer demands arising from higher global disposable incomes and workforce reforms have led consumers to demand greater scope rather than scale in the production cycles. Customers are demanding more value adding items and products with greater complexity and more value added features. This implies that more complex supply networks are required to produce these sophisticated products. The growth of electronic commerce and internet and the variety of the goods plus the variety of customer demands will lead to tighter collaboration and higher dependency and thus a dominant player is crucial to the competitiveness of supply chains.

On the other hand the growth of electronic commerce and internet shopping are leading customers to eliminate the larger commercial retailers and in effect create dis-intermediaries in supply chains that include retailers, warehouses and distributors. Customers are dealing directly with manufacturer and thus perhaps the full cycle of domination has occurred. Although when the manufacturers regain their dominance they become very dependant on the distributors so the domination in supply chains will be bi polar more bi lateral and consequently stronger. The strategies of the manufacturers will also change to adapt to the customer responsiveness needs of dealing directly with consumers. Their competitive strategies will be both efficient and effective to gain the necessary competitive advantages in this dynamic trading genre. Some Original Equipment Manufacturers (OEMs) will gain greater control as the supplier parks shrink and the manufacturers control most of the supply chain.

The entire operations strategy of a supply chain will falter if they are not linked to the business strategies and marketing strategies of the product flows. Marketing and financial strategies of participants operating within a supply chain need to be linked as well. In global complex supply chains the relationship management strategies are vital to hold the power over the total supply chain to integrate all these strategic goals of the numerous supply chain participants. The firms within a supply chain may no longer compete with other firms in their industry but as a member of an entire supply chain will compete with other global supply chains. The entire supply chain strategy needs to aim for sustainable competitive advantage. It should also aim for a healthy resilience level. Consequently in these ever increasing uncertain times entire supply chains that do not have strong resilience strategies in place to enable them to speedily return to competitive operations after a disaster or a hazardous event has occurred somewhere along the global supply chain that disrupts operations significantly then that supply chain will falter.

Further dissipation of domination in supply chains has occurred with the recent introduction of sourcing strategies. The service level agreement (SLA) enables buyers to specify a minimum performance level from suppliers. It is a contractual arrangement that the supplier must meet to gain payment. Thus any dominant player in a supply chain has to meet a given quality of performance for a given price which dissipates the ability to dominate the upstream or downstream pricing arrangements as the contracts are based on quality. An extension of the SLAs is the Performance Based Logistics (PBL) systems which require strong collaborative and integrative supply chains to produce at a given set quality of performance over the long term. The United States military introduced this system of logistical support from 2002-4 and it is now mandated for all major acquisitions of military equipment. The implementation of a sustainable and efficient PBL contract requires close collaboration and alignment of strategies of the supply chain participants. It creates a win-win position for the client and all logistics service providers involved and thus domination in supply chains by any participant must work to a win-win goal. The overall determination of the PBL agreement is based on the buyer's goals and objectives upon which the required performance metrics are based. The participants operating in the providing supply chain have a very proactive role in interacting with their client.

6. Conclusion

The current state of play in the academic debate on domination of power in supply chains and strategic supply chain management approaches has been reviewed. It shows there is still some confusion and robust debate on domination and power influencing various aspects of supply chain management and processes. It also shows that strategies in supply chain management have some overlapping elements. The debate highlights the need for leaders of supply chains to be innovative and dynamic and most importantly, lead as an agent for change to cope with increasing complexities and uncertainties through appropriate strategies. Sustainable strategic approaches occur via collaborative influence rather than dictatorial or enforcement. The overall roles of dominant participants may not have ostensibly changed but key aspects that have changed recently have been their self awareness and the means by which they exercise their dominance. Influence rather than enforcement, nurture rather than demand, common goal setting and shared visions and profits are now the necessary pre requisites for successful strategic domination in supply chains. Domination is now viewed as a means of achieving win-win solutions for all participants along the supply chain.

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8

Vertical Collaboration in the Supply Chain

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Croatia

1. Introduction

Supply chain is a research area which has attracted the attention of many researchers for more than 20 years (Mehrjerdi, 2009) due to costs and time involved in managing materials, information and financial flows from the point of origin to the point of consumption. The simplest definition of the supply chain suggests (Waters, 2003) that it consists of series of activities and companies that move materials through on their journey from initial suppliers to final customers. On that journey each company somehow is adding value to the product. However, due to an increasing competition on the market and due to more demanding and more sophisticated customers, the picture of supply chain is getting more complicated. If we take into consideration that many companies have crossed their borders and have included some geographically separate operations into their supply chain, it is very difficult to successfully integrate and to manage all related activities. In the praxis, it is normally that every company is working for its own benefit resulting in duplicating effort and reducing productivity, lowering efficiency, higher costs and decreasing the level of customer services. However, environmental uncertainty expressed through shortening product life cycle, expanding product proliferation, and more demanding customers requires from companies to coordinate production processes across company borders, to tackle problems from the viewpoint of the whole organization, and to look for the greatest benefit of all chain members.

Namely, organizations' opportunities for value enhancement and cost reduction are clearer when they look beyond their own operations. Supply Chain Management is built on the principles of partnerships, the development and use of the connections that exists between the links of the chain to provide information that will increase the efficiency of all members in the chain (Helms et al., 2000). If it is successfully developed over a period of time, those partnerships lead to collaboration. In other words, collaboration is focused on relationship between all supply chain members and it requires the availability of integrated information and the high level of motivation and trust as well. There are two dimensions of collaboration that may exist in the supply chain: vertical collaboration between suppliers and customers, and horizontal collaboration between competitors and other supply chain actors.

This chapter focuses on the vertical collaboration which is more common and easier to implement than horizontal collaboration. The chapter is structured as follows. It will begin with the theoretical background where the insight into definitions of collaboration in the supply chain, types of collaboration, motives for implementing it, benefits of its usage, the discussion about the necessary prerequisite, and limitations for the successful collaboration between supply chain partners are given. In order to illustrate what needs to be done to synchronize all supply chain activities and to establish successful integration among suppliers and their customers (i.e. retailers and wholesalers), the results of the research study among Croatian companies are shown.

2. Theoretical background

Ayers and Odegaard (2008) argue that there are many definitions of supply chain, depending on the viewpoint of the author of the definition. According to them, common viewpoints define supply chain as the procurement only, distribution, or as a collection of information system applications. On the other side, Ayers (2006) gives more precise definition of supply chain as the product life-cycle processes comprising physical, information, financial, and knowledge flows whose purpose is to satisfy end-user requirements with physical products and services from multiple, and linked suppliers. If we consider the number of business entities which are involved in above mentioned activities and processes, it is obvious that there are potential areas for cost increasing and profitability decreasing. However, in today's competitive market, supply chain should efficiently integrate suppliers, manufacturers, warehouses, and stores so that merchandise is produced and distributed at the right quantities, to the right locations, and at the right time in order to minimize system wide costs while satisfying service-level requirements (Simchi-Levi et al., 2004). All companies along the supply chain - suppliers, transport companies, warehousing, etc. – have the same goal: to satisfy the customer. They move toward the traditional view where each company is focused on its own business objectives disrupting the flow of materials, goods and information and increasing costs. Thus, they co-operate in the chain looking for a more efficient flow of materials through the chain, for faster deliveries, and reduction of stock levels, for quick response to customer changing demands, etc.

Accordingly, they have to overcome typical supply chain and move towards collaborative supply chain.

Collaboration is defined as two or more companies sharing the responsibility of exchanging common planning, management, execution, and performance measurement information (Anthony, 2000).

Lambert et al. (1996) summarised three key factors that contribute to a successful partnership in the supply chain, such as: 1) drivers (the compelling reasons for forming partnerships, such as cost reduction, better customer services, etc.), 2) facilitators (the supportive corporate factors that encourage partnerships, such as similar management style, compatibility of operations, etc.); and 3) components (the join activities and operations used to build and sustain the relationship, such as communication channels, investments, etc.).

Supply chain costs that include production, inventory, distribution, marketing and selling costs are often cited in the literature as major factors influencing the implementation of supply chain collaboration (Saha, 2004). The supply chain environment with large number of root causes for costs is possible calls for collaboration between supply chain partners. Ayers and Odegaard (2008) state that majority of waste examples in the supply chain can be tracked to one or more of root causes: 1) variability root cause which includes anything in the supply chain that creates uncertainty in operations (missed deliveries, demand fluctuations, poor quality material, etc.); 2) product design cost which includes wrong decisions related to material choices, component obsolescence, suppliers, etc.; 3) insufficient information sharing which implies failures to provide or/and to manage information; 4) weak links which relates to poor relationships between supply chain members; and 5) unintended consequences which may result in cost raising practices somewhere in the chain. Therefore, the need for supply chain collaboration is obvious, as it provides (Waters, 2003): improved performance (due to more accurate forecasts, better planning, higher productivity of resources, rational priorities), improved material flow, better customer services with shorter lead times and faster deliveries, standardised procedures, becoming routine and well-practices with less duplication on effort and information, and so on.

There are two dimensions of supply chain collaboration (Barratt, 2004; Mangan et al., 2008):

a. vertical collaboration which includes collaboration between suppliers and customers,
b. horizontal collaboration which includes collaboration with competitors and other supply chain actors, e.g. in sharing manufacturing capacity.

Vertical collaboration is more common and easier to implement than horizontal collaboration, but they are not exclusive ones. Supply chains that achieve both vertical and horizontal collaboration would gain significant business benefit.

3. Understanding the reasons and preconditions for vertical supply chain collaboration

It is widely approved that collaboration and partnering between firms is an increasingly common approach for enterprises to discover and to sustain shared competitive advantages (Mentzer, 1999). However, the implementation of this concept does not provide benefits to enterprises involved in the flow of materials between suppliers and customers, yet it leads to the win-win-win situation with focus on consumers.

Collaboration is the result of a joint effort of the supplier and the retailer to attain mutual benefit and it does not happen overnight. Therefore, some preconditions for successful vertical collaboration should be obtained (Deloitte, 2008):

- financial conditions - trade terms relating to cost reduction and joint profitability,
- relationship characteristics – personal relationships, mutual trust, interdependency and commitment,
- compatibility of strategies - jointly developing goals and strategies,
- effective negotiations – efficiently use the negotiating time and active participation during negotiations,
- quality of account management – account managers need to have the relevant facts and figures to hand, and to be well aware how their company performs.

The greatest value derived from better supplier-buyer relationships is more satisfied customer, because when chain members begin to collaborate to solve possible problems and pitfalls in the chain, and to improve service, the customer is the final winner.

Christopher (1996) summarizes situation on the market by saying that “supply chains compete, not companies”, because the opportunity to reduce costs and to enhance customer value is the basis of the interface between supply chain members. However, there are some difficulties to achieve efficient supply chain collaboration. Many organisations simply do not trust other members of the supply chain and they are reluctant to share information (Waters, 2003). Traditional business relationships, which have been built on open market negotiations, need time to convert to a trust-based win-win situation in a supply chain (Mangan et al., 2008). Figure 1 shows “step-by-step journey” needed for the development of collaboration.

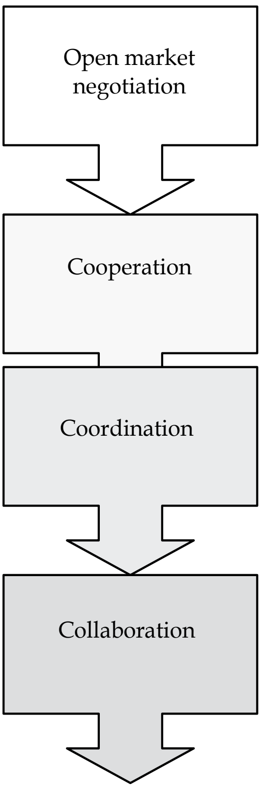

Fig. 1. The journey from open market negotiations to collaboration (Spekman et al., 1998)

Additionally, supply chain characterizes different activities, different organisations, different skills, geographical dispersion, etc., and it is very difficult to create a successful linkage within a supply network. Generally, a chain is constructed as hybrid network between independent companies (Reese, 2004) and it is intended that the companies involved in such a network work together. The efficiency of the whole supply chain of independent companies is based on a close cooperation of all chain members. Traditional customer and purchase orders are replaced with collaborative demand/order forecasts and an automated replenishment order flow (Friedman & Belkin, 2003)

Relationship between supply chain members leads to some benefits for the chain members and for the final customers as well. Some of the most important benefits are:

- improved communication and information sharing,
- elimination of activities that waste time or do not add value,
- balanced operations and lower stocks,
- more accurate forecasts and better planning,
- improved material flow,
- better customer service, with shorter lead times and faster deliveries,
- more flexible organisations reacting faster to changing conditions, etc.

Collaboration is very often recognized as an information sharing directed to sharing of production and inventory data, market places for buying and selling, and production planning along the supply chain (Ayers & Odegaard, 2008). It is widely discussed that the information technology revolution and the exchange of information are the foundation of the collaboration (Pooler et al., 2004). Mentzer, Foggin and Golicic (2000) found out that supply chain executives believed that advanced technology was essential to the success of collaborative supply chain relationships. Information technology enables collaboration by providing the necessary tools that make collaboration feasible and by supporting collaborative interorganizational relationships (Esper & Williams, 2003). However, information technology in and of itself is not enough to lead to successful collaboration (Mentzer, et al., 2000) because human factor lies behind everything. Namely, only well-educated employers, that know how to use information technology, will provide true benefits of information system.

Lapide et al. (2002) describe collaboration as a three-stage process which begins with simpler form of information sharing that are relatively easy to automate, and finishes with joint decision making and win-win partnerships across network.

Partnership that derives from supply chain collaboration could become a source of innovation. New process technologies entail collaboration because they require installation of technical capabilities all along the retail supply chain.

The development of the relationship between trading partners can be divided into three levels:

1. Initial level of collaboration, where chain members exchange information mostly to complete day-to-day transactions,
2. Cooperative collaboration, where chain members have simultaneous access to information needed,
3. Cognitive collaboration, where chain members share information to jointly gain knowledge in order to joint decision making.

Retailers make effort to build longer-term and better relationships with their suppliers. There have also been changes in the style and the technology of supplier-retailer interactions. The fact is that the larger retailers have sought to extend their control over the supply chain and move away from the use of the wholesaler (Gilbert, 2003). The size of market share gives large retailers power over suppliers to negotiate prices and to absorb the role of the former wholesale intermediary, while ensuring the quality and service of product to the customer.

Collaboration provides a number of potential opportunities for vertical supply chain collaboration on the downstream as well as on the upstream side of the supply chain (Barratt, 2004). On the downstream side of the supply chain we can find: customer relationship management (CRM), collaborative demand planning with collaborative forecasting, demand replenishment, and shared distribution. On the upstream side of the supply, there are: supplier relationship management, supplier planning and production scheduling, collaborative design, and collaborative transportation.

4. Vertical collaboration methods

It is generally accepted that the main purpose of the retailer is to satisfy consumers better than its competitors. In order to achieve this purpose, retailers have to provide an assortment of “right goods to the right places at the right time for the least cost” (Kotler &

Kevin Lane, 2006). In the past, retailers have used a large number of suppliers and they were competing against each other for individual order. The current trend is to reduce the number of suppliers and to develop long-term relationships with a small number of them. Each supplier has different capabilities and retailer select them based on a supplier selection software package. They follow some of assessment criteria in four main areas, together with the kind indicators that would determine the likelihood of a supplier meeting these criteria (Varley, 2003) such as:

- product range and quality with the quality and variety of products available, where the retailer assesses the supplier's production specialisation and flexibility, design capability, technical capability, etc.,
- prices of products and discounts available for large quantities and for rapid payment, where the retailer assesses the supplier's financial stability, willingness to negotiate, scale economies, etc.,
- delivery in accordance with the retailer's specification in terms of timing, quantities and product variety,
- service by which a supplier is adding value to the retailer, where the retailer assess the supplier's speed of new product introduction, its handling of queries and complaints, etc.

Introducing a supplier rating system for measuring mentioned criteria, a retailer has the opportunity to rationale its supply base. Furthermore, a retailer facilitates communication and develops closer relationships with suppliers. They tend to retain their autonomy yet move the business together by forming supply "partnership". Table 1 summarizes the transactional vs the partnership approach characteristics in retail supply.

Transactional approach	**Partnerships approach**
short term or one-off	long term and on-going
many suppliers and buyers	few suppliers and buyers
disloyalty and lack of commitment	loyalty and commitment
low switching costs, little or no investment made in relationships	high switching costs, significant investments will have been made in the partnership
loose or no procedures	strict procedural guidelines
exchange centred on single person in firm	many people and departments involved in exchanges
changes in customer/supplier make little difference	change in customer/supplier causes disruption

Table 1. Transactional vs partnership approach (Varley, 2003)

A time progresses, those partnerships lead to collaboration and to higher level of operational efficiency. In this new collaborative environment each supplier gains a share of the total orders based on their ability to deliver the order on time and to specifications (Mangan, 2008). However, rather than searching for new suppliers, retailers are more likely to increase business with the existing supply base, which has already made some changes in order to adapt their products and services to retailers. Some initiatives that will improve retailer-supplier relationships are shown in Table 2.

Companies that want to build holistic relationships with selected suppliers across the chain raise their revenue and lower costs (Booz & Company, 2009). There is a wide spectrum of possible collaborative measures that can improve efficiency, raise revenues, and cut costs for both retailers and their suppliers (Table 3).

• The supplier's understanding of the retailer's target customer and the brand image that the retailer is trying to build. • Detailed feedback on sales from the retailer to the supplier. • Co-operation and co-ordination in marketing activities. • Sharing of information on relevant consumer and product/market trends. • Commitment of businesses to one another, including combined forward planning, store space dedicated to supplier's ranges, provision of point of purchase materials and fixtures for the retailer, retailer involvement in product development. • System integration to facilitate information sharing, including sales data, stock and delivery information. • An understanding of the retailer's quality standard requirements, including product quality and compliance on delivery and administration.

Table 2. What can improve relationships between retailer and its supplier? (Varley, 2003)

Revenue/margin enhancement	Process improvement	Cost reduction
• Increasing penetration of core products • Building multiyear strategies to grow/build the category • Managing/reallocating shelf space and products • Driving consumer convenience and impulse shopping • Collaborating more closely with private labels	• Launching new products collaboratively • Improving effectiveness of marketing efforts • Jointly improving promotion planning and management • Practicing life-cycle management • Utilizing POS data and improving on-shelf availability • Improving demand forecasting	• Decreasing shortage • Enhancing distribution efficiency • Redesigning display operating model • Optimizing the role of merchandisers • Reducing returns • Improving efficiency through supply chain improvements

Table 3. Collaboration levers for enhanced profitability (Booz & Company, 2009).

5. Limitations to vertical supply chain collaboration

Supply chain collaboration has proven difficult to implement (Sabath & Fontanella, 2002) due to a number of elements necessary to support collaboration such as (Barratt, 2004):

- Trust –defined as a willingness to rely on an exchange partner in whom one has confidence (Moorman et al., 1992). Trend of private labels and raising retailers' ability to manage them may cause the lack of trust between the manufacturer and the retailer, because premium-brand manufacturers introducing new products and concepts are afraid that their ideas will be taken over and used by retailers for their private-label products (Deloitte, 2008).

- Mutuality –reflected through mutual benefits and risk sharing among chain members.
- Information sharing - relied on the transparency and quality of information flows between buyers and suppliers. However, there has been an over-reliance on technology in trying to implement it (McCarthy & Golocic, 2002).
- Communication and understanding – related to the importance of clear and broad lines of communication in the whole chain that will contribute to faster information sharing between supply chain partners.
- Openness and honesty – resulted in high level of trust, respect and commitment.

Collaboration is not just about developing closer relationships between supply chain members, but also needs to identify with whom to collaborate with. Sabath and Fontanella (2002) suggest that the problem in the efficient implementation of supply chain collaboration is a great failure to differentiate between whom to collaborate with. Therefore, another problem in the collaboration appears and is related to a lack of trust between trading partners (Ireland & Bruce, 2000). Gattorna (2003) propose "segmentation" approach in the context of successful collaboration. This segmentation approach should be conducted on the downstream as well as on the upstream side of the supply chain. Namely, company has to segment its suppliers and customers and to intensify its relationships with a small number of strategically important customers and suppliers. Barratt (2004) argue that if customers can be segmented by way of their buying behaviour and service needs, then separate supply chains can be designed to meet the specific needs of the various customer segments. Moreover, suppliers could be segmented according to their abilities and requirements to service the segmented supply chain (Barratt, 2004). Additionally, one of these segments may be appropriate for a collaborative approach, whereas more distinctive approach may be suitable for other segments.

Booz and Company (2009) found main limitations of retailer-supplier partnerships and collaboration in the traditional retailers' tension to view their value purely as a means of extracting lower prices or promotional support from their suppliers. It should be noted that such maintaining of relationships often caused low in-store availability. Restricted communication like that eliminates the possibility of partnerships which can put the negotiation level and to add value to the whole supply chain.

Friedman and Belkin (2003) point out that order forecasts are the key preconditions for the integration and the coordination of supply chain processes of partners in the chain, but also that sharing demand forecasts alone cannot optimize manufacturing flexibility or enable a make-to-order manufacturing process.

6. The research on the level of vertical collaboration in the supply chain

For the purpose of this chapter, a research study examining the level of collaboration between retailers and their suppliers, tools necessary to establish successful relationship between them, benefits and/or problems raised from the partnership between those two sides, years of the partnership between retailers and their major suppliers, etc. on the Croatian market was conducted. But for the purpose of better understanding of the environment where the research was carried out, the main characteristics of Croatian retailing should be presented.

6.1 An outline of retailing in Croatia

The retail industry is a significant part of the Croatian national economy. It generates EUR 15,329 mil. in revenue and employs 145,472 persons which accounts for almost 10% of the total active workforce (own calculation based on data in RCCBS First release, 23rd September, 2009.) Croatian market is dominated by a limited number of multiple-outlet retailers. The Croatian retailing counts 37,353 outlets of various formats (RCCBS First release, 23rd September, 2009). Nowadays, among the main characteristics of Croatian retailing are concentration, internationalization and consolidation, with 71.4% of the market held by 15 retailers (compared to 16.6% of the market held by 10 retailers in 2002). On the first place, with 25.8 per cent market share domestic retailer, Konzum is the market leader. It has been followed by international chain stores such as: Schwartz Group (Germany) with Kaufland stores and Lidl stores; Rewe Group (Germany) with Billa stores; Spar (Austria); Ipercoop (Italy) and Mercator (Slovenia). Renko (2008) and Knezevic (2003) note that international retailers have introduced new standards and know-how to the domestic market, including new technology, a more customer-focused orientation, and an environment-friendly approach.

6.2 Questionnaire design

The questionnaire consisted of three parts. Part I relates to the domain of the strategic integration construct, dependence, flexibility, relationship quality, continuity expectation, and supply chain collaboration tools. 31 items are created based on Cassivi (2006), Johnson (1999) and Morgan and Hunt (1994). The respondents indicated their level of agreement on a 5-point Likert scale with strongly disagree (1) and strongly agree (5) as the anchors.

Part II of the questionnaire consists of 6 statements related to performance of the company. Statements were adopted from the study of Johnson (1999). A 7-point Likert format (1=much poorer than expected and 7= much better than expected) was used to assess the level of commitments of retail managers to the statements relating to effects of partnerships with suppliers. Here, respondents were asked to evaluate their firm's performance on sales, information flows, customer's satisfaction level, time reduction, business flexibility and inventory level which arose as the result of the supply chain collaboration. Part III of the questionnaire required some information on the companies in the sample, such as assortment, number of employees, number of suppliers, number of key suppliers, the length of the cooperation with key suppliers, etc.

6.3 Sampling procedure

50 Croatian retailers with different assortment were included in the sample. There were no special criteria in selecting the retailer, but the respondents were chosen based on their specialized knowledge of and experience with supply chain relationships, and their role in the procurement or sales activities carried out in the supply chain. The method used in this study was an e-mail based structured questionnaire. The companies chosen were retail companies dealing with food and non-food assortment. Similar to Coltman (2007) pre-survey telephone calls were made at each participant to identify whether they would be prepared to participate in the survey or whether they could provide contact details for the most appropriate person in the firm. The research was conducted in the period February – March 2011.

A total of 50 completed questionnaires were received, but three questionnaires were eliminated due to a large number of unanswered questions. The collected data were analyzed using SPSS. Except from descriptive statistics calculations, testing the reliability with Cronbach's Alpha coefficient was conducted. Before using items for further analysis, the reliability testing was conducted. The value of 0.81 for statements related to relationship quality, supply chain collaboration tools, dependence, etc. and the value of 0.86 for statements related to the performance of the company as the result of the collaboration with key suppliers suggested very good internal consistency reliability for all scales used in this research (the recommended standard of 0.7 has been suggested by Nunnally (1978) and 1.00 respresents perferct reliability). Since data were not normally distributed, a significance of the findings and the level of collaboration between retailers and their suppliers were was explored using Spearman correlation coefficient.

6.4 The findings

The structure of the sample cannot indicate a satisfactory level of representativeness as the majority of responding firms are large companies with more than 500 employees (32.1 per cent of the sample) and small companies with 10-50 employees (21.4 per cent of the sample). There are mostly retail companies (57.1%), but the rest of the sample consists of companies that are involved in retail and wholesale business (42.9 per cent of responding firms). The analysis of the number of suppliers reveals that half of the sample operates with more than 200 suppliers. Among them, the largest percentage of the sample (35.7 per cent) has got 5-10 key suppliers on average and 10-20 years of relationships with their key suppliers (67.9 per cent of the sample).

The mean scores for the degree of collaboration items (from 4.25 to 4.50) are very high (on the scale from 1 to 5) suggesting that respondents are aware of the importance of collaborating with their major suppliers. The largest percentage of respondents (49 per cent) identified direct procurement (forwarding of purchase orders to pre-qualified suppliers) as the most important supply chain collaboration tool. Mean scores for the collaboration planning items (from 3.90 to 4.36) suggest that respondents highly evaluate the possibility to exchange the forecast information provided by the supplier and to improve innovativeness. Table 4 reveals main benefits of the collaboration between retailers and the suppliers. Table 4 shows that the positive impact on output measures, such as sale, has the highest average score.

Item	Mean	St.dev.
the collaboration has a positive impact on resource measures	4.18	0.819
the collaboration has a positive impact on output measures	4.39	0.951
the collaboration has a positive impact on on flexibility measures	4.11	0.737
the collaboration has a positive impact on the firm's market share	3.86	0.832
the collaboration has a positive impact on the market share of major supplier's products	4.36	1.079

Table 4. Vertical collaboration main advantages

However, the mean scores for flexibility and dependence are moderate to low. Dependence and flexibility scales were adopted from Johnson (1999). Dependence was measured with items based on replaceability, for example "if we could not buy our stock from our present major supplier, we would likely be purchasing from some other major supplier". Flexibility was measured with items wich assessed the retailers' perceptions of the degree to which they behaved flexibly in the relationships, such as „in our relationship with our major supplier, we are willing to make adjustments for any reasonable change as needed". The results point out high level of dependence and low level of flexibility in the case of the Croatian retailers. Namely, they are not ready to easily replace their product line with a similar line from another company (64.3 per cent of the sample) and to purchase from some other major supplier (64.3 per cent of the sample). Additionaly, they are not willing to put aside contractual terms to work through problems raised by their major supplier (71.4 per cent of the sample) and to make adjustments for any reasonable change as needed (92.9 per cent of the sample).

As trust, and relationship commitment were recognized as the major supporting elements of collaboration in general (Barratt, 2004), respondents were asked about their perception of the importance and the quality level of the relationships with their suppliers. The mean scores for relationship commitment and trust (from 3.86 to 4.75) are very high suggesting that Croatian retailers intend to maintain the relationship which they have with their major supplier and that the relationship which they have with their major supplier is something they are very commited to. Finally, there is a high level of trust between investigated retailers and their major supplier.

In order to find out whether relationships between the retailer and its key suppliers may significantly affect performance, six-item performance scale was developed. The items are based on previous studies of Johnson (1999) and Morgan and Hunt (1994) and they are focused on the economic performance of the firm and the supplier's direct part in it. Correlation analysis (Table 5 in Appendix A) shows only moderate ($\pm 0,6 \leq r \leq \pm 0,4$) associations (Dancey & Reidy, 2007).

As we can see, there is a moderate positive association between the vertical collaboration (between retailer and its supplier) while developing strategy and improved inventory visibility in the supply chain. In other words, the more retailers consider their key suppliers in strategic decision making, the better is the visibility of inventories in the chain. Positive association between the importance for retailer to maintain the relationship with major supplier and inventory visibility is evident. Chi-square test suggests that all respondents confirmed those findings ($\chi 2$ = 10,691, df=6, p=0,014). There is also, moderate positive association between the direct procurement and capacity planning and inventory visibility. It is interesting to mention positive association between the collaboration planning items (reflected through the exchange of information between retailer and supplier and forecasting based on those information) and the improvement in the level of services in the supply chain and the inventory visibility as well. 32.1 per cent of the respondents completely agreed that flow of information between them and their major suppliers contributed to inventory visibility in the chain. Additionally, the collaboration has a positive impact on output measures, information and inventory visibility. More than a half of the sample (53.6 per cent and 53.5 per cent respectively) point out that the „supply" partnership led them to improved inventory visibility and to increased flexibility in doing business. Moreover, it allows them to increase the service level and to reduce cycle time. Table 5 also shows moderate positive association between the level of trust between retailer and its major supplier and inventory visibility and cycle time reduction. Chi-square test suggests that 78.5 per cent of respondents highly evaluated the impact of collaboration on their economic performance ($\chi 2$ = 14,940, df=6, p=0,002). There is also moderate positive association between retailer's monitoring of every aspect of transactions with its major supplier (to ensure that nothing inappropriate happen) and the improved inventory visibility. 57.1 per cent of the sample answered that as more they monitor transactions with major supplier, the more visible inventories are.

But, it is surprisingly that in the market situation when all business subjects are aware that their customers are their most important value, study among Croatian retailers did not confirm statistically significant relationship between all "basic" dimensions that portray the sampled companies' profile and improved end-customer satisfaction which resulted from vertical collaboration in the supply chain. This finding does not correspond to previously mention theoretical assumption of more satisfied customer as the greatest value derived from better relationships between retailer and supplier. Namely, when chain members begin to collaborate to solve possible problems and pitfalls in the chain, and to improve service, the customer is the final winner.

As expected, correlation analysis showed strong positive association between some supply collaboration performance outcomes and improved end-customer satisfaction. Namely, improved information visibility and service levels (as the result of vertical collaboration) are strongly correlated to end-customer satisfaction (r=0,702**, p=0,000 for information visibility; and r=0,616**, p=0,000 for service levels). Logically, strong positive association (r=0,690**, p=0,000) between increased flexibility in doing business which resulted from supply chain collaboration and end-customer satisfaction is present. In other words, the collaboration between retailers and their suppliers leads to efficient information flows and to higher level of services. Accordingly, increased flexibility in doing business is present. Finally, this win-win supplier-retailer relationship has got large positive effect on end-customers. In such a way, successful vertical collaboration can result in win-win-win situation for all chain members.

7. Conclusion

This paper is an attempt to reveal the importance of the collaboration between retailer and their suppliers in the supply chain. The fact is that today's competitive pressure to improve efficiency and to deliver added value for customers, forced all members of the supply chain to change the way of their business relationships. As major players in the supply chain, both retailers and their suppliers have recognized benefits of their closer relationships and the need to transfer from the traditional relationship which has experienced a high level of conflict between chain members. Some of well-known initiatives of suppliers and retailers have included Efficient Consumer Response (ECR), and Collaborative Planning, Forecasting, and Replenishment (CPFR) (Booz & Company, 2009), but in the praxis, a broad-based strategic collaboration remains a rarity, and most retailers still do not consider building collaborative value a core activity.

It is widely accepted that collaboration improves performance, but collaboration between retailers and suppliers is still relatively limited (Deloitte, 2008). Today's situation characterizes many retailers with their own labels. Therefore, they are increasingly coming into direct competition with suppliers: they are competing both for physical access to consumers and for consumers' brand loyalty (which is limited) (Deloitte, 2008). In such a situation, there are objective conflicts of interest between vertical participants in supply chains. Everyone in the chain is seeking to appropriate value for themselves from participation and, assuming economically rational behaviour, must wish to appropriate more of the value for themselves if they are able to do so (Cox, 1999). The literature review suggests partnering between firms as an increasingly common way for firms to find and maintain competitive advantage (Mentzer et al., 2000) and to reduce inventory and other logistics costs for both retailer and its supplier. The study conducted in the case of the European country in transition, confirmed that Croatian retailers recognized the importance and benefits of the collaboration with their suppliers. They pointed out positive impact of vertical collaboration on their output measures and improved information and inventory visibility.

Given this, it seems clear that managers on both sides, on the retailer's and supplier's side as well, require a proper understanding how to select supplier partners and to share the benefits and costs of their joint initiative. Achieving effectively collaboration is not a one-size-fits-all process and requires improved level of negotiation and more holistic relationships between chain members.

8. Appendix A

Item		*Spearman correlation coefficient*
When developing our firm's strategy, we consider our major supplier as a large part of the picture	Supply chain collaboration improved inventory visibility	0,505**
It is very important for our company to maintain the relationship with our major supplier	Supply chain collaboration improved inventory visibility	0,569**
Direct procurement (formards purchase orders to pre-qualified suppliers)	Supply chain collaboration improved inventory visibility	0,533**
Forecasting – exchanges the forecast information provided by the supplier	Supply chain collaboration improved service levels	0,479**
	Supply chain collaboration improved inventory visibility	0,536**
Capacity planning – determines the amount of capacity required to produce	Supply chain collaboration improved inventory visibility	0,596**
The collaboration has a positive impact on output measures	Supply chain collaboration improved information visibility	0,512**
	Supply chain collaboration improved inventory visibility	0,552**
	Supply chain collaboration reduced cycle time	0,500**
The relationship that my firm has with our major supplier is something we are very commited to	Supply chain collaboration improved service levels	0,585**
	Supply chain collaboration improved inventory visibility	0,556**
	Supply chain collaboration increased flexibility in doing business	0,548**
	Supply chain collaboration reduced cycle time	0,508**
There is a high level of trust between us and our major supplier	Supply chain collaboration improved inventory visibility	0,507**
	Supply chain collaboration reduced cycle time	0,558**
We monitor every aspect of transactions with our major supplier to ensure that nothing inappropriate happen	Supply chain collaboration improved inventory visibility	0,633**
	Supply chain collaboration reduced cycle time	0,488**

** Correlation is significant at the 0.01 level (2-tailed)

Table 5. The effect of collaboration on performance

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9

Collaboration in the Design-Manufacturing Chain: A Key to Improve Product Quality

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1. Introduction

Supply china management (SCM) is a well-established discipline that involves the coordination of an organization's internal planning, designing, manufacturing, and procurement efforts with those of its external partners (i.e. designer, manufacturer, supplier, retailers, etc.). To reduce inefficiencies in a supply chain, organizations are increasingly using information systems to integrate the systems and processes throughout their supply chain. Effective supply chain integration and synchronization among partners can eliminate excess inventory, reduce lead times, improve customer satisfaction, reduce cost and increase sales (Mclaren et al, 2002).

Collaboration is a trend in SCM that focuses on joint planning, joint designing, coordination, and process integration between suppliers, customers, and other partners in a supply chain. Its competitive benefits in include cost reductions and increased return on assets, and increased reliability and responsiveness to market needs. During the past 10 years there has been a significant trend of companies externalizing a wide range of functions that formerly might have been carried out in-house. There are many reasons for this trend, including increasing global competition, more rapid technical advance and the need for faster development of products with higher quality and reliability. It is almost impossible for any one firm to possess all of knowledge and technological capability needed to develop a complex product. This means that organisation has to focus on their core competencies and draw on the best expertise available world-wide to access specialties outside that core competence (Jagdev & Thoben 2001, Chung *et al.* 2004). Increasingly, companies are concentrating on core businesses and outsourcing other non-core activities. Consequently, quality management should be carried out across the supply chain, instead of only within the company. It is vital for companies to make the best of external resources and to cooperate with their partners on the supply chain in order to enhance their end-product quality (Wang *et al.* 2006). In leading-edge firms, management of the supply chain is regarded as one important way to gain a competitive advantage. Major American corporations such as Whirlpool, Boeing and Chrysler have shifted many of their design activities to key suppliers (Hartley 1997, Utterback 1974). To be effective, supply chain quality improvement must start from the design stage because design specifications have a major effect on a product's performance, quality and cost.

Currently, as a result of the fragmented global value chain, technology also has become an independent commodity (Guo 2006). Quality management in design and manufacturing phases are normally not implemented in the same company, but from the perspective of the whole supply chain. In increasingly competitive global markets, enterprises must maintain core competitiveness by shortening time-to-market, reducing costs, improving quality and integrating the resources of other partners on the supply chain (Chung *et al.* 2004). Strengthening product design capability is therefore becoming a key target of various companies（Lyu & Chang 2007）.

To a great extent, product quality depends on design and manufacturing processes, therefore studying how to improve product quality through collaboration between designing and manufacturing companies is quite significant, from both theoretical and practical perspectives. This is one of the objectives of the, Design Chain-Supply Chain-Management (DC-SC-M) project, focusing on the coordination issues between western designers and Chinese manufacturers (suppliers). To be successful in highly competitive global marketplaces where product quality is a vital criterion, the designer and manufacturer should improve the end-product quality cooperatively.

The major purpose of this study is to analyze the impact of design and manufacturing on final product quality, and to measure the importance of design quality in product quality. The design-manufacture chain model is illustrated since it is a decisive phase for determining product quality in many industries. Finally, we developed conceptual framework and formula for our Quality Relationship Model (QRM) to identify and elucidate the relationships between design quality, manufacturing quality and product quality.

2. Literature review

2.1 Product quality

Quality has emerged as a strategic factor, making quality management a necessity for overall operational effectiveness and global competence (Desai 2008). Quality is defined to be conformance to requirements (Crosby 1984). Previous research shows that, while product design may account for only 5 per cent of the product cost, it has a critical influence on 75 per cent or even more of manufacturing costs, and influences up to 80 per cent of product quality (Huthwaite 1988). Some have asserted that more than 40 per cent of all quality problems can be directly traced back to inferior product design (Leonard *et al.* 1982, Raia 1989). Moreover, the product design phase drives 70 to 80 per cent of the final production cost, 70 per cent of life cycle cost of product, and 80 per cent of product quality (Dowlatshahi 1992) (Figure.1).

The fact that quality must be designed into the product – as well as being "built-in" by downstream operations – has added to the recent emphasis on the new product development (NPD) process. According to the NDP concept product design, which drives a product's "innate" quality, is the key to overall product quality, and the design phase of the design-manufacturing chain (D-MC) is the most important phase in enhancing quality and reducing cost.

Increasing competitive parity in the areas of cost and quality has forced global manufacturers to seek other sources of competitive advantage with new product development rapidly becoming the focal point in the quest for sustained growth and

profitability. The implementation of the integrated product development (IPD) process has come to depend on the use of multi-functional teams (Birou & Fawcett 1994). Manufacturing management indicates what is possible in terms of manufacturability and works to combine the shortest possible response time with a high degree of quality and dependability. Getting these management functions to work together to develop superior products and reduce concept-to-market time remains a challenge for many organisations (Hayes *et al*. 1988).
'Soft' technical skills such as JIT,TQM, Management methods and level of collaboration have been found to be more influential in developing products and increasing supplier collaboration than 'hard' or technically complex capabilities (O'Sullivan 2003, Von Corswant & Tuna'lv 2002). Well trained technical liaison staff, administrative standards and collaboration will lead to greater levels of supplier involvement in design coupled with increased motivation to make larger investments in the design process (McIvor *et al,* 2006).

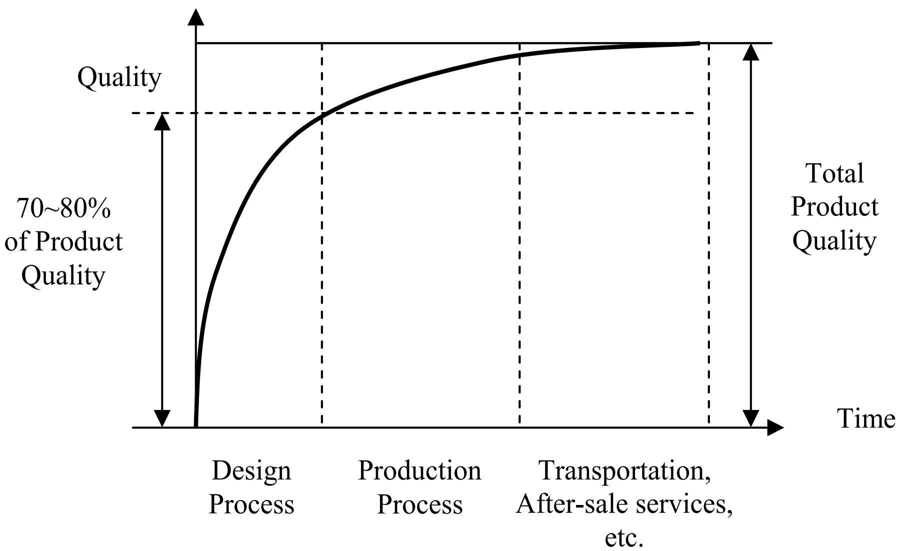

Fig. 1. Incline of Quality (Source: Dowlatshahi 1992)

2.2 Design chain

Firms in many industries are facing increased global competition and are operating in markets that demand more frequent innovation and higher quality. These firms are looking for ways to improve quality and reduce product cost. A large body of literature now exists which has identified new product development as a core process that has a major role to play in achieving success in the global economy (McIvor, Humphreys & Cadden 2006, Taps & Steger-Jensen 2007). A number of studies have identified a wide range of variables critical to successful product development.
The design chain is defined as the collection of business activities associated with all phases of product engineering, including research and development (Wognum *et al*. 2002). The design chain includes four stages: specification, concept design, detailed design, and production design (Hartley *et al*. 1997). The members in a design chain can aim to optimize the mechanical functions of a product, minimize the total production costs or achieve other settled targets (Lee & Gilleard 2002, McIvor & Humphreys 2004, Baglieri & Secchi 2007).

Design chain management is the management of the participants, both internal and external to a focal firm, that contribute the capabilities (knowledge and expertise) necessary for the design and development of a product which, on completion, will enable full-scale manufacture to commence (Twigg 1997). Thus, the design chain involves participants throughout the product development process, from concept, detail engineering, process engineering, prototype manufacturing, through to post-launch activities.

As operations become leaner (Lamming 1993), the focus of quality management will necessarily shift to earlier phases in the product development process, and especially to design relationships that a company forges with its outside suppliers. Each relationship may be considered part of a design chain (Clark & Starkey 1988, Twigg 1997) within a network of firms. Under total quality management (TQM) systems, product design efforts have two primary objectives: to design easily manufacturable products (Kitapci & Sezen 2007) and to design better quality products while minimizing costs.

2.3 Early supplier involvement

In many industries, firms are seeking to improve quality, reduce the cost of products and facilitate the smooth launch of new products. Early supplier involvement is a key coordinating process in supply chain design, product design and process design. Researchers have found that a number of benefits are attained though Early Supplier Involvement (ESI) in the product development process. Incorporating suppliers into project teams enhances the information and expertise regarding new ideas and technology (Smith & Reinertsen 1991, McIvor R. Humphreys P. & Huang, G., 2000.). In addition, it allows early identification of potential problems, thus improving the quality of the final product, eliminating rework and reducing costs (Dowlatshahi 1997, Meyer 1993, Handfield 1994).

ESI refers to customers and suppliers providing their ideas and resources in the early stages of the new product development process. It consists of two parts - early supplier involvement and early customer involvement. Many firms are also aware of the importance of the key suppliers in the early stages of their product development processes and in shortening the time-to-market. An earlier work has reviewed the involvement of suppliers in the earlier stages of a company's product development process to reduce considerably the lead-time and manufacturing costs. Today, manufacturers commonly strive for early supplier involvement in product development. Effective integration of suppliers into the product value chain is a key factor in the improving competitiveness of many manufacturers. Early involvement can occur in any of the stages of product development, as summarized in Table 1 (Dowlatshahi 1997, Hartley *et al.* 1997, Twigg 1998, Lyu & Chang. 2007).

Increasingly, suppliers are becoming involved much earlier (Appleby & Twigg 1988; O'Neal 1993, Sleigh 1993, Twigg 1998, Liker et al. 1996). Today, outside suppliers represent increasingly important members of the new product development team. Supplier involvement promotes better resource utilization, the development and sharing of technological expertise, and network effectiveness (Birou & Fawcett 1994, Wadhwa & Saxena 2007).

There is evidence that the early involvement of suppliers in product development is instrumental in reducing lead time and avoiding costly downstream production problems (Clark& Fujimoto 1991). Japanese supplier management methods involve intense and frequent communication during the product development cycle, particularly in the early stages when the product is being defined (Dyer & Ouchi 1993). This includes the in-depth and regular sharing of technical information to improve performance and reduce cost. The suppliers send 'guest engineers' to work full-time for extended periods in their customer's design offices along side the customer's design engineers (Dyer & Ouchi 1993, Liker *et al.* 1996).

Design stages	**Concept design**	**Specification**	**Detailed design**	**Production design**
ESI	Target markets Key product and process technologies Product architecture Contribute key ideas/concepts/ critical components Establish interfaces between product subsystem	Establish specification Avoid ambiguity and information distortion Identify early changes Identify key components required	Selection of proprietary parts and components Tolerance design Prototype testing and demonstration Design for manufacturability Materials selection Process design	Tooling design Design for Manufacturability Quality control and assurance Raw materials

Table 1. Early Supplier Involvement in various design stages

3. Design-Manufacturing Chain（D-MC）

Competitive pressures are forcing companies to design new products - or new versions of products - better, faster and cheaper. It is now generally understood that this can be accomplished through Concurrent Engineering (CE) (Schönsleben 2003) of the product and the manufacturing processes that make the product. From the emergence of market demand to finished-product delivery to the end consumer, the product goes through several phases including design, manufacturing, transportation, distribution and so on. The, design phase includes product planning, concept design, design specification and revision, while manufacturing includes prototyping, testing, production planning, and full-scale production. A Design-Manufacturing Chain (D-MC) (Zhu & Alard 2005, Zhu *et al.* 2006, Zhu 2007, Zhu & You 2009) is a chain or network made up of design and manufacturing companies, in which the final product is designed and produced within different companies. The simplest D-MC consists of only two companies: the designer / designing company (e.g. an Original Equipment Manufacturer, OEM) and the manufacturing company.

Manufacturers are included in the development process because they frequently possess design and technology expertise which designers usually do not know very well. Therefore, product time-to-market reduction and substantial cost savings from higher productivity, lower maintenance and fewer recalls are possible benefits of early supplier (or manufacturer) involvement in product design and development stages. A common method for accomplishing this is through cross-functional teams that bring product developers into direct communication with manufacturing engineers, marketing executives, and others whose input is important to the product development effort (Liker *et al.* 1996).

The essence of today's product development strategies is simultaneous development of the new product – also known as CE and/or design for manufacturability – such as product quality improvement, cost reduction, and lead-time shortening. CE carried out in the early stages of product and system design can bring out a series of benefits, by considering and including various product design attributes such as maintainability, marketability, manufacturability, safety, reliability and transportability.

As Design-Manufacturing Chain (D-MC) (Figure.2) shows, manufacturing process can start prototyping and tooling from the detailed design stage, not waiting until the whole design phase is completely finished.

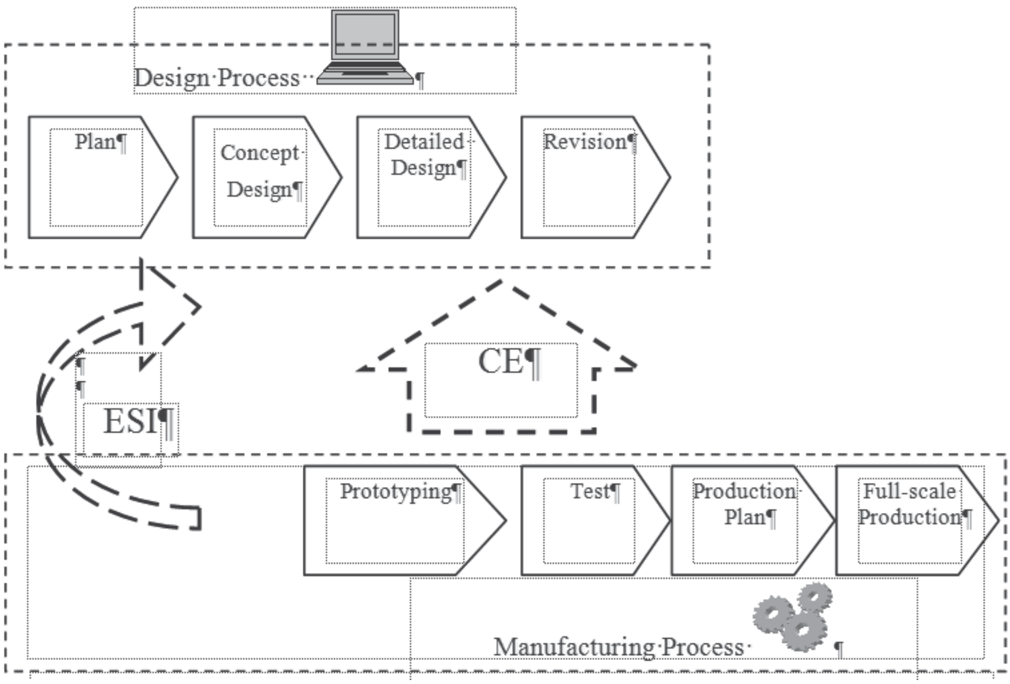

Fig. 2. Design-Manufacturing Chain（D-MC）

The philosophy of D-MC quality management is to control product quality from its roots and emphasizes early supplier (manufacturer) involvement in the process of product design and development, which may accelerate product innovation and optimize product quality. D-MC quality management is also based on win-win relationship of supply chain partners. Partners in D-MC should focus on quality information/resource sharing and on exchanges of manufacturing and testing information, rather than on bargaining.

There are many opportunities for manufacturers to be involved in major stages of the product development process. At the concept design phase, manufacturers help to identify up-to-date technologies to be incorporated into a new product. In the detailed design process, manufacturers can provide solutions for component or sub-assembly design and the selection of most suitable materials and components. Manufacturers have capabilities or know-how to provide the most effective tooling, fixtures and equipment. Throughout the product design and development processes, manufacturers may be involved in design teams to achieve DFM (Design for Manufacturability) and ensure the product will be delivered effectively and efficiently.

It is necessary to develop a methodology for better supplier involvement in the new product design and development process through a prototype web-based platform on the internet/intranets using web technology. A web-based framework can promote and facilitate early manufacturer involvement in the design stage, in practice.

4. Design-Manufacturing Chain Quality

According to the definition of quality, "quality of design process" means that design specifications should conform to the requirements of customers, and "quality of manufacturing process" means that manufacturing should conform to the design specifications. Although product quality is related to product delivery, after-sales service, maintenance, recyclability, etc., it is mainly shaped in the design and manufacturing processes, i.e., product quality depends on D-MC quality.

Based on a review of the literature and on interviews with expert partners from design, production and logistics departements as part of a research project with eight European industrial companies that cooperate on an international level, we will demonstrate the key determining factors for the final product quality . According to our research there are two primary factors influencing the final product quality: the design process of the product and the manufacturing process. Therefore, to a great extent, final-product quality lies on the quality of Design-Manufacturing Chain. Design-Manufacturing Chain Quality（D-MCQ）includes two parts, design quality and manufacturing quality. Design quality means that design requirements reflect the Voice of Customer (VoC) or the demands of market. Manufacturing quality means that the end-product conforms to the product design requirement and specification, where it is the conformance to quality. If design does not reflect the market requirements, the product can not meet the demands of market even though manufacturing conforms to the design completely, and if manufacturing does not conform to the design specifications, the finished product has poor quality and can not satisfy customers' needs.

Design-Manufacturing Chain Quality Management (D-MCQM) indicates supervision and control the quality of all activities on D-MC. D-MCQM can be depicted by three simple definitions that follow:

Design-Manufacturing Chain (D-MC) is defined as the chain or network made up of design and manufacturing companies and processes;

Quality (Q) means conformance to requirements;

Management (M) refers to the activities for design and manufacturing quality improvement.

Poor quality of D-MC includes poor quality of design and poor quality of manufacturing. Poor quality of design means that design requirements do not reflect the demands of customer adequately at the right cost, and/or at the right time. Poor quality of manufacturing means that manufacturing has not completely conformed to the design requirements/ specifications so that the final product can not meet market demands at the right cost and at the right time. Designs with technological deficiencies lead to inferior products, as do late stage design changes such as products that need to be recalled or re-manufactured. All of those are examples of poor quality.

Technological deficiencies in design, which is "innate" deficiency of product quality, may result in huge quality costs in many areas such as quality-related maintenance, warranty repairs and severe exterior (e.g. product safety liability, product returns, retail channel loss)

loss (Guo 2003). Manufacturing quality control usually can not solve the problems which are rooted in design deficiency. Therefore, design quality is decisive to product quality, so in order to create more customer value it is crucial to manage quality starting from the design process instead of focusing on the manufacturing process only.

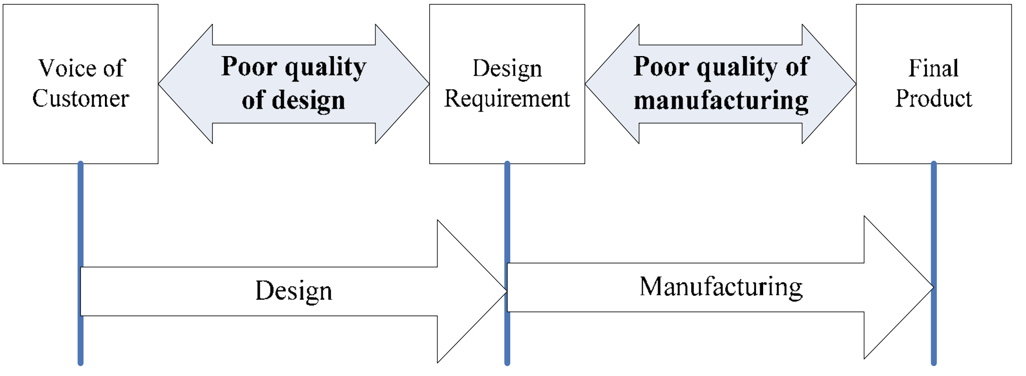

Fig. 3. Poor Quality of D-MC

An overwhelming majority of product failure costs and design iterations come from the ignorance of noise factors during the early design stage. The noise factors which crop up one by one in the subsequent product delivery stages cause costly failures. The Taguchi Method (TM) presented by Taguchi G. (1989) may help designers to select appropriate controllable factors so that the deviation from the ideal value is minimized at a low cost. Variation reduction is universally recognized as a key to quality reliability and improvement in D-MC.
Product design decisions are affected by many controllable and uncontrollable factors including technological, environmental and organisational issues.The number of controllable factors and noise factors for quality reliability change upstream (design process) and downstream (manufacturing process) in the D-MC (Figure.4). Generally, uncontrollable noise factors increase and controllable factors decrease along the D-MC. Accordingly, quality control from start or upstream is more efficient than downstream.

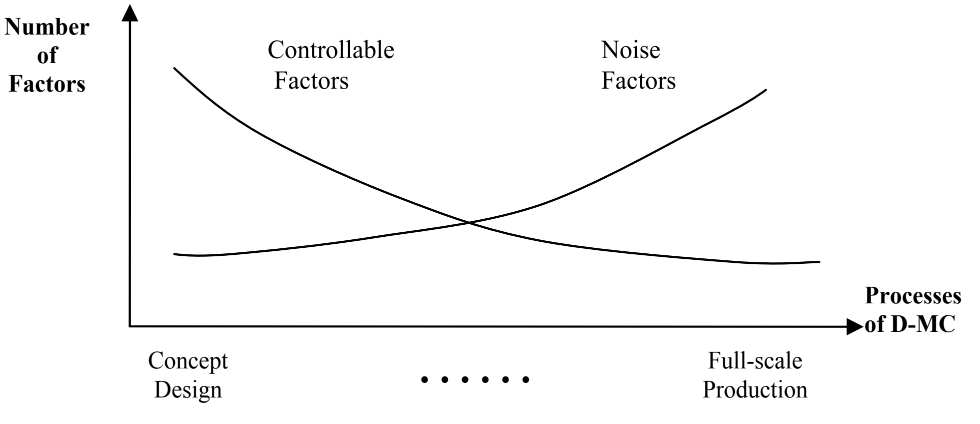

Fig. 4. Controllable Factors and Noise Factors on D-MC

5. Quality Relationship Model (QRM)

Therefore, the impact of design on product quality is much stronger than that of manufacturing. The Quality Relationship Model (QRM) can be illustrated with the leverage relationships between design quality, manufacturing quality and product quality (Figure.5).

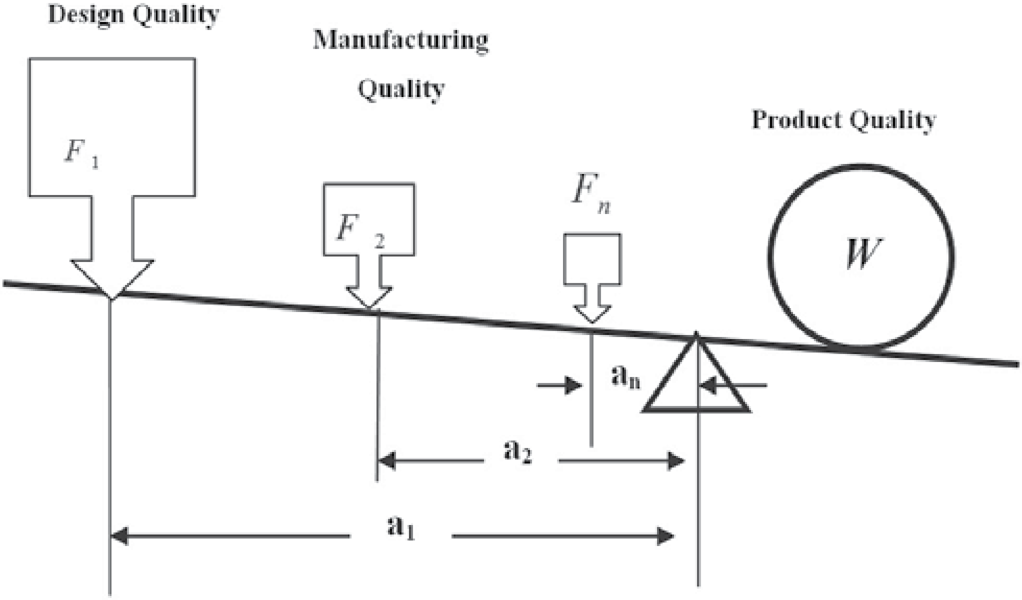

Fig. 5. Quality Relationship Model (QRM)

The followed formula expresses the leverage relationship of QRM in Figure 5.

$$W = F_1 \bullet a_1 + F_2 \bullet a_2 + \cdots + F_n \bullet a_n \tag{1}$$

where:

W denotes final product quality, the bigger W the better the final product quality;

F_1 : Design quality;

F_2 : Manufacturing quality；

F_3 --- F_n : The quality of every other process, e.g. delivery, after-sales service, etc.

If F_3 --- F_n are all of the processes influencing product quality, then

$$a_1 + a_2 + \cdots + a_n = 1 \tag{2}$$

a_1 : The impact factor of design quality on final product quality. According to Figure 1, the product design phase drives 70 to 80 percent of the product quality (Huthwaite 1988, Dowlatshahi 1992), so design influences 70 to 80 percent of the product quality (repetitive), and the impact factor of design quality is between 0.70 and 0.80,

$$0.70 \le a_1 \le 0.80 \tag{3}$$

a_2 : The impact factor of manufacturing quality on final product quality. If the impact factor of design quality is represented in formula 2, then

$$0 < a_2 \leq 0.30 \quad (4)$$

Larger numerical values of a_1, a_2 shows stronger impacts of the process on final product quality.
Certainly, the quality of other processes other than design and manufacturing, i.e. $F_3 \cdots F_n$, also has an influence on product quality. Their impact factors are $a_3 \cdots a_n$ respectively.
$F_1 \cdot a_1$ and $F_2 \cdot a_2$ respectively express the influence of design quality and manufacturing quality on product quality.
Based on an analysis of the formulae, in order to improve product quality, it is imperative to enhance design quality (F_1). A collection of tools for design engineering (e.g. QFD, DFMA, Tolerance Analysis, Robust Design, DOE, etc.) should be implemented in the product development process in order to avoid huge costs for re-design after a new product has launched. To avoid the expensive re-design activities and improve the manufacturability of the design, it is necessary to establish cross-functional teams to facilitate early supplier or/and manufacturer involvement to initiate the product research and development. The cross-functional team is made up of representatives from such groups as engineering, manufacturing and marketing. Meanwhile, it is also necessary to control manufacturing quality (F_2) to avoid manufacturing defects that arise from a manufacturer's negligence. This chapter advocates supplier involvement in the early phases of product design and development in a concurrent engineering environment. Early manufacturer involvement efforts will lead to better manufacturability, easier assembly and better quality.

6. Two cases from the toy and automobile industries

The Toy industry is a good case for a study of design and manufacturing quality because many "Made in China" toys are designed by foreign companies (brand owners, such as Mattel Inc.) but are manufactured by overseas suppliers, and especially by Chinese factories. Design problem would result in a poor-quality or unsafe toy irrespective of where the toy was manufactured. On the other hand, a manufacturing defect arises due to manufacturer errors or negligence. Toy manufacturers produce toys according to design specifications from toy designers; if the design itself has defects, the toys will definitely be faulty.
The recall of an estimated 20 million Chinese-made toys by Mattel on August 14, 2007 shocked the world. To explore the essence of this event, we have to examine deeply what the problems are and where they arose. The fault may occur due to design or due to manufacturing. The distinction between design and manufacturing is particularly important in the context of the toy industry because the design of toys is performed by toy brand owners whereas manufacturing is done by overseas manufacturers. Therefore, the effort to improve product quality and avoid recalls should be targeted at where the problems exist. Table 2 clearly shows that the number of toy recalls by flaw type over the last two decades (1988–2007) and the causes of recalls (Bapuji & Beamish 2007).
A design problem would result in a poor-quality or unsafe toy irrespective of where it was manufactured. On the other hand, a manufacturing defect arises from a manufacturer's

negligence. Toy companies develop designs and then send them to the manufacturers in China along with specifications. If a toy's design is good, it does not necessarily mean that the final toy product will be good. By contrast, if the design is poor, the final toy product will definitely not be good. In other words, only toy companies can prevent problems associated with design. On the other hand, manufacturing defects can be prevented by both manufacturers and by toy designers (brand owners).
Therefore, as Table 2 shows, the recalls of toys over the last two decades (1988~2007) are analyzed to examine if the number of recalls had systematically increased and what kind of problems resulted in recalls (Bapuji & Beamish 2007).

Year	Total Number of Recalls	Number of Recalls due to Design Flaws	Number of Recalls due to Manufacturing Flaws
1988	29	25	2
1989	52	42	2
1990	31	25	3
1991	31	29	1
1992	25	16	0
1993	20	15	1
1994	29	21	4
1995	35	32	0
1996	26	15	5
1997	22	17	1
1998	29	23	1
1999	20	15	2
2000	31	25	2
2001	23	15	4
2002	25	20	3
2003	15	14	0
2004	15	8	4
2005	19	14	3
2006	33	23	6
2007	40	26	10
Total	**550**	**420**	**54**
Percentage	**100%**	**76%**	**10%**

Table 2. Toy Recalls by Flaw Type (1988 – 2007) (Source: Bapuji & Beamish 2007)

Of the 550 recalls from 1988 to 2007, 420 of that (76 per cent) were caused by design flaws, in contrast, only 54 recalls (10 per cent) were due to manufacturing flaws. Therefore only 14 per cent of recalls stem from other reasons, e.g. transportation, storage. In other words, the majority of recalls were due to design-related problems, not manufacturing. Certainly, it is true that the percent of recalls by manufacturing flaws sequentially rose over the last three years, and Chinese manufacturers should consider this seriously, although this is not the topic of this chapter. Of the 550 recalls from 1988 to 2007, 76 per cent were caused by design flaws, in contrast, only 10 per cent by manufacturing flaws. Then other 14 per cent of recalls stem from other causes, e.g. transportation, storage.

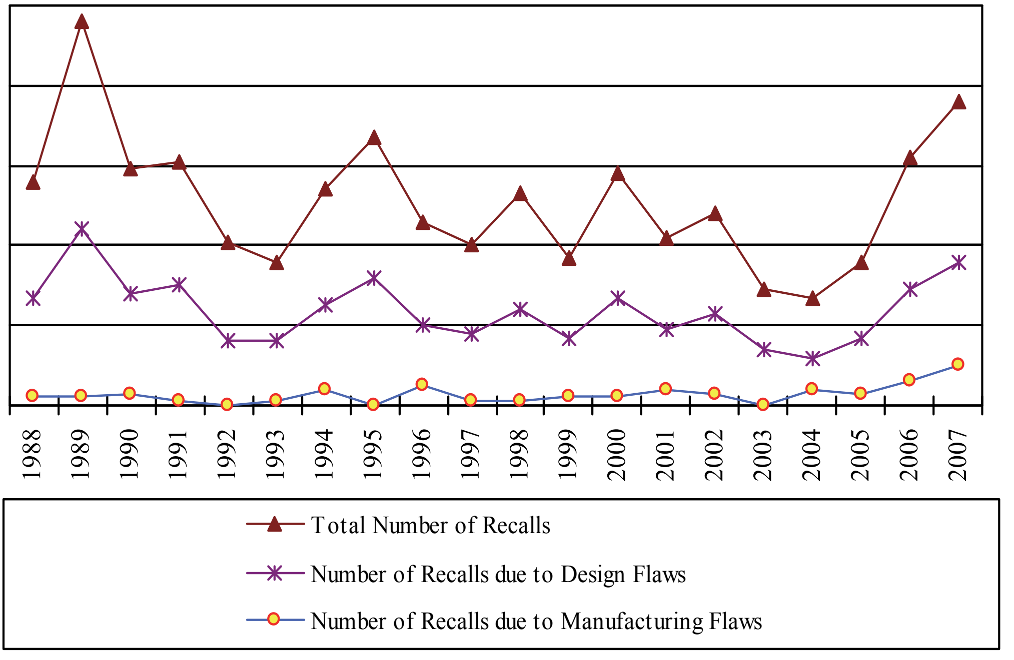

Fig. 6. Recalls by Flaw Type (1988-2007)

Applying the formula of the Quality-Relationship Model to the toy industry, if the impact factors a_1 and a_2 can be evaluated. If W_T shows the quality of toy, then the formula of QRM is as follows:

$$W_T = F_{1T} \bullet a_{1T} + F_{2T} \bullet a_{2T} + \cdots + F_{nT} \bullet a_{nT} = F_{1T} \bullet 0.76 + F_{2T} \bullet 0.10 + \cdots + F_{nT} \bullet a_{nT} \tag{5}$$

$$0.70 < a_{1T} = 0.76 < 0.80 \tag{6}$$

$$0 < a_{2T} = 0.10 < 0.30 \tag{7}$$

The formulae (6) and (7) validate the formulae (3) and (4), and accurately value the impact factors in the toy industry.

Figure.6 shows that design flaws are the crucial factor in toy recalls in the last two decades which caused severe injuries to child end-users. Toy companies must learn lesson and focus their efforts on improving the design quality. The analysis reveals that design flaws resulted in the overwhelmingly majority of toy recalls over the last two decades. Not only have design problems been more numerous but they also seriously damaged consumers. An overwhelming majority of the recalls could have been avoided with better design, and it is important to focus our efforts on learning from the recalls that occurred in the past and minimize their recurrence.

The second D-MC case is taken from the automobile industry. A survey from Mckinsey, named *The Roadmap of Chinese Automobile Companies Going Global* (Gao 2008), shows that the quality problems in assembly accounts for about 10 percent of the quality problems of all stages of automobile production. Most of quality problems originate in design. For example, one assembly company found that the excessive noise in brakes resulted from brake material which had been selected during the design stage. Some quality problems stem from process design or from design specifications. As a whole, out of the top 50 defects mentioned by the assembly company, 85 per cent were introduced prior to the assembly process (Figure.7).

According to Figure.1, about 80 per cent the quality problems of suppliers are derived from problems with component design. So, out of the "Suppliers" section in Figure.4, 80 per cent of quality problems of suppliers, i.e.36 per cent (80% multiplied by 45%) of final product problems, are derived from design. Then, in total, 76 percent (40% plus 36%) of the problems come from the whole vehicle design and the component design. This figure (76%) exactly coincides with the percentage observed in the toy industry. Certainly, it is a mere coincidence between these two different industries, but at least, these two cases indicate that the impact factors in the Quality Relationship Model (QRM) are reasonable.

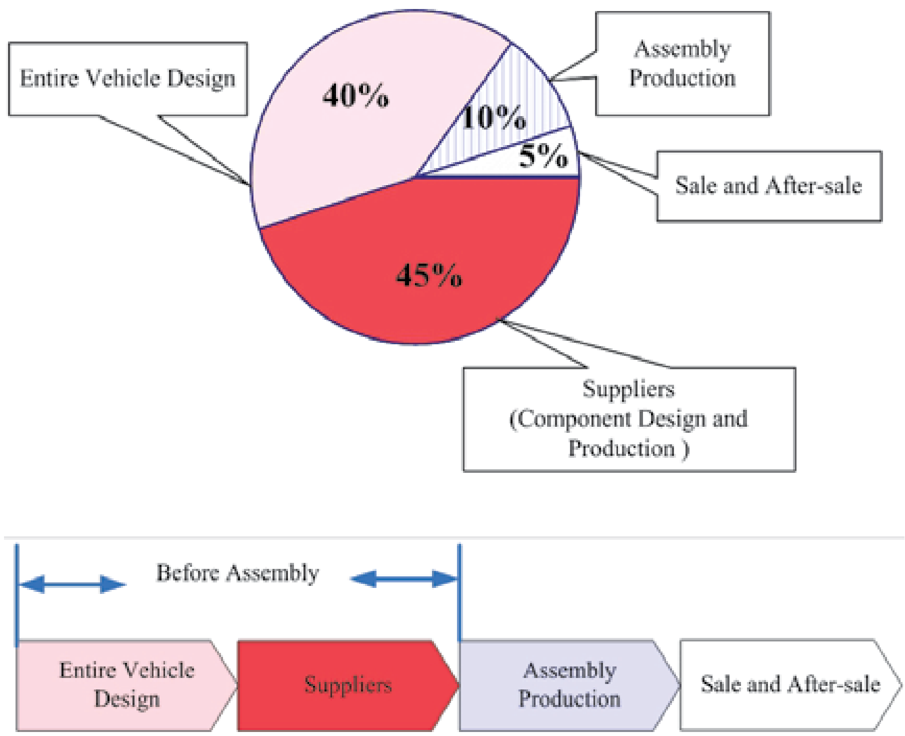

Fig. 7. Total Quality Control in Automobile Production

7. Conclusion

Compared with others phases of production, design has a crucial influence on final-product quality; in other words, the quality of design is more important than that of other quality issues on the supply chain. This study presents a formula showing a leverage relationship among design quality, manufacturing quality and final product quality, which shows clearly that improving the design process is the most effective path to improving final product quality. Based on the QRM formula and the case studies of two different industries (toy and automobile), this chapter explains and explores the impact factors of design and manufacturing on final product quality. In summary, to optimize product quality, it is crucial to manage the D-MC successfully by collaboration of the partner companies throughout the whole supply chain.

Although the impact of design on quality in various companies and industries may be different, through the analysis of the empirical cases from two different industries, the findings of this study have important implications for managers responsible for integrating suppliers into product development projects. Our findings emphasize the importance of design on the final product quality. These results should be encouraging to companies trying to decide whether involving suppliers in their new product development efforts is worth the effort required. This study reminds quality managers to turn their attention to design process to improve product quality and performance, instead of keeping their eyes solely on manufacturing.

Finally, from the view of technology and innovation management in supply chain, process or organisational innovations will tend to relate to supply chain (e.g. reducing costs, improving production quality and capabilities, shortening the time-to-market). Some barriers relate to all types of innovation (e.g. cost factors) while others relate to a subset of innovation types. There a clear need to make further investigation and validate the models put forward in this study.

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10

Integrated Logistics in the Supply of Products Originating from Family Farming Organizations

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1. Introduction

The family farming sector is of fundamental importance for food safety in Brazil and other countries. This sector mobilizes 14 million people and represents 60% of the agricultural workers. The small farms represent 75% of the rural properties, 25% of national cultivated land and 35% of the national agricultural production (IBGE, 2006)[1]. A great diversity of food, especially that which forms the basis of the diet of the Brazilian population originates from small farmers, in particular those who work in the vegetable sector.

The main characteristic of this production is that it happens in small family farms with a predominance of short production cycles, strong seasonality, intensive use of manpower and highly perishable products. Besides their logistics difficulties to access their clients, the small family farmers also have problems to insert their products in the institutional and fair trade market that requires volume, special schedules and higher quality standards. That means that the products present short post-harvest periods, which influence the location of the crops, which must be preferentially close to the consumer market. These elements presented demand researches related to process and practices that can increase the shelf life of these products.

In this context, we verify a tendency of the family farmers to organize themselves in associations or cooperatives. That is why it is necessary to analyze how logistics can be a strategic instrument of competitiveness for these organizations. They really need to be organized to access markets and that is why logistics management can improve their level of organization, helping them to become more efficient and have better management, not only of their production, but also of storage and distribution processes.

The challenge is to distinguish the context of each group of family farmers (vegetables, dairy, handicrafts, tourism and others), even if they do more than one of these activities. There are particularities existing in each one of the logistic chains of family farmers' products and that makes the complexity of these chains a challenging search for solutions.

If the implementation of integrated logistics is complex for large companies, the same logic can be applied to small organizations, even if the contexts are distinct. While large

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[1] Instituto Brasileiro de Geografia e Estatística (Brazilian Institute of Geography and Statistics).

companies have financial, human and technological resources to overcome this challenge, small ones have limited assets.

How then do we adequate a logistic management system for small family farmer organizations? Their peculiarities and limitations have to be known and understood before proposing any solutions. This discussion intends to elaborate a methodological proposal that permits an assessment of the integration of the supply chain of family farmers' products.

For the theoretical framework we used the description and concepts related to the reality of this kind of organization, that usually are presented as associations or cooperatives. Firstly we considered the definitions and relations among logistics and family farming concepts, starting with the peculiarities of the latter, in order to contextualize the logistic chain of family-based agribusiness.

Next, we treated the management of flows, according to its demands of cooperation, coordination and integration, both inside and outside the organizations. Simultaneously, we utilized the results of empirical research carried out with family farmers' collective organizations in Brazil in the evaluation of the main logistic problems.

The practice of integrated logistics begins to show its strategic importance for any kind of organization, including family farming organizations. Integrating the supply chain means to improve and minimize the costs, increasing market competitiveness. One of the advantages of integrating the logistic chain in the marketing of family farming products is that the principles found in the concept of integrated logistics corroborate for collective practices in the organization, where one of the factors of success is related to the construction of a bridge of trust between the various members of the chain.

2. Peculiarities of the family farming organizations

According to the last agricultural Brazilian census (IBGE, 2006), in Brazil there are approximately 5.17 million farms, of which 4.36 million, about 84.3%, belong to family farming. Concerning the 329.9 million hectares of existing agricultural area, only 80.25 million or 24.3% of the total area are operated by family farmers, their average size corresponding to 18.6 hectares.

Abramovay et al. (2003) define as familiar "those units where management, labor and ownership of the means of production (but not necessarily land) belong to the direct producer" (p. 9). Family farming is thus defined not by the extent of the area, but by the management and majority presence of family labor in the establishment.

Family farming represents approximately one quarter of the country's agricultural area, and corresponds to one third of the Brazilian production, being responsible for producing a number of foods that come daily to the Brazilian's table. Considering plant foods, family farms produce about 87% of the national cassava, 46% of the maize, 70% of beans, 34% of paddy rice, 38% of coffee, 16% of soy and 21% of national wheat.

The activity of horticulture in Brazil accounted for 2.1% of agribusiness GDP, moving about 11.4 million of reais (the national currency) in 2005, with a production of 17.4 million tons. It occupies an area of approximately 782,500 hectares, predominantly familiar, with 60% of production concentrated in areas of less than 10 hectares, near the cities, known as green belts. Additionally, 8 to 10 million people depend on this activity (Melo, 2007).

Family farms account for a third of the amount of agricultural production in Brazil. However, most of those family establishments are characterized by low capital investment, poor qualification of manpower and a high degree of informality (Abramovay et al., 2003). To these characteristics, one can add the facts that the products are most often perishable – which makes their storage and transportation difficult, and there is a low use of technology associated to management difficulties which are partly explained by low investments and the low educational level of farmers.

In supermarkets, the entrance of products is subject to compliance with various requirements, such as having their own transportation, quality, punctuality and competitive price. Much of the vegetables offered in supermarkets come from family farmers, but in order to sell their products in these establishments, they need to be organized in groups such as associations or cooperatives.

Abramovay et al. (2003) mentioned that it is very common for a more structured farmer to gather the production of other producers. To reduce the risk of supply shortages, supermarkets prefer to work with a large number of producers. Still, the need for production volume and the lack of organization limit the participation of farmers having more limited resources. Thus, the production of smaller producers is primarily intended for small local markets and/or to supply centers, and only then to other types of establishments. For Woods (2004), the more alternatives one organization has, the less dependent it will be and the less the chance of being overly affected by the power of another organization. One must seek product diversification and the strengthening of marketing channels for family farmers (Orsi & Melo, 2004).

Since the last decade, however, changes have occurred in order to fill some of the shortcomings experienced by family farmers. Among them are the coordinated actions by some Brazilian public institutions which provide resources for projects aimed at improving the productive and administrative processes of family farming. Corroborating these incentives, Abramovay et al. (2003) consider that the family farming organizations are production units able to incorporate important technological changes, as well as to participate in dynamic markets and to operate in a responsible manner, with the credit that they may receive.

3. Main concepts used in the construction of a model of integrated logistics for family farming organizations

For the construction of the model and its working methodology, some concepts were re-discussed. Besides the concepts related to logistics integration, there were analyzed issues related to market price formation and organization of family production. This review helped to understand how integrated logistics can contribute to the inclusion of the family farmer on the market, based in a collective organization supported by integrated logistics processes.

3.1 Marketing and pricing of family farming products

For family farmers there are two major challenges: placing their products on the market and achieving fair prices that will ensure some profitability for their businesses. In this context it is important to understand how the process of commercialization of family farmer products works.

When we analyze the commercialization process used by family farmers, one can observe that their market inclusion depends on the degree of knowledge and technology that the producers can take control in their production process. In this context, producers can find two basic levels of the marketing channel: a channel called level Zero, used when the producer sells his product directly to final consumers, being the farmer markets one of the most used in this kind channel. The advantage of this way of commercialization is the approach of the producer to the final consumer, where the price received by the producer is equal to the price paid by the consumer.

On the other hand, small volumes of products are sold in this kind of channel, which is very fragmented. Since there are many sellers and buyers, prices are determined by supply and demand and there is not a great value added to the products offered. Also, the producer is responsible for the entire logistics process. This is a market more similar to perfect competition, where prices vary depending on supply and demand of products and there is a limited market for the operating area of the local fairs. The entry and exit of one seller does not change the product prices, because the volume offered is usually large.

The channel of level One is when the producer sells his products to a retailer who sells to final consumers. In this channel the sale is no longer done directly from producer to consumer. There is the role of the middleman, meaning that the producer receives a different price paid by final consumers. In this channel, the producer has added to his logistics costs: the transaction costs related to contract negotiation to define the quantity to be delivered, quality standards of the products and forms of payment. The entrance to this channel requires aggregation of some technology in order to ensure the negotiated amount, frequency of delivery, adequacy of packaging and transportation. The price paid to the producers is set by the buyer, featuring a market closer to the oligopolistic market, where there are many sellers spread with a small production volume and few buyers. In this case, we can observe that there are other variations in the structure of this channel level, but the participation of the middleman prevails, sometimes as a wholesaler who can provide multiple retailers, sometimes as a distributor who can provide for the retail market and also to local wholesalers. This marketing configuration is usually associated to the family farming products in Brazil, although some changes have been occurring.

Wilkinson (2003) reflects on the changes occurring in this segment in Brazil, from an academic and political investment that transforms production on small family farms, including them in the modernization of the agri-food system and targeting both external markets and their reinforcement in the domestic market. During this same period, there are changes in the regulatory framework and institutional economics, as well as in the agri-food system, creating a new competitive environment, which threatens the inclusion of family farming, mainly because of its small volume of production.

One of the most promising sectors of family farming is the production of vegetables, which also accompanies the scenario which has changed due to the modernization and trans-nationalization of the retail market, in the form of super and hypermarkets. At every major supermarket created, replacing hundreds of traditional grocery stores, the requirement of scale is strongly needed in this sector. It is observed that the new minimum levels of scale units indicate the necessity of forms of association as a pre-condition for entry, as well as unprecedented levels of quality required. A number of factors – the opening and regulation of markets, the regional integration of Mercosur[2], joining the WTO and, more recently, the adoption of good practices and traceability systems as a condition of access to export markets – are already shaking traditional chains (mainly meat and milk), imposing new minimum levels of quality.

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[2] Southern Common Market – economic and political agreement among Argentina, Brazil, Paraguay and Uruguay to promote free trade and fluid movement of goods, people and currency.

Now, however, there is especially the imposition of private qualities, defined by the supermarkets themselves and covering new objectives in this sector, such as homogeneity, appearance of the products and packing conditions. Also, the supermarkets impose a new dynamic to market coordination employing logistic systems that demand a capacity to supply and pay for a minimum cart of products in a planned and continued way on the behalf of the producer. What seemed, therefore, as a great opportunity for family farmers, which are excluded from the main chains of commodities, now seems to be a challenge where the advantages of traditional factors are not very important, considering the new knowledge and organizational and managerial capabilities required by large retailers.

Corroborating this reflection, Melo (2001) examined the horticultural sector in the 1990's and found that in this sector a major restructuring in the marketing process is happening, from a central agent represented by the large supermarket chains. These changes have left negative impacts on the productive sector, which is not yet prepared to meet the demands of those markets. The author observes that the factors for restructuring the sector are related to the expansion strategies of large corporations.

The increasing complexity of business transactions has led the major supermarket chains to coordinate the whole process and take the leadership in the market, influencing the entire production chain. And this leadership has led to a greater bargaining power with suppliers, with impact on the formation of prices received by producers, characterized as an oligopolistic structure, with the asymmetries of market power. This structure of power ends up pushing down the prices paid. The result of this structure was the loss of capital in the Brazilian productive sector in the last ten years, as the bargain power of producers became increasingly reduced. They had to accept the conditions imposed by retailers, such as prices and payment terms. The author also considers it essential to think about a new form of organization and functioning of the market for agricultural products that minimize this asymmetry gained by major retailers depending on their proximity to the consumer market.

The research lead by Belik & Chaim (1999) showed that these changes are occurring especially among the various segments of the production chain of vegetables and fruits, with the emergence of new alliances in this sector in Brazil. The producers are changing the way they produce and sell. They are increasingly paying attention to issues related to quality and product segmentation. To meet the increasing demand of the final consumer, the segments of this sector are changing their way of relating, strengthening the integrated management of the chain.

The current impact observed in this segment is the organization of these suppliers in associations and cooperatives, performing in an integrated manner with the retail segment, in particular the networks of supermarkets and hypermarkets. It must be noted that this partnership and the cooperation of retailers with suppliers tends to be strengthened, forming an alliance. The development of alliances is being considered a more competitive advantage in reducing transaction costs.

This new marketing reality calls into question the traditional structures of existing organizations in family farming agribusiness. According to Ploeg (2000) apud Mior (2005), the tendency of this economy is characterized by a better income support from the development and combination of resources controlled by the farmer, plus greater flexibility and multiple use of resources. This construction requires a process of gradual development, considering the available resources, whose trend is the emergence of multifunctional companies, with local capacity for innovation and gradual change, so that the learning process happens and the focus is on the collective work and in the networks that are under construction.

Accompanying this tendency is a discussion about the need to establish a new form of collective organizations of family farmers. Araújo (2003) apud Mior (2005) argues that the concept of agribusiness is more of an aggregated view of the economic life of the system of production and distribution of food, with the growing participation of not strictly agricultural activities throughout production, processing, manufacturing, distribution and consumption of food. The author notes that it is the post-harvest activities that add more value to agricultural products and that certainly is the target of economic agents seeking to capture the value added.

Given this reality and considering the growth of competitiveness, there is the need to seek an alternative organization of family farming producers to ensure its profitability and market insertion. Several studies have sought to understand the production chain, signaling new trends for survival of the family farmers.

From an agrarian point of view, linking the rural agricultural development, the trends point to the adoption of a more systemic view, which, according to Moyano (1997), includes strategies to stimulate all resources – agricultural and non-agricultural – existing in rural communities. This new structure, taking into consideration the pressures of competitive markets that are more open and demanding, seems related to technological development and the integration of the rural areas. Thus, it is important to create an agricultural complex which, besides the production of food, can also add to its distribution.

The retailers are going through strategic organizational and technological changes, including the establishment of direct relations between retail food chains and agribusiness, thereby reducing the importance of the intermediation and wholesale sectors in retail supplies, promoting a new model of negotiation.

For Souza (2000) this new form of trading will evolve to the so-called "strategic partnerships", because even though the supermarket chains are concentrated, they cannot remain competitive without making arrangements with the productive sector. Among the forms of agreements, there are: financial, human, technological and logistics partnerships. Thus, the restructuring of production and marketing for family farming must include the tendency to make arrangements to overcome barriers to competition intensified by the globalization process.

Facing the new tendency of the structure of agriculture and its relationship with the market, it becomes necessary for family farmers to organize themselves in cooperative networks with the goal of operating in a regime of intense partnership in a given region. In this way they will be able to get products to market competitively and with higher aggregated value. In this scenario, the practice of integrated logistics can help in shaping the organization to act in this complex and globalized market.

3.2 Revisiting integrated logistics concepts for the proposed model

In this section we discuss the main concepts related to logistics, trying to place them within the family farming context. These concepts have been increasingly used as essential elements for facilitating more efficient organization managements. Another tendency that has been observed is related to the growing number of family farmers organizing themselves into associations and cooperatives, as mentioned previously.

Logistics is defined by the Council of Logistics Management as the management of flows of raw materials, materials in process and manufactured products, as well as information related to them, from the point of origin to the point of consumption. Due to its integrative character, logistics can be applied to different stages of a production chain.

Production chain is defined as a set of interactive components, including productive systems, suppliers of inputs and services, processing industries, marketing and distribution agents, as well as final consumers (Castro et al., 1998). The same authors define an agribusiness productive system as a set of interactive components that aims to produce food, fiber, energy and other animal or vegetable raw materials. The productive system is a subsystem of the production chain and refers to activities undertaken within the farms. The family farming agricultural activity is part of production systems, causing that part of the flows originated in these establishments to be coordinated by more structured agents.

Bastos & Araújo (2004) suggest the application of logistics in the development processes of small groups and initiatives as a way to provide better forecasting and planning conditions, enabling operational improvements and techniques, aiming at an integrated management of their economic activities. The authors also consider that it is possible to increase participation of local organizations in global processes through the adaptation of techniques and management tools already used in large organizations. The difference is that, instead of focusing only on economic goals, social goals should also be pursued.

Marchesnay & Foucarde (1996) emphasized the management inability of small agri-food organizations, since their activities are mainly centered on productive capacity, with little focus on management of other processes, such as storage, marketing and distribution. The same scenario can be observed in agriculture cooperatives, which lack a management culture. This deficiency distances these organizations from the market, since they are usually focused on production processes (Waack & Machado Filho, 1999).

Besides the internal management problems, producer organizations have other weaknesses: difficulties in making complex decisions, lack of criteria for allocating investments and restrictions on funding. Several authors consider the logistic problems of distribution and marketing in the cooperatives to be significant, where the scale of production is inadequate, and technology, in most cases, obsolete.

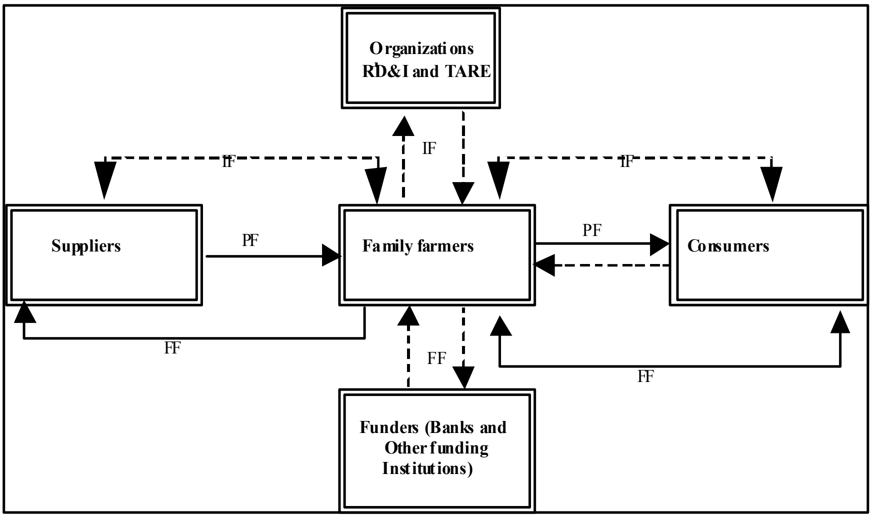
Moreover, the implementation of models of efficient management is not based on hiring the best professionals in the market or the best tools, but to adapt their management models to the characteristics intrinsically associated to the background and reality of family farming organizations. In this sense, it is essential to know the main flows concerning the process of placing the production on the market.

3.2.1 Main flows in the family farming agribusiness

Contextualizing the logistic flows within the family farming agribusiness, we found that many of them are deficient or absent. Figure 1 presents the main flows related to family farming logistic activities. In addition to the flows intrinsic to the logistic processes, there are also presented – in horizontal arrows – those flows coordinated with other institutions that are indirectly related to the supply chains and where the familiar establishments are inserted (vertical arrows). Even indirectly, these other flows influence the logistic performance of family farmers, since they represent other possibilities of supplying information and financial resources.

Among the flows inherent to the logistic processes, we considered the physical, financial and information flows of the logistic processes. The physical flows consist of i) flows of raw materials and packaging required to agricultural activities; ii) flows of sending products to the consumer market. In field research carried out with the vegetable producers in the

Brazilian Federal District it was observed that the return of returnable packaging was not systematized, which can cause delays in the delivery of products to the clients, since the vehicles have to wait for the release of the packages to then visit the next client.



Legend:
PF – Physical Flow
FF – Financial Flow
IF – Information Flow
RD & I – Research, Development and Innovation
TARE – Technical Assistance and Rural Extension
⟶ Consolidated flows
- - -▸ Deficient or absent flows

Fig. 1. Main flows in family farming-based agribusiness.

The financial flows consist of: i) the flows of material purchasing; ii) services paid by producers and iii) those exchanged with the consumer market. In this second case, the flows follow the two directions, as some producers pay for the rental of spaces in their client outlets. This situation is very common for organic products. Among the services paid for by producers, those concerning transportation, storage and equipment maintenance stand out.

Finally, the information flows cover all information that occurs between each component of the chain, from collection to final consumers. These flows are still deficient in most chains involving family farmers. This deficiency is not related only to customers, but also refers to the lack of collecting and managing information about suppliers. It is verified that larger customers utilize a more structured and better management of information, but there is still a lack of integration concerning producer information, in a way that may ensure efficiency to processes such as reducing waste of time and products.

Related to the flows indirectly connected to the family farmers supply chains, we have, mainly, financial and information flows. Financial flows occur between lenders – banks and other funding institutions – and the producers. These flows concern not only funding agencies, but also enterprises of research, development and innovation (RD&I) plus technical assistance and rural extension. The information flows must occur in both directions. i.e., between the institutions and the producers – at the time of training workshops and technology transfer – and between producers and organizations, when the priority demands must be clearly presented. In most of the cases, producers do not know how or to whom they should report their demands, once these demands should be addressed to meet collective needs. In this direction, it is important for producers to organize themselves into groups, because with this new condition they can be able to increase their access to the market. However, this is only possible if they make an assessment of logistic performance.

3.2.2 Assessment of logistic performance in family farming agribusiness

For Pessoa & Leite (1998), the performance of a production chain "can be measured by its ability to generate economic and social benefits to its participants" (p.291). Bialorskoski Neto (1999) adds that the efficiency of the agribusiness system is achieved not only through relations of price and productivity of the various factors traditionally considered by neoclassical economics, but also by reducing transaction costs along the chain and the implementation of an efficient coordination and governance.

The management of an organization uses performance indicators and other tools. These indicators should be included in management systems that integrate the various processes: financial, commercial, quality control, environmental, operational, environment, among others. Among the management systems, the systems of information and communication (SIC) are primordial to intra and inter-organizational cooperation because they encourage interaction. The quality management systems are also important, as they consider the organization as a set of processes that occur between multiple customers and suppliers.

3.2.3 Cooperation and coordination in the flows of family farming agribusiness for integration with the retail market

The term cooperation refers to joint or collaborative work. In a production chain, its members may have conflicting or cooperative attitudes. Many factors are related to this behavior, but certainly the degree of each of these attitudes depends on the degree of coordination presented by the chain. Castro et al. (1998) state that "ideally, the links of a chain should be cooperative, while competition should occur between components of the same nature" (p.16).

The coordination of agri-food production chains has been guaranteed by large retailers, who are increasingly forced to meet the demands of consumers. Thus, large retailers try to transfer the market pressures to upstream levels of production chains (Montigaud, 1992). Normally, it is the retail market that will establish the strategies and procedures needed for better supply chain integration, reducing the risks of disruption and discontent of consumers.

Chain coordination is an important element for its efficiency and success. Coordinated chains can supply the consumer market with quality products in a competitive and sustainable way. Chains that are not coordinated and do not deal with conflicts between their components can weaken and lose competitiveness and sustainability (Castro et al., 1998). Paché & Sauvage (2000) highlighted the importance of interaction between the different actors participating in the same productive project and provide some examples of reciprocal influence that contribute to reducing transportation costs, as well as maintenance and storage costs, if shared by the actors of a supply chain :

- Interaction between food industries and their suppliers (farmers) in order to establish the procedures for replenishments compatible with the intensification of flows;
- Interaction between distribution companies and industries to create compact packaging and reduce areas of storage; and
- Interaction among producers, distributors and carriers to standardize weights and volumes of the transported containers.

As already mentioned, to ens ure the integration of family farming production in the retail market, an important requirement is that producers must be organized in a cooperative way, not only among themselves, but also among their class entities, clients and suppliers. Below we present two types of cooperation that need to be adopted in the family farming agribusiness.

- Intra-organizational cooperation: this must exist primarily in activities that involve family members and the producers organization; and
- Inter-organizational cooperation: cooperation and coordination of operations between the organization and key consumers, such as supermarkets, industry, transportation companies.

The theoretical framework usually adopted to study inter-organizational cooperation is the Economy of Transaction Costs, even though in recent years several authors have demonstrated the limits of this theory in analyzing this type of relationship (Barthelemy et al., 2001; Koenig, 1999). Figure 2, proposed by Dornier & Fender (2001), presents the three possible types of logistic cooperation occurring between manufacturers and their customers: operational cooperation, trade cooperation and marketing cooperation.

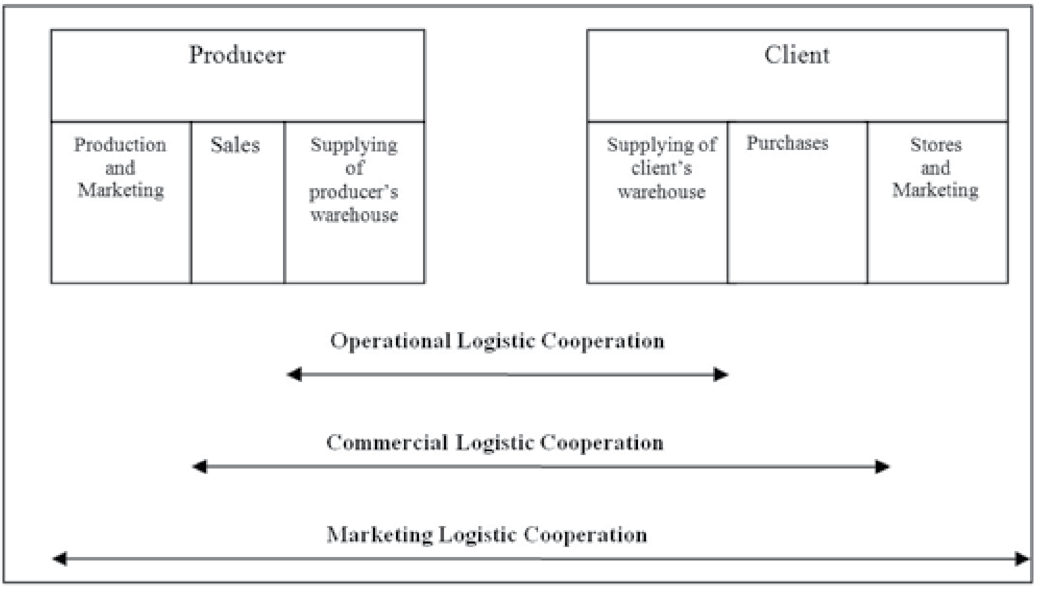


Fig. 2. Inter-organizational kind of cooperation in logistics. Source: Dornier & Fender (2001, p. 388).

In the figure, each kind of logistic cooperation implies in different organizational structures, which will be responsible for different working approaches among partners. "Questioning habits and historical relationship modes between producers and distributors are greatly raised. It should gradually be built a new space for exchange and make the theme logistics rather than a commercial operating space limited to one enterprise but a common working place which seeks not only to maximize the supply to the final customer" (Dornier & Fender, 2001, p. 390).

Concerning the agricultural cooperatives, logistic cooperation between them and their partners should not be limited to the operation level, especially because nowadays we have a scenario of strong competition among companies of all sizes. It is also a way to expand relation between actors, promoting better outcomes for two or more partners.

The next section will discuss how the concept of integrated logistics can help the construction of a model concerning the integration of family farming production with the retail market.

3.2.4 The role of integrated logistics in family farming agribusiness

The practice of integrated logistics begins to show its strategic importance for any kind of organization. Integrating the supply chain means to improve and minimize the costs, increasing market competitiveness. Some authors, like Christopher (1992), Chopra & Meindl (2003) and Romano (2003) defend the necessity of creating bridges of confidence among stakeholders, in order to share resources and information, as well as acting in networks, where the solution must be built together, with the participation of those involved in the problem, in a win-win solution.

The concept of integrated logistics applied to family farming agribusiness seeks to develop facilities for the negotiation of these organizations with the market. According to Lambert & Cooper (2000), to integrate the logistics of a chain means integrating business processes, which involve every supply needed for production till the final customer, sharing products, services and information.

One of the advantages of integrating the logistic chain in the marketing of family farming products is that the principles found in the concept of integrated logistics corroborate for collective practices in the organization, where one of the factors of success is related to the construction of a bridge of trust between the various members of the chain. In this sense, it can be inferred that the practice of integrated logistics can also help the accumulation of social capital. For Ostrom (2004), social capital is a variable in the generation of human capital and an aspect of social structure that facilitates certain forms of action and cooperation.

In a research carried out on understanding the concept of integrated logistics, Gibson et al. (2005) noticed that this practice has components related to mixing strategies and the implementation of activities that transcend individual and company roles. Moreover, it has an important component related to the collaboration between supply chain members, supported by a significant contribution in the areas of marketing, finance and sales.

Seeking alternatives of management related to integrated logistics applied to a family farming organization that works with perishable products implies understanding the interaction of different processes and activities related to the business sector to reduce time and resources involved in the chain as a whole, and not only in a single process. This strategy is crucial, once it involves highly perishable products, where the main challenge is to make them available to the final consumer in the shortest time and with adequate quality.

Authors such as Chow et al. (2005) argue that the greater the synergy among the supply chain actors, the greater the facility to find strategic solutions. In summary, it means that the experience exchanged among the various actors is one of the factors required for the construction of knowledge in the logistic chain, which will facilitate the implementation of strategies and logistic solutions.

It is worth noting the importance of information flows in adding value to products. Thus, it can be assumed that a chain is actually integrated when there is really a good flow of information, preferentially in real time among its participants. The asymmetry of information in the chain eventually can result in barriers that generate impacts on its profitability, as noted in the commercial structure still practiced in the market.

Stank et al. (2005) emphasize that the value of a chain is built from its internal activities, in synergy with external systems with the objective of adding value to the customer and by the incorporation of supply activities, marketing channels and purchasers. The authors argue that Porter’s logic can facilitate the construction of a management model that encourages the understanding of the relationship between the strategic and operational levels of integrated logistics. In a chain of perishable products, which is the case of the majority of products originating from family farms, the understanding of what is strategic or operational has a tenuous border, since a good strategy can be reducing the permanence of the product in the chain. For that it is necessary to ease the coordination of all processes, which are exclusively operational. In this context, strategic and operational planning act simultaneously to achieve the expected results.

The concepts discussed may imply that the logistic model of a chain depends on the conditions of competition that each product faces in the market, being related to their lifecycle. Since this is a chain of mainly perishable products, operational measures of performance also become strategic to maintain marketing competitiveness. These measures are linked to the performance of activities associated with speed, consistency and flexibility. The speed is measured by the time spent between the arrival of a request and the availability of the product on the shelf. When it is the case of a product whose shelf life is measured in days or even hours that time must be as short as possible.

The great challenge is to associate the shortest time with the lowest cost. Considering the speed, it is essential to have consistency, i.e., to provide products on time in a constant way. And finally, flexibility is related to competence in dealing with unexpected requests, such as a sudden increase in demand, changes in destinations, failure of supply or removal of improper products. So, it is this flexibility that facilitates the process of correction of faults and recovering from errors that may occur during the movement of goods in the chain.

Logistic quality requires a constant evaluation. It is necessary to maintain a good flow of information feeding the chain, in terms of demand as well as concerning the performance of operational logistic processes related to transportation, packaging, loading and unloading, handling of products, return of packaging, delivery schedule, and waiting time in queues for loading and unloading. These parameters directly influence the time that products are being moved in the chain.

In the particular case of a family farming chain, where usually the logistic processes are focused on time, its structure requires greater attention to the basic processes considered, requiring an appropriate planning to avoid impacts in the costs. As this is a chain where the products are usually delivered daily and are very perishable, it is ideal to plan the processes of collection and distribution to reduce the frequency of handling and loading and unloading at intermediate periods. Wherever possible, products should be delivered directly to the shelves, being available immediately to the final consumer. To plan the chain in an integrated manner, it is essential to have a precise monitoring of the demand at each point of sale, and that the information is able to be transferred to the producers' organization so that it can operate all the chain processes, ensuring consistency in supplying and in quality standards.

The structuring of networks in rural areas can be facilitated by the use of integrated logistics, which ends up supporting the organization of processes, information exchange and consistency of the bonds of trust built up from the transactions. The systemic monitoring of the chain leads to adjustments not only of processes, but also in the attitudes of the participants, strengthening the bond of trust between the chain members.

One of the most discussed points in the integration of logistic processes, which promotes representative gains for the whole chain, is to create a win-win relationship between the members, where everyone is committed to the quality and performance of their processes and concerned about the manner in which these results will be inserted in the next step of the chain.

Without this commitment and systemic view, it would be very difficult to achieve real gains from logistic operations. In fact, the gains are not concentrated in a single link of the chain, but they are distributed equally among all participants.

3.2.5 Understanding the supply chain of vegetables and fruits as an integrated supply chain

In the previous items we discussed the principal concepts and processes that favor the understanding of the logistic chain of family farming organizations, as well as its advantages in the actual market. We emphasize, furthermore, that time is a determinant for the quality of the products and in the costs of vegetables and fruit chains.

Now in this item, we want to broaden the understanding of the concept of integrated logistics to a more comprehensive one, whose main point is the integration of logistic processes.

This understanding is of fundamental importance to ensure the profitability of all members of a chain of perishable products, especially for the producers.

It is important to emphasize that the integration of logistics helps all chain members, but in the case of vegetables and fruits chains, this integration not only guarantees major profitability to producers, but also increases its bargaining power in the market.

Stock & Lambert (2001) argue that the management of the supply chain does not substitute or is not similar to the concept of logistics. While the Council of Logistics Management defines logistics as the management of material flows and its related information, from its origin to its consumption, supply chain management (SCM), for the same authors, involves the key business processes, which start at the final customer and continues until the providers of production supplies, integrating products, services and information that add value to both the client and other chain members (producers, suppliers, customers, shareholders, etc.).

It is important to observe that the understanding of this concept can be very helpful in the modeling of the integrated chain of vegetables and fruits with the market, because such integration, as has been discussed previously, impacts on time, affecting the costs and quality of products.

To integrate the supply chain of vegetables and fruits of a family farming organization it is necessary to observe some important aspects:

- Regarding the collection chain of products in the field through the warehouse of the producers organization, for the selection and classification of products, we can affirm that it is possible to establish a similar flow between producers and its properties to the distribution center; and

- regarding the distribution chain, it is not possible to establish a unique integration flow among the diverse distribution points in the market. Although the logistic processes are the same, the type of relationship with each one of these points is different and it is from the recognition of these differences that it is possible to model the chain integration.

In order to operate from a supply chain management view, Stock & Lambert (2001) argue that it is necessary to manage eight key business points: 1) from the management of customer's relationship; 2) customer service; 3) demand; 4) request compliance; 5) production flow; 6) product procurement; 7) design and marketing of the product and 8) return of products.

Analyzing these eight key points in the supply chain management in the context of family farming organizations, in particular for the vegetables and fruits sector, we verify that organizations and groups of producers that work for supermarkets or hypermarkets need to manage these key points due to buyer requirements.

However, due to lack of technology and often lack of knowledge, it is not possible to integrate the logistic processes, making it difficult to dimension the demand and the product quality, resulting in heavy losses which usually fall on producers' organizations.

Stock & Lambert (2001) argue that the structure of a distribution channel has to attend the final consumer in his needs in terms of product quality and cost. To achieve this, the authors argue that it is fundamental to structure a distribution channel in line with consumer needs. It is also important to have an integration of the different distribution channels that can exist in a specific supply chain.

Faced with this reality and market requirements, it becomes necessary to seek alternatives that permit exploration and adapt logistics and supply chain models to find solutions that mitigate the current problems faced by those organizations and consolidate an organization model.

4. Methodological proposal for farmers organization based on integrated logistics

For the construction of the proposed model for family farming organizations, we took as reference the organization of producers of fruits and vegetables, considering that this sector corresponds to 2.1% of the Brazilian GDP and employs 8 to 10 million people.

The market for fruits and vegetables had its marketing affected, particularly by the fact that the products depend on limited periods to be harvested, i.e., most of them are products that can not be stored for long periods. This means that when it is harvest time, the product should be available on the market, regardless of its demand. Most of them are seasonal products, which mean that there are periods where the offering of the products is large and the market prices are low, but also periods of scarcity, where the supply of products is reduced and the prices tend to increase. Therefore, managing all processes of collection and distribution could be a great advantage of these marketing organizations.

Assuming that it is necessary to organize and manage chains of vegetables and fruits, not in isolation, but in integration with the market, seeking to decrease the permanence of products in the chain, we chose to adapt the seven steps proposed by Stock & Lambert (2001) for the design of a supply chain from the integration of logistic processes. These steps can be constructed from:

Setting the objectives of the supply chain - the producers' organization and the other members of the chain should set goals for their processes of production, collection and distribution, based on the supply chain concept, whose main objective is to ensure quality for consumers and reduce the time of permanence of the product in the chain.
Formulation of a strategy for the supply chain - from the establishment of goals for all participants in the chain, the following items must be defined: strategies needed to ensure product quality, reduction of logistic costs and time of permanence of the product in the chain, of purchase prices more competitive and better meet the demand;
Determination of alternative structures of the supply chain - being a pulverized chain, it is difficult to establish a unique marketing channel for products. For this reason, it is important to establish other channels and thus seek a better use of available resources;
Evaluation of the alternative structure of the supply chain - it is important to analyze the structures which ensure better quality, lower costs, continuity of supply, as well as communication;
Selection of the structure of the supply chain: the one that presents the best result, i.e. that acts with the structure that can best answer the questions related to the product quality, costs, continuity of supply and communication links;
Determination of alternatives to individual members of each supply chain - as previously discussed, generally, in a family farming organization, the logistics of collection may be standardized, i.e., the organization's relationship with each manufacturer follows a pattern established according to the quota of delivery of goods or of their involvement. However, in the distribution chain that relationship can be changed in each of the points of distribution and depends on the relationship between market and organization. In this context it is extremely important to recognize the constraints and define alternatives to minimize these restrictions;
Analysis and selection of the members of each supply chain - this is an important step, considering that the result of the supply chain depends on the commitment of each member in the various processes of the chain. To recognize partnerships and create a good relationship with them is also essential for supply chain integration. This recognition helps to strengthen the bonds of trust among participants, a basic parameter for the chain integration;
Measurement and performance analysis of the supply chain - it is important to establish indicators to allow benchmarking of the various chain processes. To measure, analyze and share these indicators with the various members of the chain is a key strategy for integration and minimization of costs and better utilization of resources;
Analysis of alternatives when the proposed objectives are not being met - this is a feedback step in the system, i.e., to assess whether the proposed objectives are being met and, if necessary, redefine them. As an example, it does not help if a supermarket decides that the goal is to have fresh products and good quality on the shelf, if it leaves the vehicle of the producers' organization waiting in line for a long time.
Importantly, each of the steps in building an integrated supply chain involves the structuring of communication channels without noises, i.e., by creating a network of social relationships in order to create and enhance a relationship of trust between the members of the chain. This is a model that is constructed daily from the transactions between the organization and the various markets.
So, combined with the steps mentioned, it is also necessary to obtain information on market demand. This information is known by the retailer, but must be shared with the producers. From this information, it is possible to start the structuring of the entire flow of the chain, beginning with the collection processes of the product on the property of each producer, as well as selection and product standardization, packing, loading and transportation.

All these processes require an integrated coordination to ensure that the activities can be undertaken in the shortest time, ensuring quality and longer product availability to the client. Table 1 summarizes the description of the basic functions that need to be integrated into the practice of integrated logistics of fruits and vegetables.
In this context, the proposed structure of methodology for the integration of family farming organizations of vegetables with the retail market needs mechanisms that can overcome barriers in organizational and technological integration between familiar production and retail market institutions in an era of globalization.
The model allows the family farming organization to overcome its competitive situation of fragility, because of problems caused by its own management – internal conditions of the familiar unit itself – as a result of changes in market structures and systemic conditions – political and economic infrastructure.

Processes	Information	Responsible for the information
Offer planning	Supply capacity in each producer of the organization	Organization's purchasing manager, purchasing manager of the retailer and logistics coordinator
Demand planning	Demand capacity of each market that must be supplied	Sales manager of the organization, sales manager of the retailer and logistics coordinator
Negotiation	Terms of transaction: price, period for payment, frequency of delivery, packaging supplies, time of delivery	Sales manager of the organization and logistics coordinator
Transportation planning	Optimization of the load, selection of the type of vehicle and routes planning	Operations manager of the producers organization
Distribution	Information that can help to optimize the distribution network (time and volume of delivery at each point	Operations manager of the producers organization
Orders	Quantity of products to be delivered	Purchasing, sales and operations manager of the producers organization
Packing	Availability of packing for orders treatment	Purchasing and sales manager of the producers organization
Load / unload	Appropriate time to perform the loading and unloading of the products	Operations manager of the producers organization and from the retailer
Packing return	Availability of packaging return at the time of unloading	Purchasing and sales manager of the producer organization, purchasing and sales manager of the retailer
Coordination	At any moment of the chain and each of its components, identifying bottlenecks and conflicts	Logistics coordinator

Table 1. Processes and basic information in the integrated logistics

5. Methodological proposal for the design and test of the model

The theoretical model emphasized the necessity of creating and sustaining a bond of trust between stakeholders, and negotiations in an all-sides win style between the chain participants in order to share resources and information. The model was also based on the platform concept. This concept considers that the solution must be constructed collectively by all relevant actors involved in the problem.

The methodology developed for this study was exploratory and associated to action research, i.e., at the same time that the phenomenon of interest is observed, some interventions are made in the process, so it can be more fully examined and understood. The action research was carried out during 12 months, but sometimes such studies can take longer, with the first results emerging only after a process of technology appropriation.

More specifically, the methodological choice considers that the design and testing of a model for the integration of producer and market emerges, necessarily, from a process of cooperative learning, where groups of logistic chains of distribution have the opportunity to share experiences, information and knowledge. In an environment provided with adequate infrastructure, it is expected that the group can build gradually, through observation, reflection and joint action, a management model that allows the full implementation of combined and interconnected actions, seeking a more effectively and efficient production chain of vegetables, considering the concepts of integrated logistics.

5.1 Designing of the model

The delineation of the model concentrated on increasing the profitability of the producers from the sale of their products, focusing on the integration of the producer with the retail market, in order to improve its marketing, maintaining an integrated supply chain of vegetables with the buyer (the retail market). For the structuring of the preliminary model, some assumptions were constructed as guiding principles:

- Involvement of all links of the chain, from producers to buyers. It is not possible to involve only one party.
- The collective construction holds as a premise that the participants should find a common goal and develop all the work towards that goal;
- The guiding concept should be the idea of chain integration, i.e., all members involved must be committed to the processes from production to product delivery to consumers;
- It is essential to create a bond of trust and commitment among all participants of the group;
- It is vital for the development of this culture of integration that one seeks a unique coordination with the objectives of facilitating the negotiation process and solutions for the conflicts and bottlenecks identified in the chain.

5.2 Details of the design of the integrated chain of vegetables

The design of the proposed integrated chain is built of several actions taken by producers and retailers under a unique coordination which acts as group facilitator in the role of negotiator of common interests and mitigates the conflicts that arise in the chain. Thus, the group coordinator, who may be called the logistic coordinator, is responsible for directing negotiations in the group, in all its actions, and should have the following profile, as shown in Table 2.

Technical Skills	Relational Skills
Agricultural sciences	Systemic view
Knowledge concerning the profile of the family farmer	Negotiation
Production and post harvest of vegetables	Leadership
Logistics of distribution	Communication
Supply chain	Knowing how to act on teamwork
Legislation for sorting and packaging of products	Planning

Table 2. Profile of the Logistic Coordinator

In this step, from discussions with groups of producers and retailers, it was found that at least at the beginning of the process, the coordination should be made by a local institutional delegate, outside the group, to provide technical support to facilitate the processes, considering the weakness of the managerial structure of most family organizations. In the case study an employee of the Enterprise of Technical Assistance and Rural Extension was chosen to act as coordinator. This organization maintains good relationships with both producers and retailers.

After identifying and choosing the coordinator, the design of the integrated supply chain begins with the search and identification of common interests among the actors in the chain of vegetables, particularly the producers and retailers. This identification was accomplished through the following actions.

5.2.1 Awareness

This phase aimed to raise awareness among the members of the supply chain concerning the importance of acting in an integrated manner for the marketing of products. It consisted of meetings among producers and retailers, organized by the logistic coordinator. The meetings transmitted the importance and benefits of an integrated operation in the distribution chain of vegetable producers and the importance of managing the logistic processes of the chain.

This was also the moment of introduction of some logistic concepts, essential for a good performance of the chain.

For producers, the approach was aimed to educate and raise awareness about the demands of each of the distribution channels and the importance of being prepared technologically and organizationally to act in each channel. It is understood that the lack of conditions of the producer in meeting the demands of a particular channel can increase the loss of profitability. Therefore, producers must meet the requirements of each channel and assess their conditions to serve individually or collectively.

For retailers, the approach was driven to demonstrate the benefits of an integrated performance, creating a bond of trust between producer and retailer, providing significant gains for both. It is important to make the retailer aware of the importance of logistic management, since we are dealing with perishable products. The time of availability from producer to consumer, as well as handling and packaging are also important factors to ensure the quality of the product to the consumer.

5.2.2 Instruments used to create awareness

These meetings were carried out in order to work with instruments directly related to the weaknesses and needs of each actor involved, as well as to explore comparative advantages.

The instruments used to sensitize were lectures presented by specialists in the area, leaflets about awareness and introduction to logistic concepts, technical visits to become familiar with other successful experiences of cooperation within groups, testimonies from producers and retailers with experience in acting as a group or in cooperatives. In these talks the main focus was on how the integrated chain works and the advantages of working this way. The holding of workshops for rural settlements identified several groups of producers that are interested in using this model as a base.

5.2.3 Formation of the groups

Based on the adhesion of producers in the awareness phase, the group that would perform in the integration experience was formed targeting the commercialization of their products in the retail market. The formation of these groups can be generated in two ways: from the demand of a retailer or from the need for groups of producers who have to improve access in marketing channels and consequently their incomes. In this research the group was formed from the demand of a retailer. After creating the group, the plan of action was started, resulting in the design of the integrated logistic chain and the resources necessary for its implementation. The actions undertaken concerned the establishment of a common goal, the creation of a pilot of the integrated channel of distribution and planning of the production scheduled.

5.2.4 Establishing a common goal

This action was structured in several negotiation meetings. On the average, there were four meetings with the group participants – basically producers and retailers - chaired by the logistic coordinator. In these meetings, everything that was decided was registered. The participants evaluated the advantages of acting in a collective manner, debated about selling prices and the group's commitment to continuously supply quality products.

Another meeting was carried out with the retailer, in order to discuss what his expectations were for the supply, quality of products and the price he would pay for the products and payment conditions. Once these points were settled, two meetings between producers and retailers were organized. At the first meeting the common goal of the stakeholders and the negotiated conditions of supply for an experimental project were established, noting that the information should be shared among participants, especially information concerning demand.

Another meeting with producers and retailers aimed to discuss the general aspects of the partnership. These meetings concerned creating a bond of trust between chain participants. Actually it is the principle of strategic alignment of the chain, where participants discuss each stage of the process until the product availability to consumers. Responsibilities were established for each link of the distribution chain.

5.2.5 Prototype of the integrated supply chain

This action was crucial to consolidation and model fitting. A prototype project was planned, with the delivery of a producers group and a retail chain, as monitored by the logistic coordinator and a group of researchers. The design of the distribution chain began, with the first delivery of products to the marketing. The following subjects were decided upon: the goods, quantity, selection processes and the quality of products required, quantity to be supplied by each producer, time delivery and who would be responsible to transport produce in each section of the roadmap.

During the development of this prototype conflicts occurred. They were mainly caused by the lack of an integrated vision of those involved. They are limited to analyzing and worrying about their processes. It was observed that, although the members of the chain have been sensitized to act in an integrated way, they still do not have this practice. At this time, the role of the logistic coordinator is fundamental, since he intervened in the pursuit of an agreement between the parties and the correcting processes.
The logistic coordinator also has the role of identifying the training needs, and their bottlenecks, of the members of the chain. In the prototype the necessity to improve internal processes was identified, in order to facilitate the integration of external processes. From this experience one can see that the need for training of human resources is vital to the functioning of the chain. The themes identified in the research as basic to the classification of producers and retailers are those concerning the handling, packaging, transportation, preservation and classification of foods. In the producer and retailer relationship, the major bottleneck is the lack of information concerning the real demand. A deficiency of this information eventually generates oversupply of some products and lack of other products. Generally, the experience of the prototype project showed that many of the bottlenecks in the chain are due to the lack of information on demand, difficulties in the negotiation of prices, more precise specification for standardization in selecting the most appropriate products and packaging.

5.2.6 Qualification of the chain

Qualifying was done with the participation of producers and retailers. Problem solving was done in groups, taking advantage of the platform concept, in which solutions are proposed by those involved, trying to visualize the chain from the production through the purchase of products by the final consumer. Therefore, the entire chain process, both physical and informational, must be carefully run to ensure the quality and integrity of products for the consumer. The proposal was carried out until this step and the development occurred with the implementation of the planning of scheduled production and the assessment and monitoring of results.

5.2.7 Planning of scheduled production

After assessing the experience of delivery, some needed adjustments were made, offering a basic training for the group, so its members could evolve in the negotiation for planning the production schedule, i.e., decide, among the producers who is going to plant, in which period and which products and quantities, in order to maintain the continuous supply of products. This step only moves forward if the information regarding the demand of the products supplied by retailers and producers with availability to plan their production, based on the demand information is guaranteed.
This step is an important evolution in the model because it helps build the bond of trust and commitment among the participants: the producer commits the group to plant what was established and the group commits itself to provide the amount requested by the retailer. The latter commits to purchasing the required amount within the standard of quality and price agreed. This step should be led by the logistic coordinator, requiring more formality in relationships, including the establishing of more formal contracts. Some key definitions for these activities:

- **Products**: definition of products that will be provided and the producers who will do the planting or deliver it. Not all the producers will plant the products, as this decision will result in the producer's experience in growing and the quantity demanded by the retailer;
- **Quantity**: establish how much of each product must be grown or supplied;
- **Frequency**: whether the product will be grown in an incrementally or seasonal way;

- **Responsibility**: the commitment of the group of producers to supply the retailer and the retailer to buy the product. Requires a more formal contract of supply;
- **Price**: a basic agreement on how the prices will be paid for the products, which may be the same deal made in the prototype or based on prices of the local supply center.

5.3 Assessment and monitoring of results

This phase should be sustained by the principle of integrated coordination of the chain, i.e., the involved parts must follow, and obtain information on how the product is reaching the final consumer.

The producers must know if the products are providing competitive advantages to the retailer and they must track every step of the chain to the final consumer. It is essential that participants understand that the exchange of information between stakeholders on how the product is reaching the consumer is the key point for the technological development of the chain. It is from this point that we can determine the needs for training producers and buyers and then design an integrated qualification plan for the chain.

It is worth noting that, since this chain has no high technology to conserve and maintain the product, it was perceived that all logistics need to improve processes to ensure that the product arrives in the shortest time possible to the final consumer. This will ensure the quality (product freshness) and decrease the loss rate (increase profits).

In this context, it is necessary to follow certain processes to verify product integration and guarantee the availability of the product in the shortest time possible. Therefore, this evaluation must begin by basic tracking of the chain with the monitoring of chain performance indicators. The way to structure and monitor these indicators should be done from the principles established in the theoretical framework involving mainly the following processes:

- **Harvesting and product selection**: adequate time and standardization in product selection, as agreed upon with the retailer. This standardization in the selection is of fundamental importance, for it avoids this conference during shipment;
- **Handling and packaging**: handling should be restricted to the smallest possible number. The use of packaging that goes straight to the gondola is an alternative that contributes significantly to reduce time;
- **Storage of retailers**: storage conditions of the retailer and product distribution time to retail outlets. It is noteworthy that this time should be minimal and preferentially find ways to distribute products directly from distribution center to outlets;
- **Condition and suitability of the site for product exposition in retail outlets**: these conditions can be of great importance for the maintenance of product quality for consumers;
- **Profits for the agents involved:** mainly verify if producers managed to negotiate their product at more competitive prices than the one they negotiated before.

5.4 Consolidation of the group in the first stage of the model

Once the agreements on the production schedule and the adjustment of processes in order to speed the chain are signed, the group begins systematic marketing operations with support from the logistics coordinator.

This consolidation phase seeks to improve the methodology of price formation (harvest and inter-crop period) and a mechanism to exchange information between agents in the chain. Approximately 12 months is necessary to consolidate the group. During this period, the group will continue to be made aware of the advantages of acting in an integrated way. This will give rise to the need of expanding the training of the group to improve chain management.

Importantly, this initial phase is crucial for a paradigm shift of the actors involved in the production chain and construction of a bond of trust between stakeholders, because the undertaken actions permits the initiation of a culture of cooperation and trust between players. It also permits both the organizational and the technological evolution of the group. It is observed that in this first design of the chain, although there is an introduction of modern management concepts and logistics, the priority is to explore in depth all the conditions and existing knowledge of those involved. This means that the major emphasis is on organization and on the creation of relationships of cooperation and trust between the players, starting with the sharing of experiences, essential conditions to implement the model.

6. Conclusion

Based on the results of the action research and in the development of the methodological proposal for the prototype of the integrated supply chain, one can observe that the model is not limited, having a dynamic and evolving approach that facilitates the integration of small producers with market structures. It incorporates new technologies and thus guarantees performance changes in the chain – offering higher quality products to final consumers, increasing participation in the market and obtaining profitability.

In summary, the research has shown that there are alternative activities for small farmers that can be more fair and equitable. Noteworthy is the evidence that the availability of small farmers to incorporate new technology is a determining factor in the level of their income, i.e., the higher the qualification, the greater the producer bargaining power in the market.

These results showed that the losses due to the waiting time for delivery in the retail market, uncertainty of selling the production and the transaction costs in the market negotiation represent an almost 30% increase in logistic costs. Considering a peculiarity of this market – perishable products – we started the construction of a methodology to assess the logistic chain taking into account some assumptions. Empirical observation of the family-based agribusiness production chain showed that a clear and agile treatment of the information flow is a determinant for the quality of the product and for the profitability of the chain.

It is essential to seek to establish among the chain members all the relevant information that has to be shared. The improvements observed in information technology in recent years make this process easier. The facility and availability of technology helps to promote the changes from logistics into the concept of supply chain management. This involves key processes from the organization until the consumer, where processes, services and information are integrated. The challenge is to adapt this technology to family-based agribusiness chains.

Considering this chain and its integration with the retail market, one of the main goals to achieve this integration is to obtain demand information. Then it is possible to structure every flow in the chain, starting with the processes of collection in each farm, selection and standardization of products, packing, loading and transportation.

All these processes require an integrated coordination in order to optimize activity times, assuring quality and greater available time of the product for the consumers. It is observed that this set of processes has to be coordinated and integrated by all the involved actors, since any obstacle in the chain results in losses in the quality of products. So, the commitment of the actors to the overall performance of the logistic chain and the degree of commitment of each member determines its level of integration. The greater the degree of member integration, the higher its commitment with the final result: the commitment of assuring good quality products in the marketplace.

The model focused on the farmers' integration with the retail market, in order to improve their position in commercialization, maintaining an integrated vision of the distribution chain. The preliminary model had the following guidelines:

a. Commitment of all production chain members in the construction of the model;

b. Collective construction, where all relevant actors seek a common goal;
c. Focus on chain integration, which means that all members must be committed to all the processes, from production to consumer delivery;
d. Establishment of a bond of trust and commitment among all the chain members;
e. Unique logistic coordination of the chain, where all members know and help to solve the bottlenecks that appeared during products flow until the market;
f. Understanding that each marketing channel needs a different modeling of logistics processes.

To rationalize more effectiveness of the logistic chain, the function of market channels – which are a means of bringing the product to the final consumer – must always be considered. Cooperation among agents also has to be emphasized, in order to identify the best way to optimize resources, taking into account that one of the main functions of market channels is to assure that the consumer will receive quality products, within specified deadlines and with minimal cost.

In this context, it is important to emphasize that each step in the construction of an integrated family farming supply chain includes the structuring of good communication channels - creating a social network that permits the creation and enhancement of a bond of trust among the chain members. This is a model that is daily constructed by transactions between organizations and different markets.

It is important to emphasize that there is still a big challenge to overcome, since implementing the practice of integrated logistics concepts in a chain is still too fragmented to become a model of management and organization. The concept of integrated logistics can be considered a kind of paradigm breaking.

7. References

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11

Optimal Supply Chain Formation Using Manufacturers' Negotiation in the Environment that the Sub-Contracts are Allowable

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1. Introduction

The level of a service and its cost have a trade-off relation in the supply chain, but most companies aim to achieve both quality service and low cost at the same time by means of effective supply chain management. In an effort to achieve this goal, many researches have been made to minimize the uncertainties related to the supply chain through its effective design and operation. It is noteworthy that the goal of each participant in the supply chain does not lead to the maximization of the efficiency and effectiveness of the supply chain (Lee & Billington, 1992; Towill, 1996). Therefore, the cooperative effort between the members in the supply chain is needed to respond to the customer's demand effectively. This indicates that the integration concept from the viewpoint of the whole supply chain is necessary. Traditionally, more efforts have been made to remove the imbalance of supply and demand in the production management, generally putting emphasis on reducing a total cost (Bowersox & Closs, 1996). Also, most preceding studies have focused on the flexible organization in the vertical integration as shown in the companies having a controlling power in the supply chain.

However, this study has focused on the competitive relations between participants in the horizontal integration instead of the vertical one. In the competitive relations, a certain number of buyers and manufacturers usually make a decision only depending on the price information because of no further information sharing (Bylka, 2003). But manufacturers in the horizontal integration, although they keep a competitive relation between them, are trying to have a strategic cooperation with others by means of sharing information on their order situation.

Related to the topic, several research studies have been conducted with concepts such as supply chain collaboration, supply chain coalition, and supply chain configuration. Moyaux et al. (2004) experimented with three levels of collaboration schemes regarding demand information transmission among supply chain members to reduce the bullwhip effect. They adopted game theory with multi-agent simulation and showed that they can reach Nash equilibrium and minimum supply chain cost. Nagarajan and Sosic (2006) reviewed coalition formation models in a supply chain from the viewpoint of game theory. They suggested new ideas such as foresightedness among supply chain players and future research in applying cooperative game theory to supply chain management.

As a solution to the problems of supply chain configuration, this study has used agent negotiation. Due to dynamic changes in the internal and external environments, it is not easy to coordinate the conflicts of interests among supply chain members. What's more, quick response to those dynamic changes is required. Coordination of activities across a network of suppliers is essential for reacting quickly to uncertain environments (Chan, H. & Chan, F., 2010). For this reason, the use of an agent system has come to the fore. An agent system uses a coordination mechanism to approach a global optimization, along with the local objective of each agent. In addition, negotiations are widely being used as a coordination mechanism (Guan, 1995).

The use of intelligent software agents along the supply chain has been investigated by a number of researchers. The benefits of adopting agent technology in supply chains have been recognized in an increasingly wide variety of applications involving inter-enterprise collaboration, extending the boundaries of strategic partnership to wherever the network technologies can reach. One way that such agents can be adaptive is to consider multiple ways to solve their sub-problems so that they can adjust their solution to produce the best possible result, subject to the restrictions on available processing, communications and information resources, etc (Lin et al., 2008). A number of recent studies have led to significant advances by placing more emphasis on complexity and dynamics of supply chains (Caridi & Cavalieri, 2004). Monteiro et al. (2007) addressed a hierarchical architecture to integrate individual planner agent, negotiator agent, and mediator agent with a decentralized control for achieving robustness and flexibility of the supply chain network. To model and simulate complex supply chains in a mass customization context, Labarthe et al. (2007) proposed a methodological framework based on an agent paradigm. Forget et al. (2008) explored a framework to design multi-agent behavior in a supply chain planning system, where agents were able to dynamically change their planning and coordination mechanism and, ultimately increase overall performance. Min and Bjornsson (2000) presented a conceptual model of agent-based supply chain automation, in which a project agent gathers actual construction progress information and sends to subcontractor agents and supplier agents, respectively, over the Internet. They evaluated an agent-based SCM model compared with traditional SCM practice through simulation.

Most work in this area has concerned with distributed planning and scheduling system that models the supply chain as a set of semi-autonomous and collaborative entities acting together to coordinate their decentralized plans.

This paper has defined this relationship as a subcontract environment. This study assumes that the manufacturing cost of each manufacturer is based on the SET model(Single Machine Earliness/Tardiness Model). Therefore, the total manufacturing costs involving earliness production cost and tardiness production cost can be changed according to which order is placed with which member. In other words, we assume that the manufacturing cost can be changed according to what orders can be placed together.

Actually, when making a decision by price information only, manufacturers become rivals to receive an order from the buyer, but in the subcontract environment, they can maximize their profits by means of a cooperative relation, while optimizing the whole cost from the viewpoint of the supply chain.

This paper runs as follows. The second chapter deals with the preceding studies on SET model, introduces the scheduling applied to this study, and defines the problem of the supply chain in this study. Chapter 3 introduces the optimal solution by means of the Branch & Bound method. Chapter 4 presents the negotiation method and its algorithm, while testing the optimal solution of the negotiation method through experiments. Chapter 5 comments on the limit of this study and future research direction.

2. Definition of the problems in the SET model

2.1 Single machine earliness & tardiness model

The scheduling problems can diversely be categorized as a single machine, parallel machine, flow shop, and job shop. With regard to the scheduling problems, this study, however, has focused on a single machine, because the SET model is widely used due to the advantage that it incurs the least tardiness production cost and earliness production cost when a due date is not met (Pinedo, 2001).

The dynamic supply chain means an environment in which a large number of orders can be carried out by numerous manufacturers, previous orders can be cancelled, and new orders can be added. Moreover, since multiple manufacturers are in a competitive relationship, it is possible for all the orders to go to one manufacturer, or no orders to go to a certain manufacturer.

Since the concept of "just-in-time" was introduced in 1980's in Japan with regard to the studies on scheduling, the importance of irregular measure, which considers earliness and tardiness simultaneously, has been emphasized (Kim & Yano, 1994). In particular, Baker and Scudder (1990) had defined an Earliness and Tardiness model(E/T model) in the single machine according to the assumption of the objective function and restricted conditions. The basic objective function of E/T model in the single machine can be defined as follows.

$$f(S) = \sum_{i=1}^{n} [\alpha_i (d_i - C_i)^+ + \beta_i (C_i - d_i)^+ = \sum [\alpha_i E_i + \beta_i T_i] \quad (1)$$

E_i : earliness, T_i : tardiness

C_i : completion date, d_i : due date

$E_i = \max\{0, d_i - C_i\} = (d_i - C_i)^+$

$T_i = \max\{0, C_i - d_i\} = (C_i - d_i)^+$

α_i, β_i : a unit earliness penalty, a unit tardiness penalty

In the formula 1, the tardiness cost is caused by breaking the duty of observing a due date, and the earliness cost comes from the inventory cost. And a manufacture should bear both costs of tardiness and earliness. Therefore, an ideal scheduling demands to finish each job in its due date. In other word, the purpose of scheduling is to minimize the deviation of the due date and the job completion, that is, to minimize the total amount of tardiness cost and earliness cost (refer to formula 2), (Baker & Scudder, 1990; George, 1997; Kim & Yano, 1994; Peng, 1989).

$$Min\ f(S) = \sum_{i=1}^{n} \mid C_i - d_i \mid = \sum (E_i + T_i) \quad (2)$$

2.2 Definition of problems

This problem deals with the case of a make-to-order manufacturing company. Accordingly, its production begins after accepting an order from the buyer, and the manufacturing company doesn't keep inventory in advance in its factory. As shown in the <formula 3>, the manufacturer puts emphasis on the due date considering the CTP (Capable To Promise) function, which is composed of the manufacturing cost, tardiness cost, and earliness cost.

$$f_{CTP} = f_{manufacturing} + f_{tardiness} + f_{earliness} \tag{3}$$

In particular, the problem of breaking the duty of observing the due date is considered in this section. It means the processing time of the product order cannot meet the distinct due date of the order (Kim & Yano, 1994).

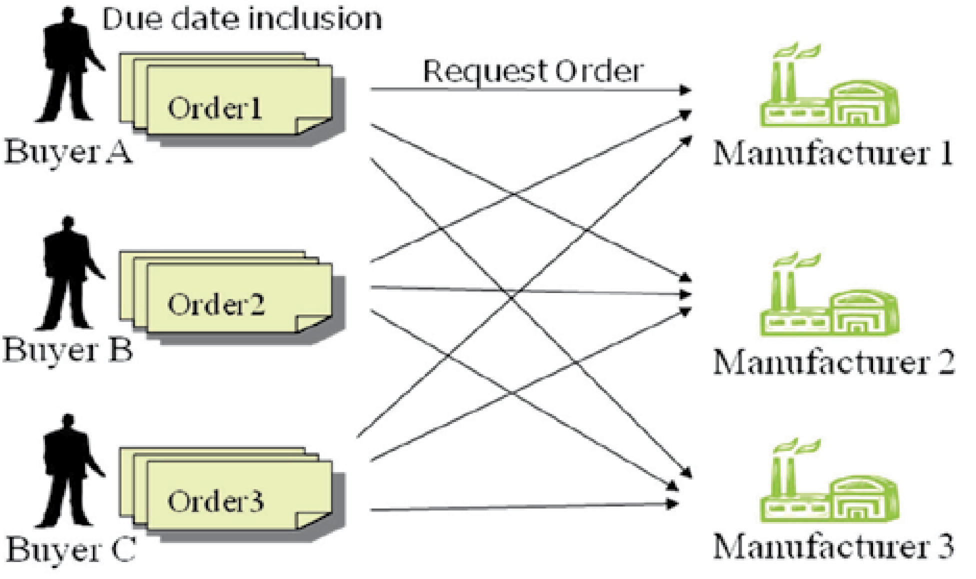


Fig. 1. Problem of the supply chain composed of multiple buyers and multiple manufacturers

Concerning the range of the supply chain, this paper has dealt with the relationship between multiple buyers and multiple manufacturers. As shown in the <figure 1>, multiple buyers make requests for the estimates of more than one from all the manufacturers in the supply chain. And the manufacturers who have received a request for an estimate are making preparations to establish an optimal scheduling. In this case, let's suppose that there is no difference in the product's quality of each manufacturer, but some difference in their production cost according to the CTP function. Also this study supposes that the orders from the buyers are placed at the same time or in a nearly the same time.

In the <figure 1>, the manufacturer A, B, and C have received a request of the estimate for order 1 from buyer A, and then establish a scheduling for production. Soon after that, they have also received a request of the estimate for order 2 from a new buyer B, and so they are making a rescheduling for both orders. In this case, the manufacturer A's scheduling changes like <figure 2>. In the second scheduling, the manufacturing priority for each order is to be made based on the E/T model. At this time, the processing for the priority order

(order 1) can cause an earliness cost due to early production, and the processing for the next order (order 2) can cause a tardiness cost owing to the delayed due date.
The rescheduling that has to consider all orders simultaneously causes both an earliness cost and a tardiness cost, and these additional costs will increase in proportion to the deviation between the due date and the order fulfillment date (refer to the formula 2). This production cost increase is to happen likewise to the other manufacturers.

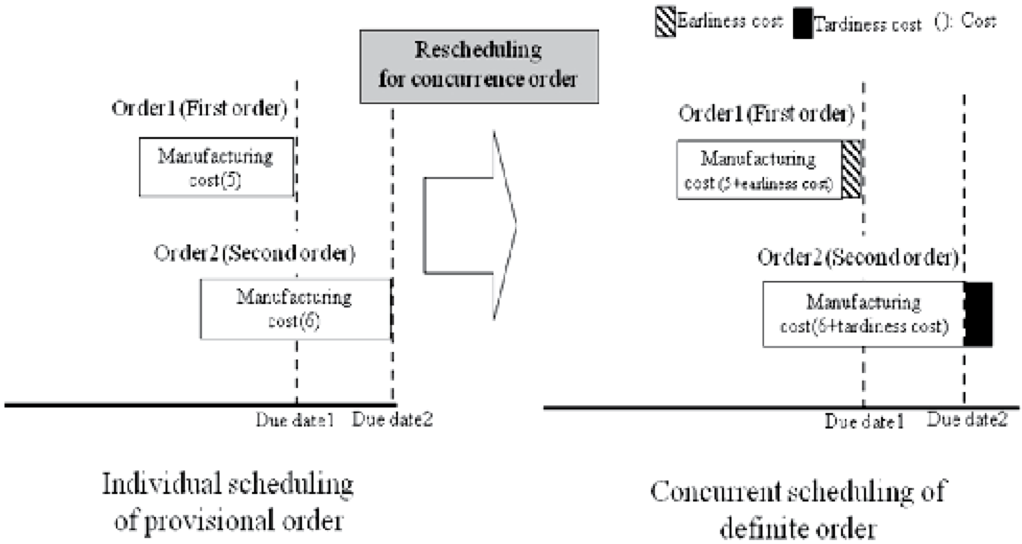


Fig. 2. Sequential scheduling based on SET model considering simultaneous orders

Based on the expected orders, manufacturers are to make scheduling and rescheduling, and then offer the buyers their production cost estimated on the basis of the rescheduling. If the number of orders decreases because of competition between manufacturers, the actual manufacturing cost will be lower than the cost based on the scheduling, thus causing the difference between both of them. This difference can cause the danger of losing competitiveness. Another difficulty follows when the manufacturer has accepted an order at a lower price than its production cost because of competition with his rival. In addition to these, there are a burden on keeping the delivery time and a late response to the buyer's demand. All these problems lead to the imbalance of supply and demand, thus making it difficult to achieve an optimization. In order to solve these problems, this paper has suggested a negotiation method that gives priority to the strategic alliance between manufacturers.

3. Optimal solution based on the branch & bound algorithm

The branch & bound algorithm has been introduced for an optimal solution in this section. This method is different from the branch & bound algorithm applied to the ordinary scheduling. As the supply chain environment is under the competitive situation, two cases can be considered. The first is that one manufacturer handles all the orders, and the other is that other manufacturers join in fulfilling the orders. In the latter case, it is important how to distribute the orders among those manufacturers. The branch and bound method can be explained as follows by means of a simple scenario.

As shown in the <table 1>, let's suppose that there are three manufacturers and three orders, and that since the written estimates of manufacturer A are lowest, all the buyers has simultaneously placed their orders with the manufacturer A. In this case, the A has to make a rescheduling for three orders, and the new estimate based on this rescheduling is much higher due to the SET model than the first estimate. Because of this, the A has to reduce these production costs by means of cooperation with other manufacturers. When all the orders have been placed with the A, the possible combinations between manufacturers and orders are shown in the below <table 2>.

	Manufacturer A			Manufacturer B			Manufacturer C		
	O 1	O 2	O 3	O 1	O 2	O 3	O 1	O 2	O 3
1th Scheduling	10	12	15	12	14	16	13	16	23
2nd Rescheduling	13	18	21						

* O : Order

Table 1. Definition of the problem in the branch and bound method

Order combination / Member (Manufacturer)	{1}	{2}	{3}	{1,2}	{1,3}	{2,3}	{1,2,3}
A	80	60	50	150	160	150	220
B	30	90	20	130	**60**	140	200
C	80	**40**	40	140	130	100	210

Table 2. Order allocation problem for supply chain members to minimize the total manufacturing cost for supply chain formation

In the case of <table 2>, considering the number of members and order combinations, iterative allocation has to be conducted 21 times in total. Under the assumption that we know all the costs, each cost table by branch should be made. However, in an effort to overcome a full search, this study has introduced a newly developed heuristic Branch-and-Bound method. This has the following strategies that do not depend on a full search.

- Strategy 1: the total manufacturing cost in the optimal solution is at least the same or less than that of all the orders placed with one manufacturer. In the first branch, the manufacturer that has the least cost for all the orders will be the first starting point in branching. This manufacturing cost is the first bound.
- Strategy 2: The series of branches that have generated the least value will be the same as the optimal solution or near to it. Therefore, a lower branch is basically inherits the bounds of upper branches.

This strategy should be more efficient than a full search algorithm. Therefore, branching starts from 'n' number of simultaneous orders that have generated the first bound, and the lower branch inherits the order combination of the upper branch. At this time, the lower branch will have one less order combination than the number of order combinations of the upper branch, i.e. n-1 order combinations. This new Branch-and-Bound method is a heuristic Branch-and-Bound. Therefore, it does not guarantee optimality but stops sooner than a full search. The algorithm of the heuristic Branch-and-Bound method is as follows.

- Step 0: When each manufacturer has 'n' number of orders placed, calculate each sum of the cost of orders assigned to each manufacturer. The order set assigned to a manufacturer i that has the least sum of cost becomes the starting order-manufacturer combination Ts. Name this starting set of orders as Oi for further consideration. Name the set of manufacturers that are not the 'i' manufacturer as L.
- Step 1: Remove each order from Oi and assign it to a manufacturer in L. Select the least cost manufacturer that can take the order. Compare the cost of all the selected manufacturers for each order removed from Oi and choose the least cost order k and its manufacturer j.
- Step 2: If the sum of the cost of orders from Ts after removing the order k, and the cost of order k manufactured by j is smaller than or equal to that of Ts, let Oi = Oi – {order k}, Ts = Ts - { (i, k) } + {(j,k)} and go to Step 1. Otherwise, go to Step 4.
- Step 3: If Oi has only one order, go to Step 4.
- Step 4: The Ts becomes a final solution.

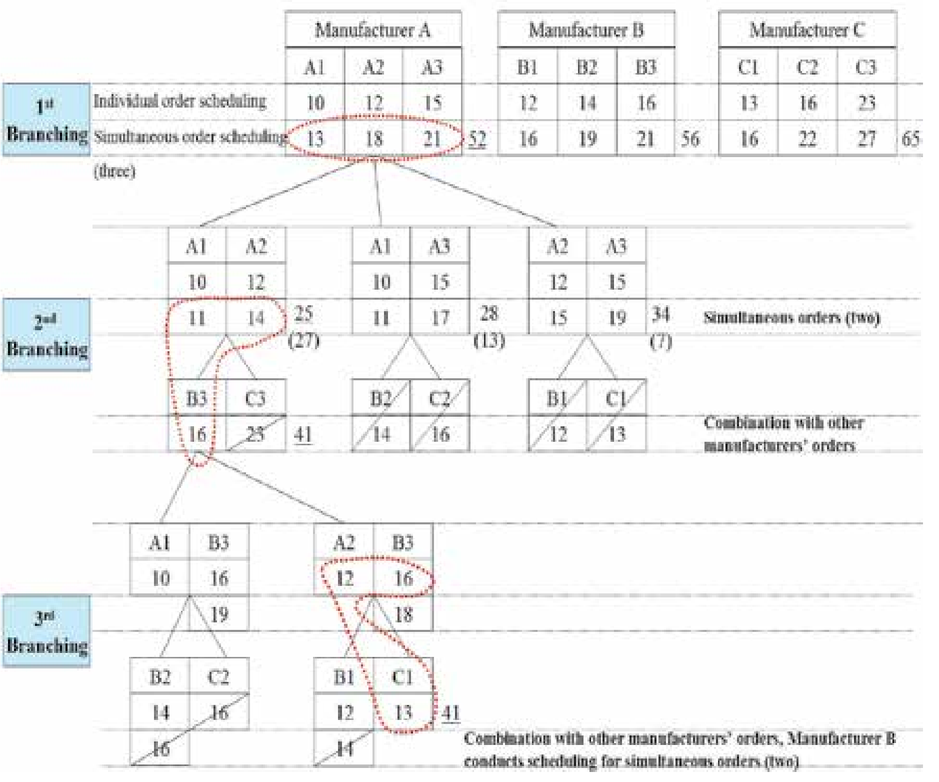


Fig. 3. Scenario of heuristic Branch-and-Bound method

We suppose in this problem that the branch and bound method knows all production costs, and so the cost tables are available by branch. <Figure 3> shows branch tables by combination of manufacturers and orders based on the <table 2>. However, in case of the branch and bound method, if the size of a problem becomes larger, its calculation time increases rapidly. Therefore, this method is not appropriate for the supply chain management that seeks an equal transaction opportunity among multiple business partners.

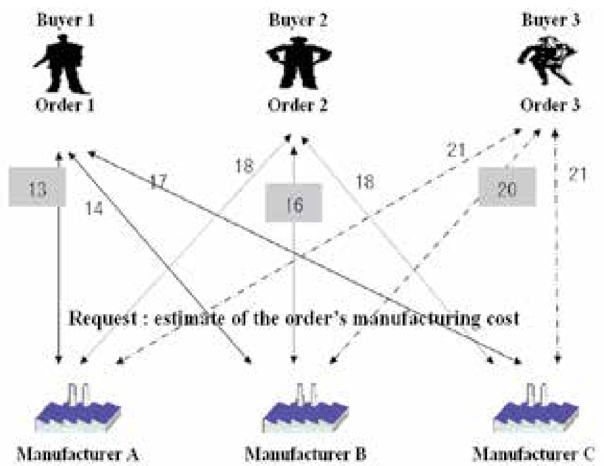
In addition, it is different from the negotiation method in the sense that it cannot show the profit and loss of each manufacturer.

4. The negotiation method among manufacturers

4.1 Scenario

This study presents a concrete method as a solution to the supply chain formation problem by using agent negotiation based on a SET model. In particular, through information sharing, both internal and external factors are considered when making a decision. In addition, by capitalizing on agent negotiation, all members are rewarded simultaneously, consequently accelerating performance of the whole supply chain.

The negotiation method, which can be made by means of strategic alliances among manufacturers, will be used not only to minimize the production cost but also reduce the total cost of the whole supply chain. The negotiation method can be explained through a scenario as shown in the below <figure 4>.



	Manufacturer A order1	order2	order3	Manufacturer B order1	order2	order3	Manufacturer C order1	order2	order3
Individual Scheduling	10	12	12	12	14	16	15	15	14
Simultaneous Scheduling	13	18	21	14	16	20	17	18	21
Actual manufacturing cost	10				15	18			
Difference	3				1	2			

Fig. 4. Basic scenario

The request of the estimates for order 1, order 2, and order 3 has been made to the three manufacturers - A, B, and C nearly at the same time. These orders' delivery periods are tight, and these orders have respectively been placed by buyer 1, buyer 2, and buyer 3. All three orders have been placed nearly at the same time with a similar due date. Accordingly, joint scheduling for three orders has been made, and the simultaneous scheduling cost means the cost coming from this joint scheduling. However, due to the earliness cost and tardiness cost, the simultaneous cost for each order is much higher than each individual

cost. When these production costs have been offered to the buyers, the order 1 has been placed with manufacturer A, and the order 2 and 3 with the manufacturer B, but no order has been placed with the manufacturer C. In this case, the manufacturer B has become to receive two definite orders. A definite order here means the order confirmed by a buyer.
An actual manufacturing cost is shown in the <figure 4>, and in case of the manufacturer B with whom two orders have been placed, its simultaneous scheduling cost for two orders is higher than the individual scheduling cost for each order, but lower than the simultaneous scheduling cost for three orders. The difference between the simultaneous scheduling cost and actual manufacturing cost has happened in case of manufacturer A and B, but the total of both actual manufacturing costs is 43, and this figure cannot reach the optimal solution for the whole supply chain.

	Manufacturer A			Manufacturer B			Manufacturer C		
	Order1	Order2	Order3	Order1	Order2	Order3	Order1	Order2	Order3
①Individual Scheduling Cost	10	12	12	12	14	16	15	15	14
②Simultaneous Scheduling Cost	13	18	21	14	16	20	17	18	21
③Actual Manufacturing Cost	10				15	18			
④Difference(Definite Cost - ③)	3				1	2			
⑤Request sub-contract from other manufacturer(Order2)	10	12			15	18		15	
⑥ Simultaneous scheduling Cost in case of sub-contract (1)	11(-1)	15		16	15(0)	16(2)	15	15	
⑦ Request sub-contract from other manufacturer(Order3)	10		12		15	18			14
⑧ Simultaneous scheduling Cost in case of sub-contract (2)	12(-2)		15	17	14(1)	14(4)	14		14
⑨Final order after manufacturer nego	10				14				14
⑩ Each manufacturer profit after nego ( ): the amount of increase	3(-)				8(+5)				0(+)

Definite Order Optimal Value Removal of Definite order after Nego

Table 3. Process of the negotiation method and generation of optimal solution

At this point in time, the manufacturer B, who has two definite orders, begins to figure up whether it can produce more profit, if he subcontracts one order to the other manufacturer. To this end, he has to make a decision on what to subcontract and which subcontractor to choose. First of all, the manufacturer B asks the manufacturer A and B to subcontract for the order 2 (refer to No. 5 of the table 3). As a result of the subcontract estimation, in case of the manufacturer A, the simultaneous scheduling cost for the definite order 1 and the subcontract order 2 has been generated, thus increasing to 11 and 15 respectively. Accordingly, in case of the definite order 1, the cost has increased by 1 due to the simultaneous scheduling cost, and so to make up for this loss, he asks the manufacturer B for 16 instead of 15 (refer to No. 6 of the table 3).

Meanwhile, in case of the manufacturer C who has no definite order, he demands 15 for the order 2. Therefore, the manufacturer B makes a negotiation with the manufacturer C. In this case, the B's profit increases by 2 through negotiation. When trying to subcontract the order 2, the manufacturing cost of the C is 15, and so it is the same with his actual manufacturing cost. But because he fulfills the definite order 3 individually, his profit increases by 2.

Finally, in case of subcontracting the order 3, as shown in the previous case, if he subcontracts to the manufacturer C, the C can fulfill the order at 14. In this case, the profit coming from the order 3 increases by 4. And also his profit increases by 1 from the definite order 2 due to the individual scheduling cost. So, his total profit increases to 5 (refer to No. 8 of the table 3). In conclusion, the manufacturer B decides to subcontract the order 3 to the manufacturer C. In this case, the total production cost for three orders is 38, thus achieving the minimum cost for the whole supply chain (refer to No. 9 of the table 3). Furthermore, all the participants make a profit from the negotiations (refer to No. 10 of the table 3).

4.2 Definition of negotiation factors and algorithm

The definition of the negotiation factors and algorithm based on the above scenario is as follows.

- Definition of Negotiation Factors
  - Individual scheduling cost: this is the first scheduling cost when one order is placed with the manufacturer.
  - Simultaneous scheduling cost: this is the rescheduling cost when an additional order is placed with the manufacturer and so he needs the rescheduling as a group.
  - Definite order: the order that is placed with the manufacturer who has suggested the minimum price after the simultaneous scheduling.
  - Profit (income cost): this is the cost for a definite order. The manufacturer receives this production cost from the buyer.
  - Actual manufacturing cost: the production cost inputted by the manufacturer for order fulfillment.
  - Difference: a definite order will be suggested after simultaneous scheduling, but if the actual manufacturing cost of the definite order is smaller than the simultaneous scheduling cost, then the difference will take place (difference = income - actual manufacturing cost).
  - Lowest individual order: the order with the lowest cost among the individual scheduling cost by manufacturer.
  - Determination of a subcontract order: when there are more than two definite orders, and the manufacturer wants to decide which order to subcontract.
  - Selection of subcontractor: the negotiation leader is to select the subcontractor among the other manufacturers. The criteria is that the actual manufacturing cost of the subcontract candidate should be lower than that of the negotiation leader and also that if there are more than two subcontract candidates, the manufacturer with a lower actual manufacturing cost should be chosen.

The flow chart of the <figure 5> shows us a make-to-order production system between a buyer and a manufacturer and the process of an ordinary negotiation.

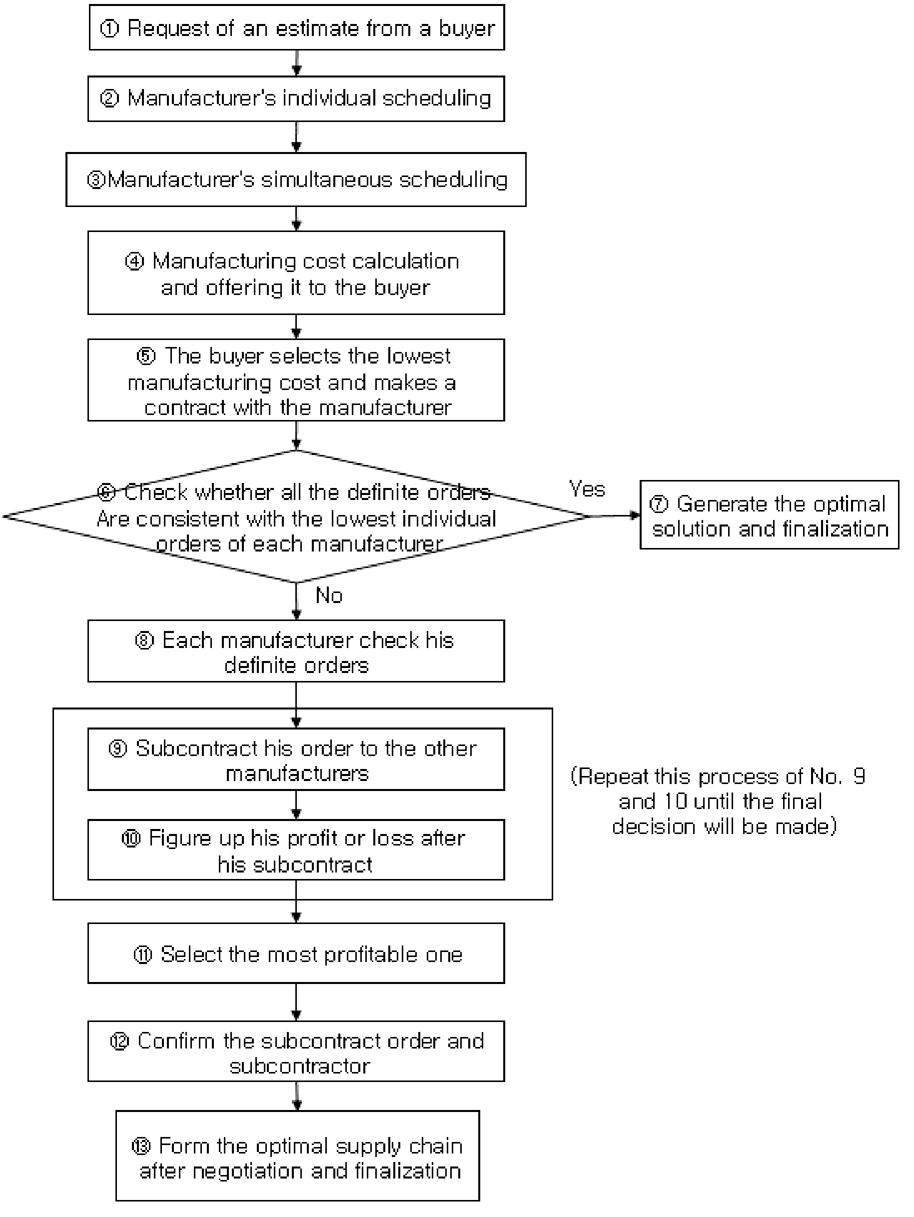


Fig. 5. Algorithm chart of a make-to-order production between a buyer and a manufacturer

4.3 Optimization experiment

Based on the above-mentioned algorithm and scenario of the negotiation method, experiments have been made. The purpose of the experiment is to prove that the algorithm of this negotiation method can lead to the optimization of the supply chain. To this end, this test has used the program language C++. Also the algorithm of the branch and bound method has been tested for a comparison with the negotiation method. The range of the experiment includes three manufacturers and four orders, and each individual scheduling cost has been coordinated for generation of a variety of negotiations.

The results of these experiments are shown from the <figure 6> to the <figure 9>. In the figures each individual scheduling cost has directly been inputted by the experimenter, and each simultaneous scheduling cost has been made to produce random numbers automatically, but not allowing the same order to produce the same random numbers.

	Manufacturer 1					Manufacturer 2					Manufacturer 3					
	O11	O12	O13	O14		O11	O12	O13	O14		O11	O12	O13	O14		
Individual Scheduling	7	8	9	10		10	9	8	7		8	8	7	8		
Simultaneous Scheduling	12	12	14	15		14	13	12	13		13	15	11	15		
Actual manufacturing Cost	(9)	(10)							(7)				(7)			33
Difference	3	2							6				4			
Subcontract_Nego(1)	7(2)						9		7			8	7			32
Subcontract_Nego(1) Result		11(-1)			1		10		9(-2)	12		10	8(-1)		11	
Subcontract_Nego(2)		8(2)				10			7		8		7			
Subcontract_Nego(2) Result	10(-1)				1	11			8(-1)	12	9		8(-1)		10	32

Fig. 6. Scenario 1

	Manufacturer 1					Manufacturer 2					Manufacturer 3					
	O11	O12	O13	O14		O11	O12	O13	O14		O11	O12	O13	O14		
Individual Scheduling	10	12	14	11		15	8	12	13		12	9	13	12		
Simultaneous Scheduling	18	20	20	17		22	21	23	25		19	21	21	19		
Actual manufacturing Cost	(18)	(20)	(20)	(17)												75
Difference	0	0	0	0												
Subcontract_Nego(1)		18(2)	17(3)	16(1)		15				15	12				12	
Subcontract_Nego(1) Result	12(6)				12											
Subcontract_Nego(2)	15(3)		18(2)	14(3)			8			8		9			9	55
Subcontract_Nego(2) Result		8(12)			20											
Subcontract_Nego(3)	16(2)	17(3)		15(2)				12		12			13		13	
Subcontract_Nego(3) Result			12(8)		15											
Subcontract_Nego(4)	15(3)	17(3)	17(3)						13	13				12	12	
Subcontract_Nego(4) Result				12(5)	14											
Subcontract_Nego(5)	13(2)			13(1)			8	12					13			47
Subcontract_Nego(5) Result			13(5)		8		12(-4)	16		20			13		13	
Subcontract_Nego(6)	10(3)						8		13				13	12		
Subcontract_Nego(6) Result				17(-4)	-1		10(-2)		16	18			16(-3)	14	17	

Fig. 7. Scenario 2

	Manufacturer 1					Manufacturer 2					Manufacturer 3					
	O11	O12	O13	O14		O11	O12	O13	O14		O11	O12	O13	O14		
Individual Scheduling	12	10	13	18		11	11	12	12		10	12	11	10		
Simultaneous Scheduling	18	17	19	20		16	21	18	19		20	16	16	15		
Actual manufacturing Cost						(11)						(15)	(14)	(13)		53
Difference						5						1	2	2		
Subcontract_Nego(1)		10			10	11	11						13(1)	11(2)		45
Subcontract_Nego(1) Result						13(-2)	14			16		10(5)			8	
Subcontract_Nego(2)			13		13	11		12				14(1)		12(1)		
Subcontract_Nego(2) Result						13(-2)		14		16			13(1)		3	
Subcontract_Nego(3)				18	18	11			12			12(3)	12(2)			
Subcontract_Nego(3) Result						14(-3)			13	16				16(-3)	2	
Subcontract_Nego(4)		10	13			11		12						10(1)		
Subcontract_Nego(4) Result		12(-2)	15		17	13(-2)		14		16			16(-3)		-2	
Subcontract_Nego(5)											10		13	11		
Subcontract_Nego(5) Result						10(-7)				-7	15		14(-1)	13(-2)	10	

Fig. 8. Scenario 3

	Manufacturer 1					Manufacturer 2					Manufacturer 3					
	O11	O12	O13	O14		O11	O12	O13	O14		O11	O12	O13	O14		
Individual Scheduling	12	11	13	15		12	14	16	16		14	14	16	18		
Simultaneous Scheduling	19	20	19	22		18	19	20	25		17	20	22	25		
Actual manufacturing Cost			(15)	(10)			(14)				(14)					61
Difference			4	6			5				3					
Subcontract_Nego(1)			13(2)				14		16		14			18		
Subcontract_Nego(1) Result				20(-2)	0		16(-2)		18	20	15(-1)			19	20	
Subcontract_Nego(2)				15(3)			14	16			14		16			
Subcontract_Nego(2) Result			19(-4)		-1		17(-3)	17		20	15(-1)		18		19	
Subcontract_Nego(3)		11	15	18							14	14				
Subcontract_Nego(3) Result		17	17(-2)	20(-2)	21		17(-3)			-3	15(-1)	16			17	
Subcontract_Nego(4)	12		15	18		12	14									
Subcontract_Nego(4) Result	17		17(-2)	19(-1)	20	13	15(-1)			14	14(0)				0	

Fig. 9. Scenario 4

According to the results of the scenario 1 experiment, the definite orders are as follows. The manufacturer 1 fulfills the order 1 and 2, the manufacturer 2 fulfills the order 4, and the manufacturer 3 fulfills the order 3. And the total manufacturing cost in this case is 33. After this, the subcontract negotiation has taken place twice, i.e. subcontract negotiation 1 and 2. Both subcontract negotiations have made the same profit of 1 respectively. Eventually the definite orders have been changed as follows.

- Manufacturer 1: {order 1}, manufacturer 2: {order 4}, manufacturer 3: {order 2, order 3}: optimal value 32
- Manufacturer 1: {order 2}, manufacturer 2: {order 4}, manufacturer 3: {order 1, order 3}: optimal value 32

	Definite Order	Number of subcontract Negotiation	Sub contract Negotiation result	Profit	Optimal Solution
Scenario 1	Manufacturer1 {order1,2} Manufacturer2 {order4} Manufacturer 3 {order 3}	2	① Manufacturer 1 {order1} Manufacturer 2:{order4} Manufacturer 3:{order2,3} ② Manufacturer 1 {order 2} Manufacturer 2:{order4} Manufacturer 3:{order1,3}	Two subcontract negotiations have generated profit 1 respectively	32 (decrease by 1 in with the definite orders)
Scenario 2	Manufacturer1:{order1,2, 3,4}	6	① Manufacturer 1 {order1,2} Manufacturer 2:{order4} Manufacturer 3:{order3}	Increase by 28 as a result of the subcontract negotiations	47 (decrease by 28 in with the definite orders)
Scenario 3	Manufacturer 1 {order1} Manufacturer 3: {order2, 3,4}	5	① Manufacturer 1 {order2} Manufacturer 2:{order1} Manufacturer 3:{order3,4}	Increase by 8 as a result of the subcontract negotiations	45 (decrease by 8 in with the definite orders)
Scenario 4	Manufacturer 1 {order3,4} Manufacturer 2 {order2} Manufacturer 3 {order1}	4	All four negotiations have produced a minus value		Current value is the solution

Table 4. Results of four scenarios

The above results that come after the negotiations are forming a new supply chain, consequently generating the minimum value for the optimal supply chain formation. The same results are being generated in the other scenarios. The results of four scenarios have been summarized in the <table 4>

The optimal values from the above negotiation method have been the same as that of the branch and bound method. However, thanks to the limitation of the number of orders and manufacturers, both methods have generated their results nearly at the same time. As mentioned in chapter 3, in case of the branch and bound method, all the information on the simultaneous scheduling cost of each relevant manufacturer and order cost should be known. Therefore, if the number of manufacturers and orders increases, its calculation time increases rapidly. More importantly, the negotiation method can be made on a real-time basis, making it possible to figure out the profit and loss of negotiation, consequently improving the negotiators' understanding.

5. Conclusion

Until now, the researches on the supply chain formation have focused on integrated scheduling mainly dealing with the integration of the vertical relationship. However, this paper has tried to consider the competitive environment of the member organizations having a horizontal relationship in an effort to expand the vertical relationship in the supply chain. Due to the excessively competitive environment, the diseconomies of scale are taking place, thus causing losses by producing below the marginal cost of a manufacturer.

However, a manufacturer tries to seek a cooperative relationship with other manufacturers to secure much more stable profit, and this effort leads to the origin of the negotiation method. Currently, in the free economy market the cooperative relationship develops into the strategic alliance, thus pursuing competitive superiority through this strategic alliance.

As shown in the previous experiments, the negotiation method has contributed not only to making a profit for the participating manufacturers but also to bringing the optimal solution to the supply chain. Nevertheless, this study needs more efforts in the sense that the negotiation method has used a limited number of manufacturers and orders. Also we admit that this study has to apply a real case to this negotiation method. From now on more researches will be made on these problems.

6. Acknowledgment

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Part 3

Optimizing Distribution Operations

12

Information Gathering and Classification for Collaborative Logistics Decision Making

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1. Introduction

Collaboration is perceived as a powerful tool for companies to deal with an increasingly demanding global economic environment. Collaboration impact upon the logistics processes is analyzed in this chapter. Logistics naturally implies the concurrency of a set of companies being part of products and services value chain. However, collaborative logistics imposes new challenges that effectively faced by companies and government institutions will produce the expected return. Such challenges relate to effective decision making process involving logistics activities planning, scheduling, control, and coordination at different companies being part of the logistics network. These decision making processes require the effective capability to capture, process, and analyze information on processes, partners, environment, regulations, etc. That information is, of course, dynamic, and it is available in a scattered way all through a variety of sources, periodicity, and formats. Effective and efficient tools for capturing, classifying, processing, and report useful information for supporting the collaborative logistics decision making processes are required. Large amounts of digital text available on the web contain useful information for enabling collaborative logistics. The amount of digital text it is expected to increase significantly in the near future, making the development of data analysis applications an urgent need. Information gathering has been traditionally faced integrating systems and databases at the various institutions and companies participating in the logistics network. This approach has at least two difficulties that have not been solved properly: 1) It requires the data be available in structured databases and stored in terms of the same attributes, and 2) Organizations need to provide access to their systems for obtaining and processing the data. An alternative approach is using data available in the web as input to automatic text classifiers implemented with machine learning techniques. Automatic text classification (or categorization) is defined as the assignment of a Boolean value to each pair (d_j,c_i) belonging to the set $D \times C$, where D is the domain of documents and $C = \{c_1, \ldots c_{|C|}\}$ is the set of predefined labels. Binary classification is the most simple and widely studied case, in which a document is classified into one of two mutually exclusive categories or classes. Document representation has a high impact on the task of classification. Some elements used for representing documents are: N-grams, single-word, phrases, or logical terms and statements. The vector space model is one of the most widely used models for ad-hoc information retrieval, mainly because of its conceptual simplicity and the appeal of the underlying metaphor of using spatial proximity for semantic proximity. In the vector space model (VSM), the contents of a document are represented by a vector in the term space: $d = \{w_1;...,w_k\}$, where k is the size of the term (feature) set. We propose a solution based on automatic text classifiers using web documents (such as twitters or microblogs) for supporting collaborative logistics decisions making processes such as planning, identifying, and creating value, enabling the flow of value stream, allowing customers to pull value uninterrupted, responding to unpredictable change, or forming tactical and virtual partnerships. Testing of the proposed solution was carried out with a prototype implementing the automatic text classifier for the above decision making processes.

2. Modeling the supply chain

For the last decade a new generation of reference frameworks has been developed in response to developments in supply-chain management. Such frameworks have been devised to model inter-company relationships as a basis for inter-enterprise software development with examples such as the Supply Chain Operations Reference-model (SCOR) and the Collaborative Planning, Forecasting, and Replenishment initiative (CPFR). Industry applications in Customer Relationships Management (CRM), Advanced Planning Systems (APS), Product Life Cycle Management (PLM), and other enterprise areas have been further developed to exploit and foster these frameworks (Hvolby & Trienekens, 2010).

2.1 Business systems integration frameworks

Next, four of the major supply chains modeling frameworks are presented briefly:

- Collaborative Planning, Forecasting, and Replenishment (CPFR)
- ISA-S95 standards for enterprise and manufacturing integration
- Integration Specifications developed by Open Applications Group (OAG)
- Supply Chain Operations Reference-model (SCOR)

CPFR has developed a set of reference business processes, which can be used for collaboration on a number of buyer/seller functions towards overall efficiency in the supply chain. The framework focuses on efficient and effective retailer–manufacturer relationships to support high consumer value. The key supply-chain functions in CPFR are planning, forecasting and replenishment. On manufacturer and retailer level specific business processes are defined (such as logistics and execution monitoring for the manufacturer and store execution and supplier scorecard for the retailer). On the interface level processes such as joint business plan, sales forecasting and order-planning are defined and worked out. Their XML specifications have been integrated with the broader set of EAN-UCC XML specifications endorsed by the Global Commerce Initiative (GCI) to ensure full coverage of the CPFR process without creating overlapping or redundant message formats. The existing core EAN-UCC messages for item synchronisation, party (trading partner) synchronisation, purchase order, invoice, dispatch (shipment notice) and other information have been augmented with the CPFR product activity, forecast and other transactions.

ISA-S95 (IEC62264) addresses the interface or exchange of data within the enterprise systems (planning, scheduling and procurement) and the production management systems (production dispatching and execution). The ISA-S95 standards are based upon 4 functional levels: business planning and logistics (level 4), manufacturing operations management (level 3), manufacturing process systems for batch, continuous and discrete control (level 2) and finally level 1, which e.g. is sensing the production process. The scope of the standard is limited to describing the relevant functions in the enterprise and the control domain and which objects normally exchanged between these domains. The standard consists of three parts: Models and terminology, Object model attributes and Models of Manufacturing Operations. The development is based on the work by Williams (1992) on the Purdue Reference Model (PRM) for Computer Integrated Manufacturing (CIM), but two other works have also a great deal of influence, which are the ISA Sp-88 ''Batch Control' committee and the Mesa International MES context model (Hvolby & Trienekens, 2010).

OAG includes a broad set of XML schemas for sharing business information. OAGIS XML is the most mature XML language today, based on over 10 year's development. It addresses the needs for traditional ERP integration as well as supply-chain management and e-commerce. This specification provides the structure of business documents and additional meta-data, which is required as a part of the application processing. ISA-S95 standardizes a variety of models and terminology that is limited to describing the relevant functions, and serves only as a foundation for implementation elements. OAGI, on the other side, defines implementations elements, but without explicitly defining standardized models and terminology, as ISA-S95. OAGI and ISA-S95 are collaborating on development of integration standards for process, discrete, and mixed-mode manufacturers. ISA-SP95 has started this effort by including a portion of the OAGIS standard in its ANSI/ISA-S95 Part 5 – Business to Manufacturing Transactions standard. Also delivery of the ISAS95 Part 4 – Object Models and Attributes of Manufacturing Operations Management standard has greatly accelerated by leveraging the work of OAGI (Hvolby & Trienekens, 2010).

In 1996 a group of 70 companies founded the Supply-Chain Council (SCC). The aim of the council was to create a Supply Chain Operations Reference-model (SCOR-model) that is branch independent and allows the exchange of information between companies in a supply chain. Furthermore, the SCOR-model was designed to enable companies to compare and learn from companies within and outside their own field. The SCOR-model approach gives these companies the chance to standardize the description of supply chains, which is very useful in order to form a unified understanding of operations and to compare different supply chains (Röder & Tibken, 2006).

The SCOR-model has been developed to describe the business activities associated with all phases of satisfying a customer's demand. The model itself contains several sections and is organized around the five primary management processes of Plan, Source, Make, Deliver and Return (Supply Chain Council, 2010; Corsten, 2001; Schönsleben, 2000). These five management processes are represented in Figure 1.

By describing supply chains using these process building blocks, the model can be used to describe simple supply chains as well as very complex enterprise networks using a common set of definitions. As a result, disparate industries can be linked to describe the depth and breadth of virtually any supply chain. The model is able to describe and provide successfully a basis for process improvement for global projects as well as site- specific projects.

The SCOR-model spans all customer interactions (order entry through paid invoice), all physical material transactions (supplier's supplier to customer's customer, including equipment, supplies, spare parts, bulk product, software, etc.) and all market interactions (from the understanding of aggregate demand to the fulfillment of each order). It does not attempt to describe every business process or activity. Specifically, the model does not address sales and marketing (demand generation), product development, research and development and some elements of post-delivery customer support.

The structure of the SCOR-model includes four levels that represent the path a company takes to improve its supply chain. The four levels are described in Figure 2.

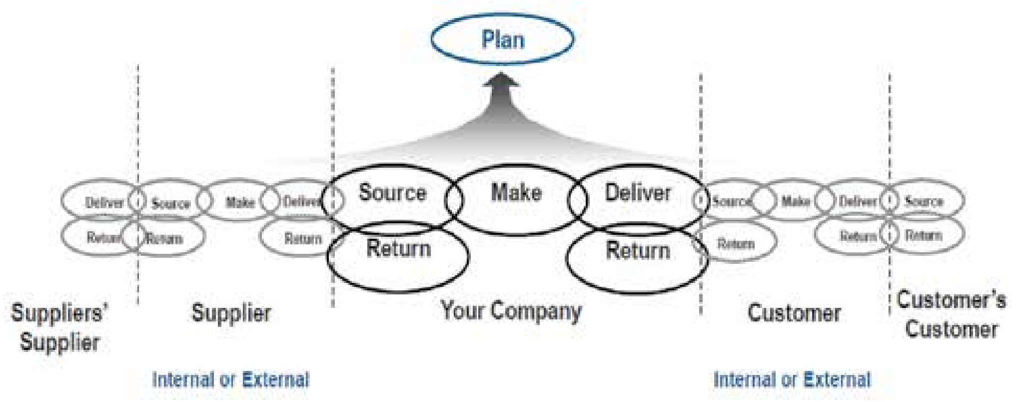


Fig. 1. The five major management processes of SCOR-model (Supply Chain Council, 2010)

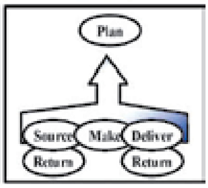
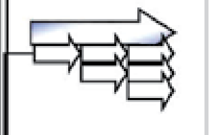
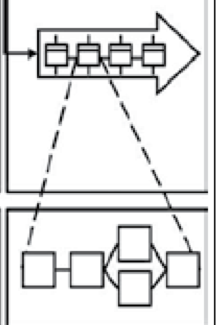
	Level	Comments	Schematic
Supply Chain Operations Reference-model	(1) Top Level (Process Types)	Level 1 defines the scope and content for the Supply Chain Operations Reference-model. Here the basis of competition performance targets is set.	
	(2) Configuration Level (Process Categories)	A company's supply chain can be "configured-to-order" at level 2 from 26 core "process categories". Companies implement their operations strategy through the configuration they choose for their supply chain.	
	(3) Process Element Level (Decompose Processes)	Level 3 defines a company's ability to compete successfully in its chosen markets. It consists of: • Process element definitions • Process element information inputs and outputs • Process performance metrics • Best practices, where applicable • System capabilities required to support best practices • Systems/tools Companies "fine tune" their operations strategy at level 3.	
Not in Scope	(4) Implementation Level	Companies implement specific supply chain management practices at this level. Level 4 defines practices to achieve competitive advantage and to adapt to changing business conditions.	

Fig. 2. Overview of Supply Chain Operations Reference-model (Röder & Tibken, 2006).

- Level 1. This level provides the definition of the plan, source, make and deliver process types. At this level the company defines its supply chain objectives.
- Level 2. Level 2defines 26 core process categories that are possible components of a supply chain. Organizations can configure their ideal or actual operations by using one or several of the core process categories.
- Level 3. Level 3 provides the information required for successfully planning and setting goals for supply chain improvements. This includes defining process elements, setting target benchmarks, defining best practices and system software capabilities to enable best practices.
- Level 4. This level focuses on the implementation, i.e., putting specific supply chain improvements into action. These are not defined within the industry standard model since implementation can be unique to each company.

2.2 Modeling intra- and inter-company supply chains

In order to validate concepts of cooperation and collaboration in inter- and intra-company supply chains and to optimize business processes in existing supply chain structures realistic modeling of supply chains is necessary. The realistic description includes the evaluation of different supply chain structures and configurations as well as different sets of parameters describing production and inventory processes. Therefore, the modeling methodology has to fulfill the following requirements of the industry:

- Requirements concerning the structures of supply chains
  - Description of intra- and inter-company supply chains.
  - Modeling of divergent sourcing and supply structures.
  - Describing company sectors by using logistic processes as source, make, and deliver processes.
  - Modeling different types of inventories (e.g. inventory for incoming goods, inventory for outgoing goods).
- Requirements concerning the material and information flows of supply chains
  - Integrated description of material flows and information flows as well.
  - Modeling of time interdependencies and time lags in material and information flows.
  - Modeling of different types of capacity constraints.

2.3 Configuration of intra- and inter-company supply chains

In order to describe the logistic processes and to assess the benefits of an integrated product and process documentation, logistic processes of intra- and inter-company supply chains have to be modeled in detail. Modeling the structures in order to configure supply chains represents the first part of the modeling methodology. The modeling is based on the SCOR-model, which flexibility and especially modularity are very useful for the configuration of structures. SCOR allows describing whole production processes as well as detailed manufacturing processes. The different methods to initiate orders, e.g. make-to-stock, make-to-order, engineer-to-order, have been incorporated as well (Supply Chain Council, 2010; Corsten, 2001). Depending on the focus of modeling, the SCOR-model approach allows a wide range of modeling material and information flows within inter- and intra-company process structures as well as high degrees of adaptability and flexibility to fast changing interdependent processes and structures.

3. Considering transportation capacity in the logistics modeling framework

By 2050, the total U.S. population is projected to reach 420 million, a 50 percent increase over 50 years. This growing society will demand higher levels of goods and services, and will rely on the transportation system to access them. In turn, this will cause travel to grow at an even greater rate than the population. As part of an increasingly integrated global economy, the U.S. will see greater pressures on its international gateways and domestic freight distribution network to deliver products and materials to where they are needed. The Nation is faced with a massive increase in passenger and freight travel (NSTPRC, 2008). This particular situation in the United States is assumed to hold for most of the countries with open economies, which depend heavily on exchange of products. As the Revenue Study Commission points out, the cost and consequences of inaction are enormous and lead to:

- Country's transportation system assets will further deteriorate
- Automobile casualties will increase, adding to the 3.3 million lives lost to traffic crashes in the last 100 years
- Congestion will continue to affect every mode of surface transportation for ever-lengthening periods each day, as a result of the mismatch between demand and supply of limited capacity
- Underinvestment in all modes will continue
- America's economic leadership in the world will be jeopardized when we cannot reliably and efficiently move our goods
- Excessive delays in making investments will continue to waste public and private funds
- Transportation policies will remain in conflict with other national policy goals
- Transportation financing will continue to be politicized

To avoid such a disastrous scenario, a capacity evaluation framework was proposed. We propose the framework can be adapted from the U.S. reality to other countries as well. The transportation decision making process is made of many individual steps. Most of these steps are work activities that take place in the technical decision making process. Key decisions are those places in the process where the general work activities need review and approval from higher levels of authority or where consensus needs to be reached among diverse decision makers before the project can advance further. For this reason key decisions most often occur in the policy decision-making process. Key decision points, therefore, represent only a portion of the overall decision-making process, but these points effectively link existing planning and project development processes and practices. Many key decision points will be common among transportation agencies. Some of them are defined by law. Others have been created through the development of standard or best practice application. The individual work activities that link and feed key decision points can be quite different from country to country.

The Capacity Project C01 "A Framework for Collaborative Decision Making on Additions to Highway Capacity" of the Strategic Highway Research Program (SHRP 2, 2010) has produced the Collaborative Decision-Making Framework (CDMF) to identify key decision points (KDPs) in four phases of transportation decision-making processes. For the purpose of this project the environmental review process is considered to be merged with the permitting process. The four phases of the CDMF are:

1. Long-Range Transportation Planning
2. Corridor Planning
3. Programming

4. Environmental Review and Permitting

The CDMF incorporates overall context sensitive solutions and project management principles and is built on a set of design goals established by the Technical Coordinating Committee for Capacity research. The design goals provide the following guidance:

- Establish a collaborative decision-making approach that identifies participant roles and responsibilities at each KDP and includes:
  - Early and on-going involvement of formal decision makers and individuals who have the potential to significantly impact the timely and cost-effective delivery of transportation improvements.
  - A tiered decision-making approach to capacity improvements that encourages binding decisions at the earliest possible point.
- Encourage timely and cost-effective project delivery through a process that:
  - Ensures transfer of information and decisions between phases
  - Encourages early and comprehensive agreement on data sources, level of detail, evaluation criteria and performance measures
  - Establishes a comprehensive and proactive risk management strategy
- Encourage a decision-making approach that evaluates transportation needs within broader community and natural contexts and integrates land planning and development policy, capital improvement planning, protection and enhancement of the human and natural environment, and addresses sustainability issues to the greatest extent possible in order to support community vision and goals.
- Encourage consideration of a wide range of options to address capacity problems during the planning phase of decision making as well as early and on-going incorporation of operational elements as a part of the overall decision-making approach.
- Establish a decision-making approach based on fulfilling the intent of legal and regulatory requirements while providing implementation flexibility and adaptability consistent with the design goals.

The CDMF is intended to be readily available to all practitioners who wish to incorporate a collaborative decision-making approach throughout the entire transportation process or only in specific areas. For this reason the ultimate vision is for the framework to be accessed through a web-based tool. The architecture of the CDMF is being designed with this in mind. The structure of the CDMF represents a series of portals through which increasingly detailed information can be retrieved for each KDP, first at the Entry Level and then at the Practitioner Level.

The diagram in Figure A1 represents the CDMF Entry Level through a series of portals in each phase of the transportation process where one or more KDPs may occur. This level demonstrates the upper-level steps in decision making as well as how the individual phases relate to one another. The community visioning process illustrated here is recommended as a best practice to ensure that the transportation decision-making process includes the larger goals and visions of the region. However, this process exists outside the transportation process, and therefore is not detailed within the CDMF. The Entry Level allows the practitioner to select an area of specific interest within the process to approach at the more detailed level.

Although the Entry Level provides a concise overview of the CDMF, transportation practitioners will need specific information at each KDP in order to consider implementation of the collaborative decision-making process. The CDMF Practitioner Level (Figure A2) provides access to the full extent of information available at each KDP including:

- Purpose and outcome of the KDP
- Decisions made at this step
- Roles and responsibilities of the formal decision makers
- Stakeholder/project champion roles and relationships
- Supportive data, tools, and technology
- Related influencing and sub-processes
- Primary products of this step
- Associated best practices
- Linkage to other Strategic Highway Research Program (SHRP2) Capacity research such as the C02 Performance Measurement Framework

There are other community planning processes that are external to the transportation process but which have an impact on transportation decision making. Within the CDMF these processes are identified as sub-processes or influencing processes. While sub-processes have a direct effect on the transportation process through certain critical-path steps, other external processes strongly influence transportation decision making and best practice in collaboration would engage these processes as well. The CDMF contains KDPs that link the air quality, land use, and fiscal constraint sub-processes to the transportation process as well as to detailed information to allow integration of the influencing process such as the natural and human environment, safety and security planning, and capital improvement planning.

We propose that SCOR and CDMF frameworks can be integrated. Such integration would allow to assist the logistics operation planning and control with information regarding the planning and operations of the transportation system for the given infrastructure available in each case. At the same time, the actual and foreseen requirements for transportation infrastructure would be adequately considered in government and private investments.

4. Facing the challenge of data availability for supply chain planning and control

Supply chain planning and control processes, even though they might be designed and organized according to reference frameworks, will perform better if they use environmental information available from different sources, for instance blogs, microblogs such as Twitter, or other sources of unstructured data. Based on the proposition by Trkman et al. (2010) for supporting the demand planning and build better forecasts, we propose to use information available on the web for assisting the planning and control supply chain decision making processes. The proposed architecture is shown in Figure 3.

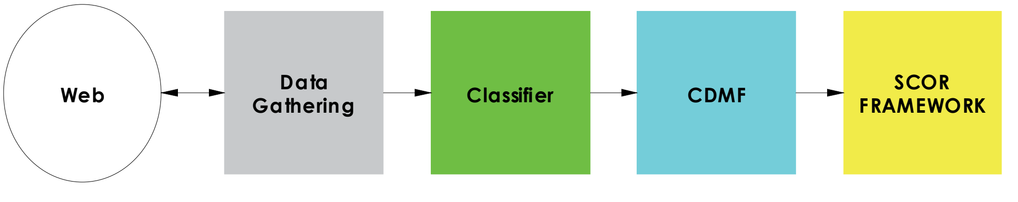


Fig. 3. Proposed architecture.

4.1 Automatic text classification

The processing of automatic text classification consists in selecting attributes representing the most of every class. The attributes allow to distinguish specific texts from the rest, process that permit us to assign the text being classified to a category or set of categories to which it belongs. It seeks to approximate a classifier function f, as well as possible on the basis of experience or data available through the construction of a function f 'f match most of the domain, ie:

$$f{:}D \times C \rightarrow \{0,1\} \tag{1}$$

$$f'{:}D \times C \rightarrow \{0,1\} \tag{2}$$

where $C = \{c_1, ..., c_k\}$ is the set of predefined categories and $D = \{d_1, ..., d_n\}$ a collection of documents.

4.2 Automatic classification types

There are a large amount of digital texts available on the web, as well as organizational databases containing useful information for a wide variety of purposes. It is expected that the amount of digital texts increase in the future so there is a need to develop machine learning techniques to analyze them effectively and efficiently. One type of analysis is the classification or pattern recognition (pattern recognition), which seeks to automatically detect certain regularities in the data using algorithms, to subsequently use these regularities to classify new data into different categories (Bishop, 2006). That is, it seeks to develop a model that, based on an analysis of the characteristics of a set of objects previously labeled, allow the assignment of correct labels to new objects.

In particular, automatic text classification is defined as assigning a Boolean value to each pair $<d_j, c_i> \in D \times C$, where D is the domain of texts and $C = \{c_1,\ldots c_{|C|}\}$ is the set of predefined tags (Sebastiani, 2002). Binary classification is the simplest and most widely used in such classification, each document is classified in one of two mutually exclusive classes, i.e. each label represents a partition or set disjoint. Moreover, multi-class classification allows each document is classified in one of several classes, also mutually exclusive. Binary classification can be extended to solve multi-class problems.

Also, a text can be classified according to one label (single-label classification) or more than one label at a time (multi-label classification). To address multi-label classification problems, two approaches are mainly used: adaptation algorithms and problem transformation (Tsoumakas, 2010). Another type of classification is based on how the assignment to classes is made: hard or soft classification (Qi & Davison, 2009). Based on the relations between classes, there are two types of classification: flat and hierarchical (Sun, et al. 2002).

4.3 Problem representation

The performance of artificial systems depends crucially on the quality of representation of the problem. The same task can be easy or difficult depending on how you described (Fink, 2001). When using an explicit representation of information or restrictions yield a better machine. In addition, a more complex representation can work better with simpler algorithms.

The complexity of a problem in pattern recognition, or classification, is determined by its representation in feature space (Duin & Pękalska, 2009). In particular, the representation of

the texts has a high impact on the performance of the classification task (Keikha et al., 2008). Some features of the text used to represent documents are: N-grams, words, phrases, logical terms and statements. The vector space model is one of the most used models for information retrieval, mainly due to its conceptual simplicity and the use of metaphor underlying the use of spatial proximity to estimate the semantic proximity (Manning and Schütze, 1999). This model assigns a weight to each feature of the document so that similar documents will have similar characteristics. To solve the problem of how to weigh the terms in the vector space model uses the frequency of a word in a document. However, there are effective methods for weighting terms. The basic information used in the balancing of weight is the term frequency and document frequency.
According Lan et al. (2009), two important decisions for the choice of a representation based on vector space model (VSM), are: 1) What should be the features to represent? For example, development of sub-word, word, several words or meaning, and 2) What is the weight of each feature? For example, weights can be binary, or tf-idf (Salton & Buckley, 1988).

4.4 Support vector machines

The theory of Support Vector Machines (SVM) is a classification technique and is based on the idea of structural risk minimization (Vapnik, 1989). In many applications, SVMs have shown a great performance, rather than traditional learning machines such as neural networks and have been introduced as powerful tools for solving classification problems. A first SVM maps the entry points to a feature space of higher dimension and finds a hyperplane that separates them and maximize the margin *m* between the classes in this space.
Maximizing the margin *m* is a quadratic programming problem (QP) and it can be solved by solving its dual problem by using Lagrange multipliers. Without any knowledge of the mapping, the SVM finds the optimal hyperplane using the dot product functions in the space of characteristics that are called kernels. The solution to the optimal hyperplane can be written as the combination of a few entry points are called support vectors.

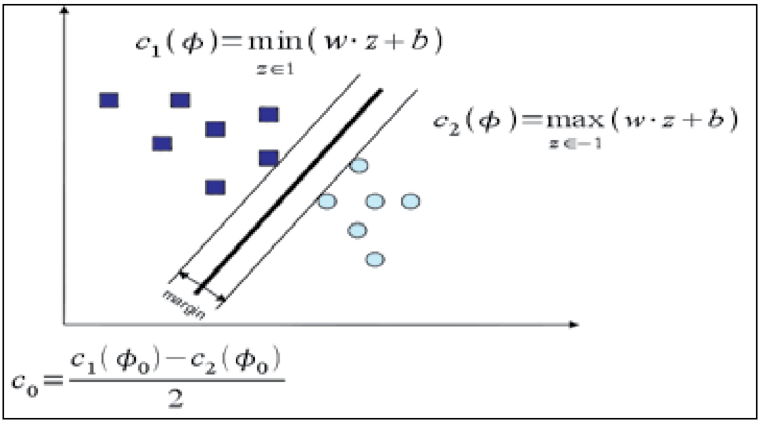


Fig. 4. Separations SVM hyperplane and margins

For linearly separable, given a set S of a labeled training example $(x_1,y_1),\ldots(y_i,x_i)$,each training example $x_i \in R^n$ belongs to one of two classes and has a label $y_i \in \{-1, 1\}$ for $i = 1$,......, l. In most cases, the search for a suitable hyperplane in an input space is too restrictive to be of practical use. One solution to this situation is to map the input space into a feature space of higher dimension and find the optimal hyperplane there. Let $z = \Phi(x)$ the corresponding vector notation in the feature space Z. Being w, a normal vector (perpendicular to the hyperplane), we find the hyperplane $w \times z + b = 0$, defined by the pair (w,b) such that we can separate the point x_i according to the $f(x_i)= \text{sign}(w \times z_i + b)$, subject to: $y_i (w \times z_i + b) \geq 0$.

In the case that the examples are not linearly separable, a variable penalty can be introduced into the objective function for mislabeled examples, obtaining an objective function $f(x_i)= \text{sign}(w \times z_i + b)$, subject to: $y_i (w \times z_i + b) \geq 1- \xi_i$.

SVM formulations discussed so far require positive and negative examples can be separated linearly, i.e., the decision limit should be a hyperplane. However, for many data set of real life, the decision limits are not linear. To cope with linearly non-separable data, the same formulation and solution technique for the linear case are still in use. Just transform your data into the original space to another space (usually a much higher dimensional space) for a linear decision boundary can separate positive and negative examples in the transformed space, which is called "feature space." The original data space is called the "input space." Thus, the basic idea is that the map data in the input space X to a feature space F via a nonlinear mapping Φ,

$$\Phi: X \rightarrow F \tag{3}$$

$$X \rightarrow \Phi (x) \tag{4}$$

The problem with this approach is the computational power required to transform the input data explicitly to a feature space. The number of dimensions in the feature space can be enormous. However, with some useful transformations, a reasonable number of attributes in the input space can be achieved.

Fortunately, explicit transformations can be avoided if we realize that the dual representation, both the construction of the optimal hyperplane in F and the corresponding function assessment decision/classification, only requires the evaluation of the scalar product $\Phi(x) \cdot \Phi(z)$ and the vector $\Phi(x)$ is never allocated in its explicit form. This is a crucial point. Thus, we have a way to calculate the dot product $\Phi(x) \cdot \Phi(z)$ in the feature space F using the input vectors xyz, then it would not need to know the feature vector $\Phi(x)$ or even mapping function Φ. In SVM, it's done through the use of "kernel function", which is referred to as K. $K(x,z)$ equals to $\Phi(x) \cdot \Phi(z)$ and are exactly the functions for calculating dot products in the transformed feature space with input vectors x and z. An example of a kernel function is the polynomial kernel, $K(x,z)=\langle \mathbf{x},\mathbf{z}\rangle^d$, which can replace all dot products $\Phi(x) \cdot \Phi(z)$. This strategy of directly using a kernel function to replace the dot products in the feature space is called "kernel trick." Where would never have to explicitly know what function Φ is. However, the question remains how to know a kernel function without making its explicit referral. That is, ensuring that the kernel function is actually represented by the dot product of the feature space. This question is answered by the Mercer's Theorem (Cristianini & Shawe-Taylor, 2000).

4.5 Automatic classification of opinion (sentiment analysis)

Today, large amounts of information are available online documents. In an effort to better organize the information for users, researchers have been actively working the problem of automatic text categorization. Most of this work has focused on the categorization of categories, trying to sort the documents according to subject (Holts et al., 2010). However, recent years have grown rapidly in online discussion groups and sites reviews, where a crucial feature of the articles published is his way or global opinion on the subject, for example if a product review spoke positively or negatively (Pang & Lee, 2008). The labeling of these items with your sentiment would provide added value to readers, in fact, these labels are part of the appeal and added value of sites like www.rottentomatoes.com, which labeled the movie that do not contain explicit rating indicators and normalizes the different rating systems that guide respondents' sense. It would also be useful in business intelligence applications and recommender systems, where user input and feedback can be quickly summarized. On the other hand, there are also potential applications for filtering messages, for example, one might be able to use the information to recognize the meaning and discard comments that were not interested in reading. This chapter examines the effectiveness of applying machine learning techniques for the classification problem of meaning. A challenging aspect of this problem that seems to distinguish it from the traditional classification based on themes is that although the topics are often identified by keywords, the meaning can be expressed more subtly.

An expert system using machine learning for text categorization has a relatively poor performance compared to other automatic classification applications. Moreover, differentiating positive from negative text comments is relatively easy for humans, especially when comparing to the problem of standard text categorization, where issues can be closely related. There are people whose use specific terms to express strong feelings, so it might be sufficient to generate a list of terms to classify the texts. Many studies indicate that it is worth to explore techniques based on domain-specific corpus, instead of relying on prior knowledge to select the features for feelings and sorting.

5. Case of study: Premium Chilean wine supply chain

For testing the supply chain framework and its assisting information retrieval technology, we select model the premium Chilean wine supply chain and use Twitter available comments as unstructured data source for assisting the demand planning and the supply chain control. This domain is experimentally convenient because there are large collections online readily available, but they are not labeled. Therefore, there is a need for hand-label data for supervised learning. The comments were taken automatically from the popular Twitter platform and categorized into one of three categories in relation to demand growth: positive, negative, or neutral. For the situation at hand, we assume that an increment of positive comments implies that demand will increase (at least for the next business cycle). While neutral comments are considered as not affecting the demand. Comments considered as advertisement where classify within this category. Finally, negative comments are considered to affect the demand negatively.

Chile has a long history in winemaking (Visser, 2004). In 1551, a Spanish conqueror managed to make wine at a location 500 kilometers north of Santiago. During the colonial period, wine was made for religious purposes. In the 18th and 19th century, rich families in Chile made wine imitating French Chateaux and thus importing classical grape varieties and technology from France. The outbreak of Phylloxera in Europe at the end of the 19th century stimulated the export of quality wines. In the 20th century, wine production slowed down, as import-substitution policies did not favor exports and wine-makers depended on a small domestic market. In the 1980s, changes in macroeconomic policies and national law joined crucial developments in the domestic and international wine markets, boosting vineyard area, wine production and exports in the 1980s and the 1990s.

It takes about three years before new vines are in production, so the growth of wine production is likely to increase at least until 2004, as a result of the accelerating increase of the planted area in 1999/2000. In international perspective, only China and Australia surpass Chile regarding the speed of increase in the vineyard area during 1995-2000, with a 57 and 73% respectively.

Despite the fast increase of the vineyard area after 1995, Chile ranks 11th in the world on this count (ibid.), holding a share of 1.3% in 2001. Spain is first on the list, with a 15.5% share of the global vineyard area. France (11.9%), Italy (11.5%), Turkey (6.7%), and USA (5.2%) follow, while Argentina had a 2.6 % share in 2001.

The industry's main focus is red vines. Important grape varieties are Cabernet Sauvignon and Merlot. Syrah and Carmenère are relatively new additions to Chilean wine. The planted area of these four wine grape varieties increased considerably. The Carmenère grapes will continue to increase in importance during the following years, as this variety disappeared in Europe (where it comes from), due to the world wars and several plagues. At the moment, Chilean wine producers aim at expanding Carmenère production, branding it as a typical Chilean vine, like Shiraz reds for Australia or Malbec for Argentina.

Chile's wine industry is an example of an effective turnaround from a focus on domestic towards export markets. Several indicators can be used to sustain this point, e.g. the share of wine sold abroad; export sales volume, value, and share in global markets; the geographical diversification and penetration of markets; and the number and location of exporting firms. The share of Chilean wines sold abroad increased from 7% in 1989 to 63% in 2002. In volume terms, only 8,000 hectoliters were exported in 1984, a figure rising to 185 thousand in 1988, and then accelerating throughout the 1990s, so that in 2002, more than 3.5 million hectoliters of Chilean wine found their way to the world market. This is the fastest growth recorded for New World wine producers during the period under review (Coelho 2003). With this, Chile's share in global wine export volume rose from about zero in 1984 to over 4% in 2000. Export value rose from a meager 10 million US-dollars (FOB) in 1984, to 145 million US-dollars (FOB) in 1994 and a dazzling 602 million US-dollars (FOB) in 2002. Premium Chilean wine supply chain considers national and international suppliers as well as mostly international customers (Figure 5).

According to the architecture proposed and shown in Figure 3, a total of 1004 Twitter comments were gathered from January 26, 2011 until March 29, 2011. An example of twitts comments are shown in Table 1.

Then, a manual classification was performed on a subset of 200 comments, to label them into positive, negative, or neutral categories, in order to use them as testing and training sets to be input to the Support Vector Machine devised. The results of the classification process performed over the entire data set are shown in Table 2.

Given the result in Table 2, the behavior of the demand must be expected to grow. How much growing in the demand should be expected is matter of a business intelligence system. These scattered signals gathered in the system we propose, must act jointly with systems at every level in the logistics chain to prepare each company for the situation ahead. According to our solution schema, this information should be passed through the highway capacity framework to the SCOR supply chain model and plan accordingly. Action regarding selection of transportation routes and modes as well as production, supply, and logistics processes planning in the supply chain should take place after feedback information is obtained. Long term planning must take place based on aggregated information, both from structured and unstructured information.

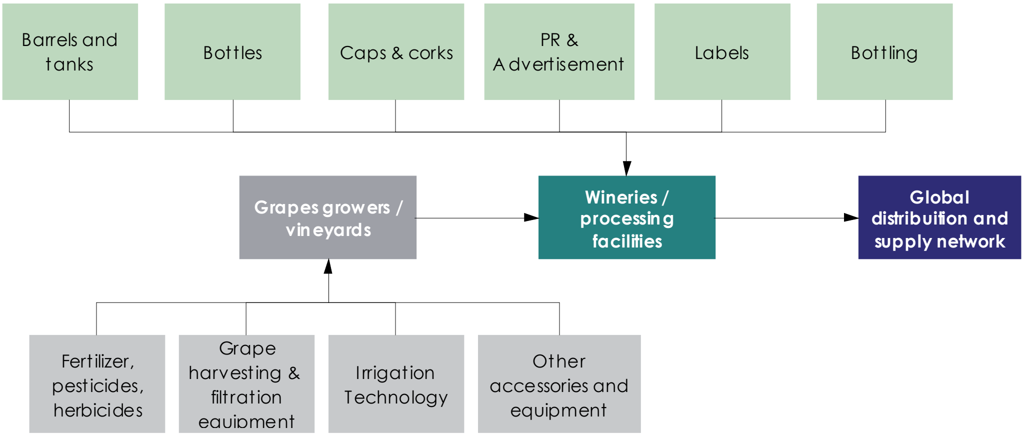


Fig. 5. Premium Chilean wine supply chain.

Date	Comment	Category
01/26/11 10:47 PM	Tabali Reserva Especial 2008 Syrah http://bit.ly/gdKos3	neutral
02/02/11 10:52 PM	So Jr. wants to do study abroad in Chile next year. My 1st question is..."How much wine can you bring back home?" Me loves Chilean wine.	positive
02/04/11 03:32 PM	Jeez, you could clean windows with these personalized bottles of chemically-enhanced Chilean wine.	negative
02/10/11 03:50 PM	Enjoying a Chilean wine this Valentine's Day? Whether it's red, white, sparkling or still, we want to hear about it!	positive

Table 1. Examples of twitts about "Chilean wine"

	Neutral	Positive	Negative
Accuracy	19.64%	95.71%	NA
Percentage	38%	60%	2%

Table 2. Performance measurements of sentiment classificator.

6. Conclusion

An integrated framework based on SCOR and CDMF by the U.S. Transportation Research Board for modeling supply chains is proposed. The proposed framework is comprehensive in terms of considering all the processes taking place in the supply chain for a given product and at the same time assist by taking into account the transportation system capacity. We also propose the operation of the supply chain model, obtained with the integrated framework, should operate considering both structured data (available mostly in companies or government agencies databases) and unstructured data (available from web sources such as social networks). However, the enrichment that unstructured data provides to classical decision making processes is important but does not eliminates the need for structured data. Nevertheless, the amount of unstructured data available on the web is increasing by the minute and its processing requires of powerful technologies of data processing and storage, becoming available in a continuous basis. Thus, the processing of huge amounts of, apparently, unrelated data produces rich information at low price, situation that has no comparison to structured data (or that might be obtained at a very high price). The proposed integrated framework and information retrieval assisting technology is scalable to supply chains and applications in fields other than logistics.

8. Appendix

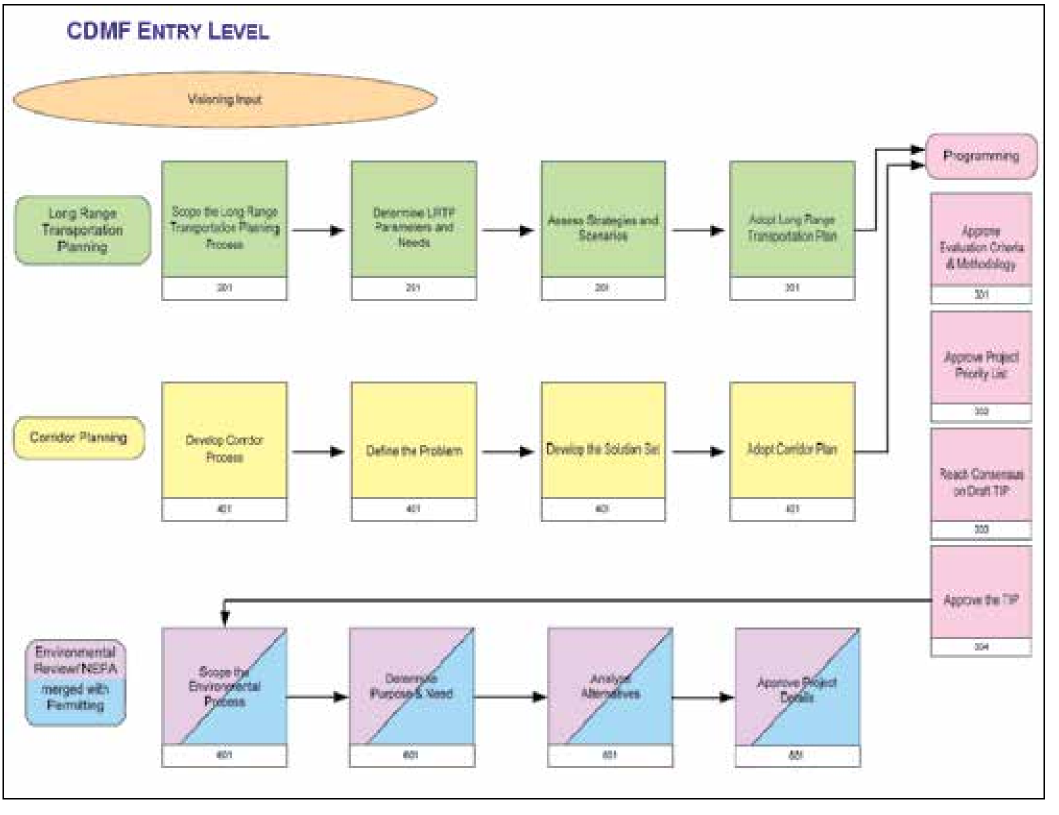


Fig. A1. Collaborative Decision-Making Framework Entry Level (SHRP 2, 2010)

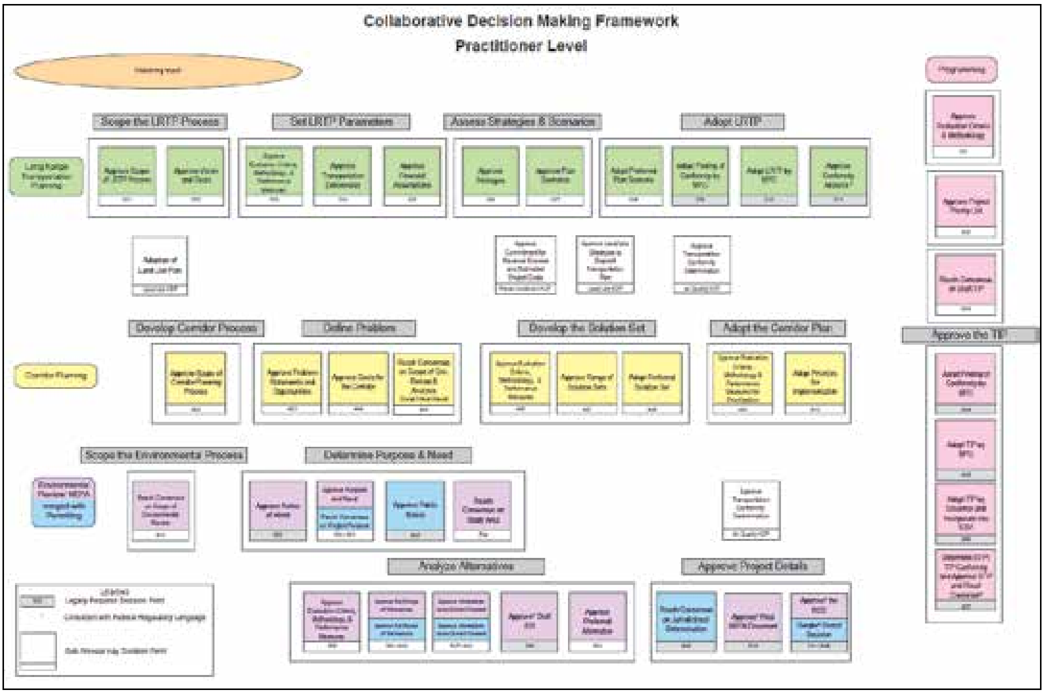


Fig. A2. Collaborative Decision-Making Framework Practitioner Level (SHRP 2, 2010)

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13

A Supporting Decision Tool for the Integrated Planning of a Logistic Network

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1. Introduction

Design, management and control of a logistic distribution system are very critical issues in supply chain management (SCM). They involve a large number of interdependent decisions, such as the determination of the best location and capacity of a distribution center (DC), a production plant, a wholesaler etc., the allocation of customer demand to suppliers, e.g. regional DC (RDC), the adoption of a transportation mode, e.g. rail and truck, the vehicle routing adopting/not adopting a "groupage" strategy. This chapter presents an original and automatic supporting decisions platform for the integration of strategic (long-term), tactical (mid-term) and operational (short-term) decisions in the design, management and control of a logistic network including up to four operating levels: sources (production plants), central distribution centers (CDCs), RDCs, and customers (points of demand-Pods). A case study is illustrated and obtained results discussed in presence of different problem settings and operating hypotheses.
The main contribution of this chapter is the illustration of an automatic supporting decisions tool for the design, management, control and optimization of a logistic network.
The remainder of this chapter is organized as follows. Section 2 presents a review of the literature studies on the design and management of a supply chain. Section 3 illustrates the proposed conceptual framework for planning a supply chain: this framework has been adopted by LD-LogOptimizer. Section 4 presents a case study and illustrates the obtained results. Finally Section 5 presents conclusions and further research.

2. Supply chain planning

A supply chain (SC) is a network of suppliers (sources), production plants, warehouses, and distribution channel organized to acquire raw materials, convert them to finished products, and distribute products to customers. The flow of goods between a supplier and customer passes through several levels and stages, and each level consists of many facilities (Bidhandi and Yusuff, 2011).
A generic SC network is depicted in Figure 1. It is made of 4 levels (sources, CDCs, RDCs, Customers) and 3 stages (Sources-CDCs, CDCs-RDCs, RDCs-Customers). The generic stage involves two different kinds of entities, e.g. CDCs and RDCs, linked with a direct flow of

materials. In general by-pass flows are admissible, e.g. from the source level to customers, i.e. points of demand (Pods).

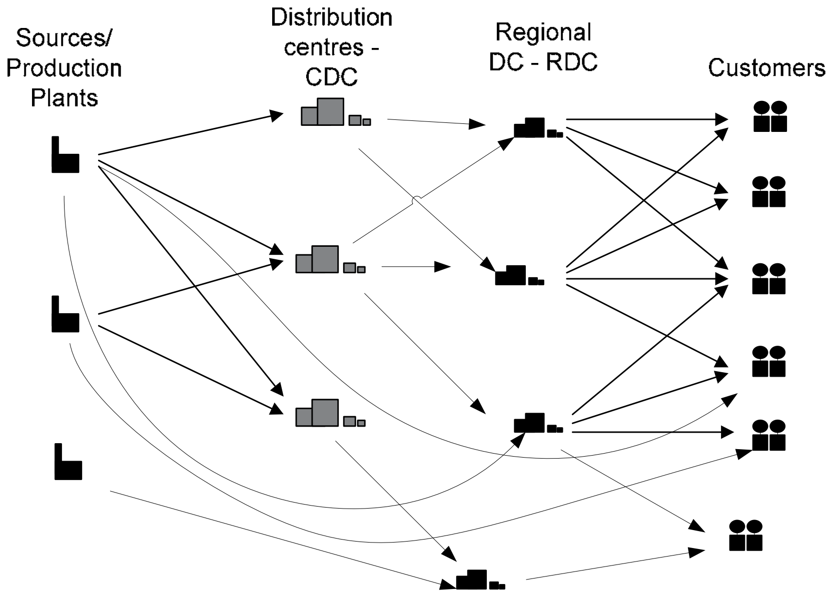

Fig. 1. A generic supply chain network

Supply chain management (SCM) is the integration of key business processes among a network of interdependent suppliers, manufacturers, distribution centers, and retailers in order to improve the flow of goods, service, and information from original suppliers to final customers, with the objective of reducing system-wide costs while maintaining required service levels (Simchi-Levi et al. 2000).

Stadtler (2005) presents a framework for the classification of SCM and advanced planning issues and targets: there are several commercial software packages available for advanced planning, the so-called advanced planning systems (APS), incorporating models and solution algorithms and tools widely discussed by the literature. In particular, Su and Yang (2010) discuss the importance of enterprise resource planning (ERP) systems for improving overall SC performance. ERP systems are essential enablers of SCM competences. Nevertheless there are not yet valuable integrated tools as supporting decisions makers for planning strategic, tactical and operational issues and activities of a wide and complex logistic network. In particular, ERP systems and APSs do not support decision making on the whole system (logistic network) optimization and design. The great complexity of such a problem forces the managers to accept *local optima* as sub optimizations renouncing to identify the best configuration of the whole network. The so-called best configuration usually corresponds to an admissible solution of minimum logistic cost and/or maximizes customer's service levels.

Planning a SC network involves making decisions to cope with long-term strategic planning, medium-term tactical planning and short-term operational planning as summarized in Figure 2.

Figure 3 reports main decisions for the strategic planning (e.g. supplier selection, production facilities location), the tactical planning (master production planning, DCs assignment, storage capacity determination) and the short time operational planning and scheduling

(scheduling, multi-facility MRP, vehicle routing) classified in terms of decision typology: *purchase & production* decisions, *distribution* decisions and *supply* decisions (Manzini and Bindi, 2009).

Fig. 2. Classification of planning decisions

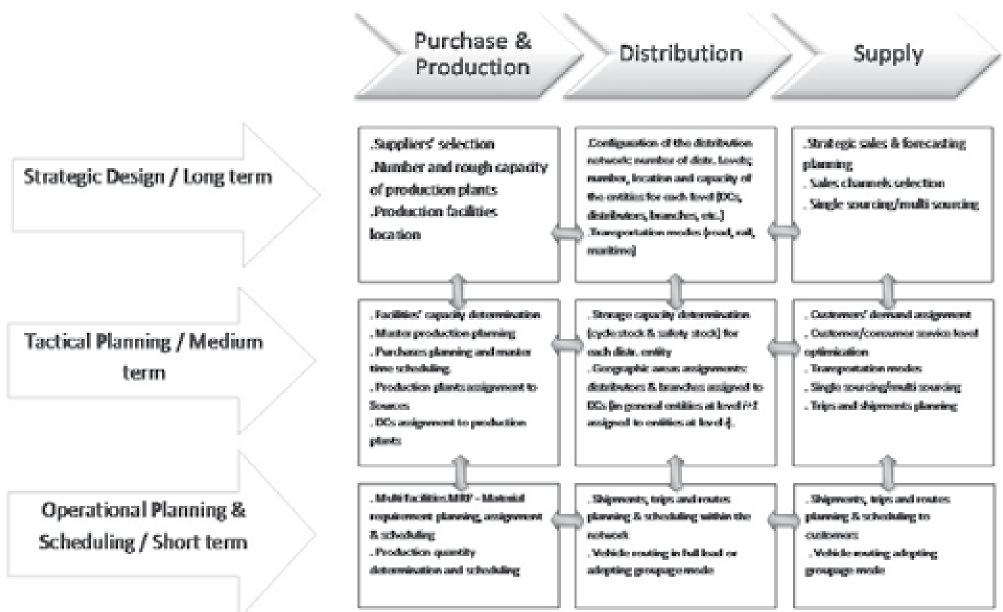

Fig. 3. Issues and decisions (Manzini and Bindi, 2009)

2.1 Strategic planning

The strategic level deals with decisions that have a long-lasting effect on a company (Simchi-Levi et al. 2004) and supports the design and configuration of a logistic network. The terms "network design" and "SC network design" are usually synonymous of *strategic SC planning*. Melo et al. (2009) classify the literature on strategic planning in accordance with some typical SC decisions: capacity decisions, inventory decisions, procurement decisions,

production decisions, routing decisions, and the choice of transportation modes. Additional features of facility locations models in SCM environment are: financial aspects (e.g. international factors, incentives offered by governments, budget constraints for opening and closing facilities), risk management (uncertainty in customer demands and costs, reliability issues, risk pooling in inventory management), and other aspects, e.g. relocation, bill of material (BOM) integration, and multi period factors. To avoid sub-optimization, these decisions should be regarded in an integrated perspective (Melo et al. 2009).
As a consequence, the strategic planning usually deals with long-term decisions, *single period* modelling, and the so-called location allocation problem (LAP) (Manzini and Bindi, 2009). The strategic planning can be considered as the design of a "static network": the aim is the determination of the best configuration, i.e. the architecture, of the logistic system.

2.2 Tactical planning

The tactical planning deals with medium-term and short-term decisions by a *multi-period* modelling. This planning activity defines the best configuration of the multi-echelon inventory distribution fulfilment system. It generates also the list of deliveries/shipments between suppliers and customers at different stages of the distribution system. As a consequence the aim of the tactical planning is the determination of the best configuration and management of the fulfilment system. The tactical planning is similar to a multi-echelon and time-dependent capacity constraint material requirement planning (MRP) combined to a distribution requirement planning (DRP). This planning is multi-product (i.e. multi-commodity), multi-period and the duration of the planning horizon of time is generally a few months. Different transportation modes are available. Storage, handling and production capacities are modelled for each distribution/production center.

2.3 Operational planning

As a result of the application of a multi-period tactical planning to a distribution network, the logistic manager needs to daily supply products to a large set of customers/consumers, the so-called points of demand (Pods), by the adoption of a set of different transportation modes. The operational planning of a SC network deals with the short-term scheduling of vehicle missions & trips necessary to supply products to the demand points, in presence (or in absence) of the groupage strategy. This strategy consists in defining groups of Pods that can be visited by a vehicle in a single trip. Consequently, adopting the groupage strategy the customers/Pods are grouped in disjunctive pools and a single vehicle serves the members of each group simultaneously in a multi-stop (multi-visit) trip (route/mission). This is the well-known vehicle routing problem (VRP), which is a non-deterministic polynomial-time hard (NP-hard) combinatorial optimization and nonlinear programming problem seeking to service a number of customers with a fleet of vehicles (Baldacci and Mingozzi 2009, Dantzig and Ramser 1959). In particular CVRP is the so-called capacitated VRP, where a fixed fleet of delivery vehicles of uniform capacity must serve known customer demands from a common depot, e.g. a distribution center CD, at minimum transit cost (Güneri 2007).
In SC planning, given a point in time t, e.g. a day, and a defined depot (e.g. a production plant, a central distribution center CDC, a regional distribution center RDC), there are many Pods assigned to that facility as the result of a tactical planning: their demand values are allocated to that facility in t. For example in presence of a 3-stage and four levels SC made of production Plants (level 1), CDCs (level 2), RDCs (level 3), customer Pods (level 4), it can

be necessary to define the daily scheduling of deliveries from the central DCs to the regional DCs, and the daily scheduling from the RDCs to the customers in presence of fractionable and/or non fractionable (single-sourcing hypothesis) demand of products, and adopting and/or non adopting the groupage strategy.
The daily SC planning is a very complex problem and consists in defining the best groups of customers and the best geographical routings minimizing the global logistic costs in accordance to different kinds of constraints, e.g. time windows, load capacities, pickup and delivery sequencing, set-up, etc. Literature presents several models and methods to help the manager to find good solutions; but they are generally very complex and not effective given a real instance/application of the transportation problem characterized by a realistic dimension, e.g. hundreds of Pods and many depots.

3. A framework for an integrated planning

Figure 4 presents the conceptual framework of the proposed integrated planning process. The proposed automatic tool LD-LogOptimizer has adopted this framework. It is a multi-step supporting decisions framework for strategic, tactical and operational planning activities. This is the basis for the development of an automatic tool, named LD-LogOptimizer. LD-LogOptimizer is illustrated in this chapter and has been applied to a significant case study as discussed in last sections of this chapter. This tool deals with many input data and generates a lot of results and system performance as discussed below.

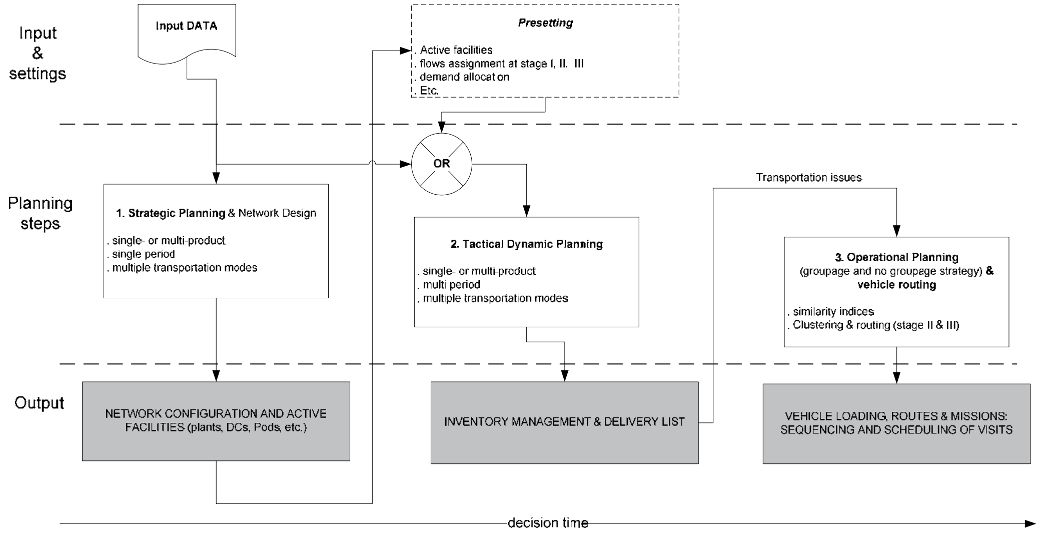

Fig. 4. Framework for an integrated planning of a distribution network

Figure 5 presents the input data to be collected for the implementation of the approach briefly illustrated in Figure 4. For the generic Pod: geographical location and demand quantity for each product and each point in time *t*, e.g. daily demand. For the generic RDC and CDC: location, fixed operating cost, variable operating (inventory and handling) costs, maximum admissible capacities (storage and handling). For the generic production plant: location, fixed operating cost, variable unit costs (also including the production unit cost), maximum admissible capacities (also including the production capacity), etc.

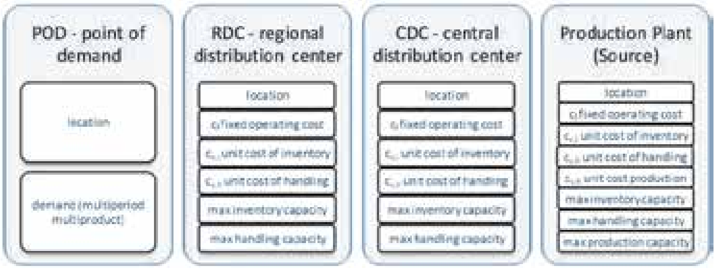

Fig. 5. Input data for the implementation, logic scheme

3.1 Strategic planning in LD-LogOptimizer

Figure 6 illustrates the strategic planning as modelled and implemented by the proposed automatic tool LD-LogOptimizer. In particular, given previously illustrated input data, a 3-stage (4-levels) single-period multi-product mixed integer linear programming (MILP) model for the location allocation problem (LAP) is defined. Euclidean distances are generally adopted to model the distances between two locations, e.g. a source and a RDC. A set of input data on variable and fixed costs and vehicles' settings has to be introduced because different transportation modes are available.

The model can be solved as-is (see "strategic model 3S" in Figure 6) or reducing the number of levels from four to three (i.e. the number of stages to two) by the generation of two distinct sub-problems: the assignment of Pods demand to RDCs by the execution of a heuristic rule and the assignment of materials flows to the higher levels of the network (from RDCs to the sources passing from the CDCs). The in-depth illustration of the heuristics is not the aim of this chapter. The simplification introduced by the heuristic approach to problem solving significantly reduces the computational complexity of the decision problem: the as-is "strategic model 3S" is substituted by the so-called heuristic rule at the first stage combined with the "strategic model 2S" at the second and third stages. The as-is problem modelling is for the optimal solution of the LAP; the simplified reduces the computational time but accept feasible solution very closed to the unknown optimal one. The strategic planning as reported in Figure 6 generates a large number of output results.

3.2 Tactical planning in LD-LogOptimizer

The tactical planning implemented by LD-LogOptimizer is illustrated in Figure 7. The dynamic multi-period, multi-product, multi-transportation mode, 3-stage LAP can be solved as a result of the application of the so-called "pre-setting" process (see Figure 7), i.e. by the activation of facilities and/or flows and/or transportation modes adopted at the strategic decisional step, or as an optimization problem without assuming any hypothesis/decision generated at the previous step. In absence of pre-setting the model is called "tactical model 3S" (see Figure 7). Examples of output data, mainly time based, for the tactical planning are: inventory levels at production/distribution facilities, material flows, picking/delivery lists of products at the generic Pod for a point in time *t*, transportation mode adopted for a specific product from a supplier level to a point of demand level in *t*, costs, etc.

3.3 Operational planning in LD-LogOptimizer

Figure 8 illustrates the adopted operational planning for a 3-stage, multi-period, multi-product, multi- (transportation) -mode. It is a cluster-first and route-second procedure based

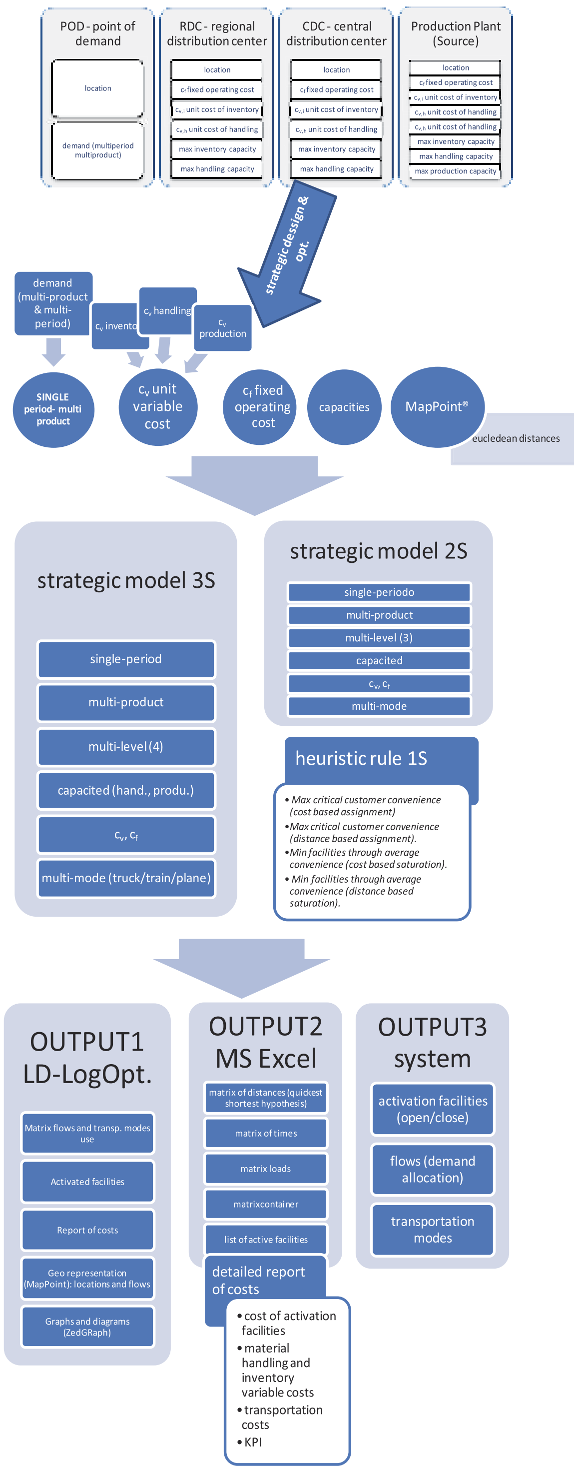

Fig. 6. Strategic planning, LD-LogOptimizer

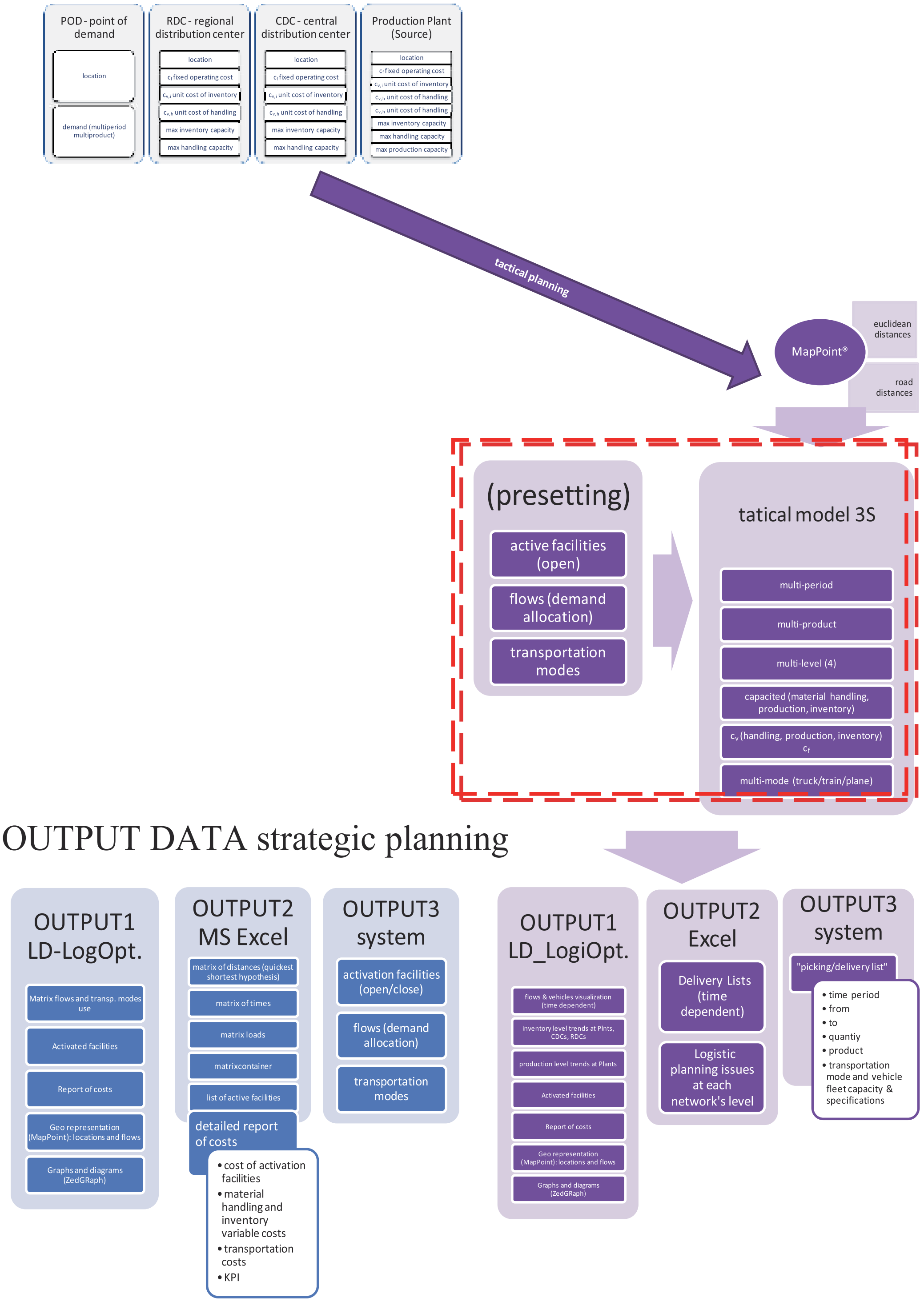

Fig. 7. Tactical planning, LD-LogOptimizer

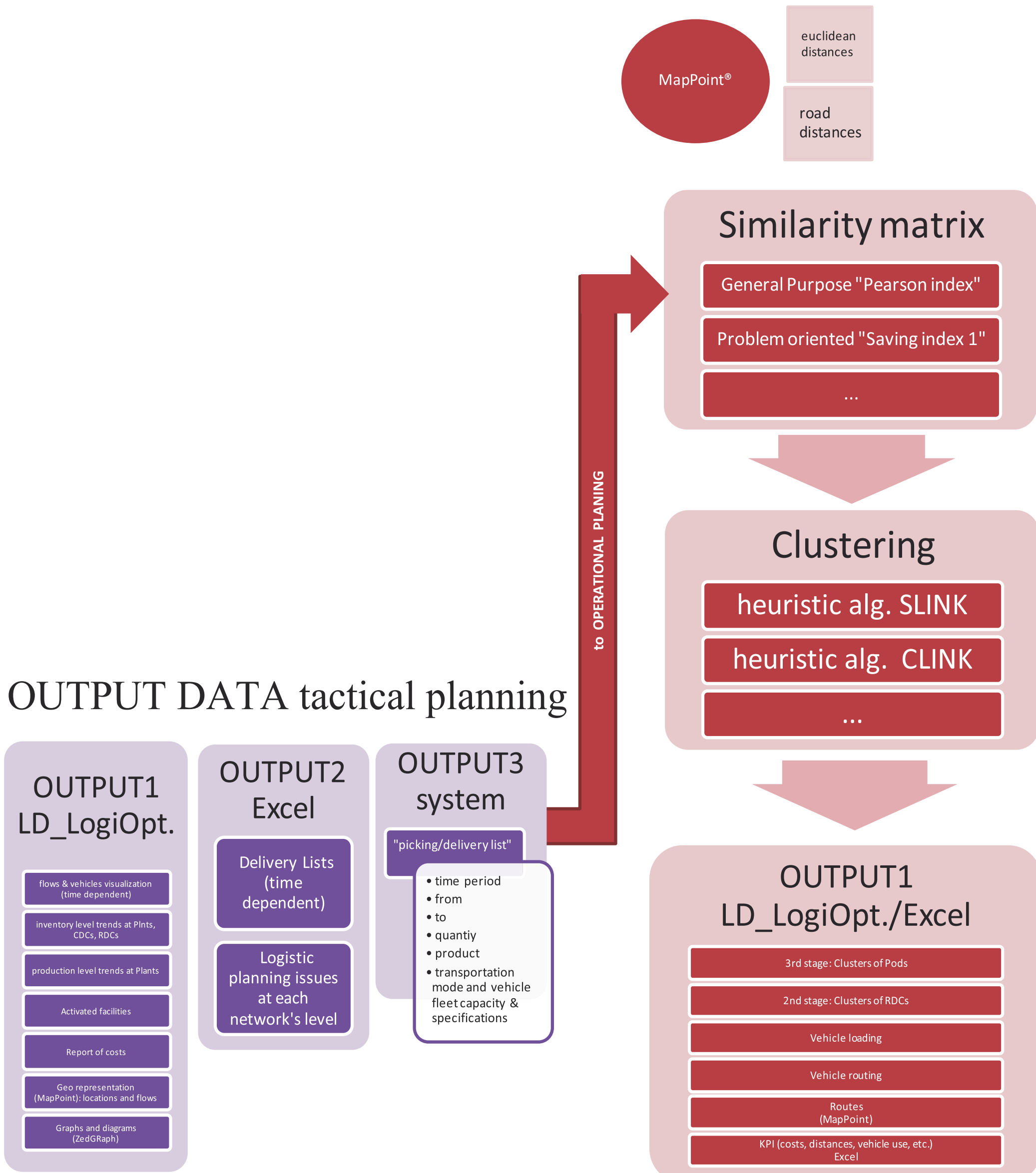

Fig. 8. Operational Planning, LD-LogOptimizer

on the introduction of original similarity indices for clustering of demand points (e.g. Pods at the first stage RDCs-Pods or RDCs at the second stage CDCs-RDCs) and sequencing/routing of visits (e.g. Pods) within each cluster of demand points assigned to a supplier (e.g. an RDC). Examples of output data generated by the tool are: configuration of clusters, vehicle loading and saturation, vehicle routing, routes, costs, distances, etc.
Figure 9 shows the conceptual framework adopted by LD-LogOptimizer as the integration of strategic, tactical and operational planning activities.

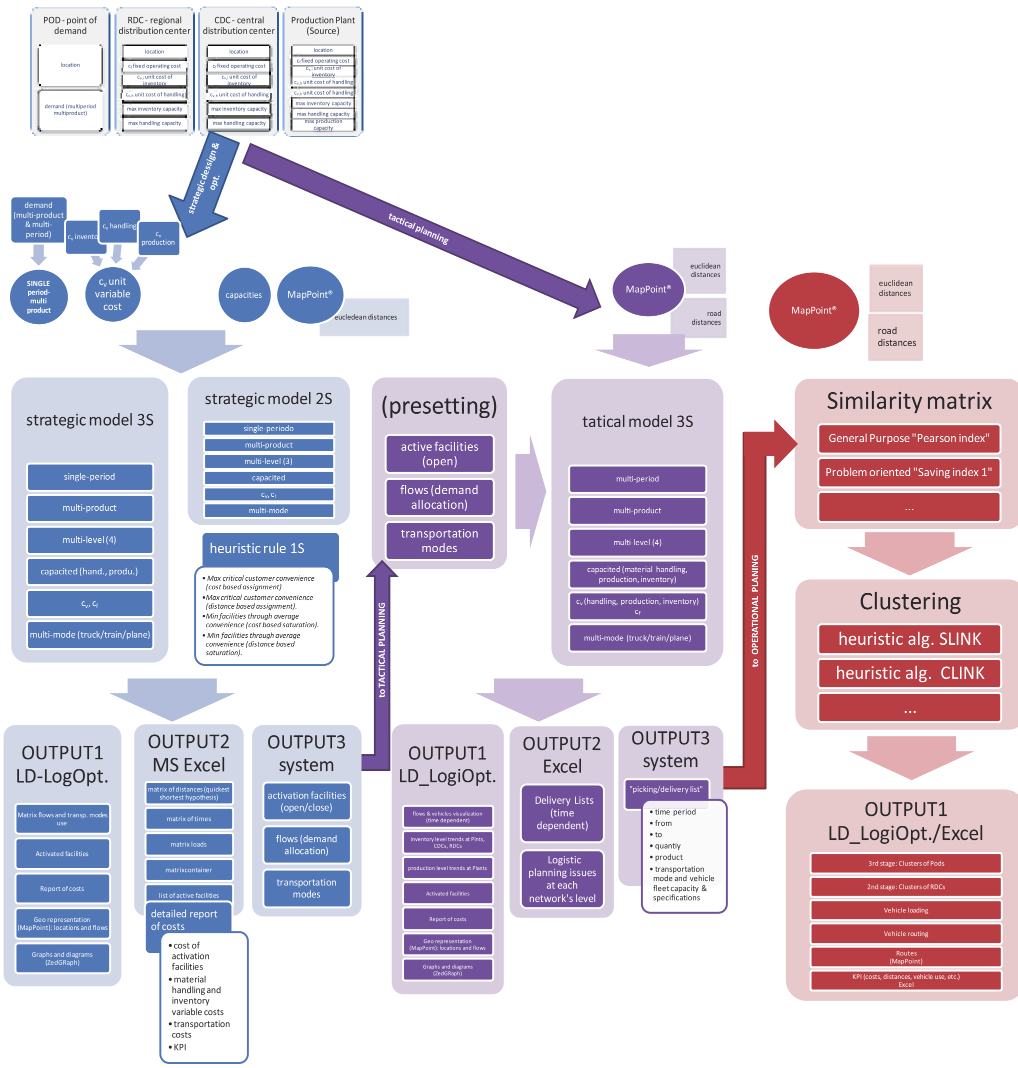

Fig. 9. LD-LogOptimizer tool for the integrated planning

4. A case study

This case study refers to a 3-stage US distribution system operating in USA and made of:

- 3 production plants located in Sacramento (California), Philadelphia (Pennsylvania) and Topeka (Kansans);
- 3 CDCs located in Baltimore (Maryland), Kansas City (Missouri) and Reno (Nevada);
- 12 RDCs whose location, capacities and costs are reported in Table 1;
- 120 Pods all located in USA;
- the number of time units for the planning period is 20 corresponding to days (20 days are about one month);
- 3 transportation modes are available: truck, train and plane.

Id	Address	Zip	City	Country	Activation cost [€]	Handling variable cost [€/load]	Handling capacity [load]	Storage variable cost [€/load]	Storage capacity [load]
RDC1	425 Toland St	94124	San Francisco, California	USA	11129000	0.09	1950000	0.05	115000
RDC2	2768 Winona Ave	91504	Burbank, California	USA	11129000	0.09	1950000	0.05	115000
RDC3	768 Taylor Station Rd	43230	Columbus, Ohio	USA	11129000	0.09	1950000	0.05	115000
RDC4	1890 Elm Tree Dr	37210	Nashville, Tennessee	USA	11129000	0.09	1950000	0.05	115000
RDC5	393 Telluride St	80011	Aurora, Colorado	USA	11129000	0.09	1950000	0.05	115000
RDC6	509 Carroll St	11215	Brooklyn, New York	USA	11129000	0.09	1950000	0.05	115000
RDC7	7211 S Lockwood Ave	60638	Chicago, Illinois	USA	11129000	0.09	1950000	0.05	115000
RDC8	3640 Atlanta Industrial Dr NW	30331	Atlanta, Georgia	USA	11129000	0.09	1950000	0.05	115000
RDC9	618 W West St	21230	Baltimore, Maryland	USA	11129000	0.09	1950000	0.05	115000
RDC10	3915 SW Moody Ave	97239	Portland, Oregon	USA	11129000	0.09	1950000	0.05	115000
RDC11	2412 Commercial St	72206	Little Rock, Arkansas	USA	11129000	0.09	1950000	0.05	115000
RDC12	5518 Export Blvd	31408	Savannah, Georgia	USA	11129000	0.09	1950000	0.05	115000

Table 1. Regional distribution centers - RDC

4.1 Strategic planning, case study

Figure 10 shows the main form of the strategic planning in LD-LogOptimizer. It is made of different sections for input and output data. A quick report guides the user to the full comprehension of the tool activities. Figure 11 presents the input data including the geographical map. In particular, on the map yellow flags represent the production plants (sources), white flags the RDCs, light blue flags the CDCs, green flags the Pods.

Figure 12 shows the results of the application of the strategic planning: the activated nodes of the network and the activated material flows are visible. For example, RDC1 and RDC6 are closed at the third stage of the system; Pod98 is supplied by RDC3 that supplies also other points of demand, e.g. Pod99, Pod101, Pod106. The total logistic cost and different contributions are reported in the quick report.

6 of 12 available RDCs are closed; 1 of 3 available CDCs is activated (open); 1 of 3 available plants is open. Closed plants are represented in black colour, in blue closed CDCs and in red closed RDCs. Figure 12 show also the flows of material for a specific product at the first stage.

Figure 13 presents the results of the strategic planning showing also the flows at the third stage (RDCs-Pods). Similarly Figure 14 shows the flows activated by product P2.

Figure 15 reports the graph of the distribution of costs within the system as the result of the strategic planning in LD-LogOptimizer: about 21% of the total cost is due to transportation activities; about 34% to fixed costs (e.g. to open/activate facilities as CDCs and RDCs); about 45% of the total cost is variable (e.g. handling cost).

Table 2 presents the obtained results in terms of KPI. The activated facilities are: 6 of 12 RDCs, 1 of 3 CDCs, 1 of 3 production plants. The total cost refers to the whole planning period of one year. It is a very expensive cost because it includes all fixed cost contributions necessary to build the network, i.e. to open/active logistic facilities, and to move materials from suppliers to demand points.

4.2 Tactical planning, case study

Tactical planning is a time-dependent planning. Consequently, for each product and the generic point in time *t* a set of facilities and materials flows are activated in order to ship products from sources (production plants) to Pods passing through CDC and RDC facilities, in accordance with capacity constraints, lead time, variable and fixed unit costs, etc.

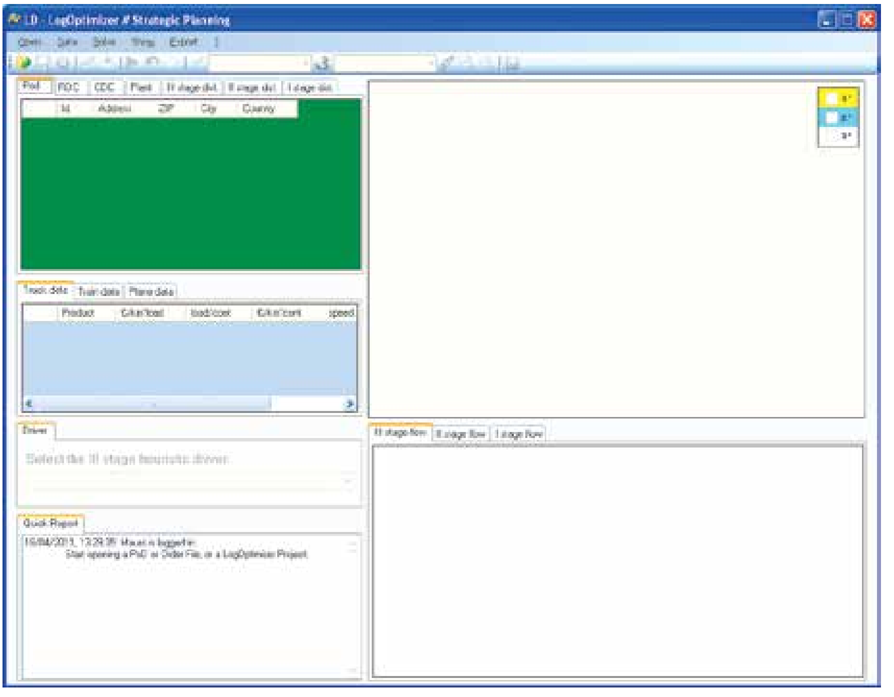

Fig. 10. Strategic planning, LD-LogOptimizer, main form

Fig. 11. Input data for the strategic planning

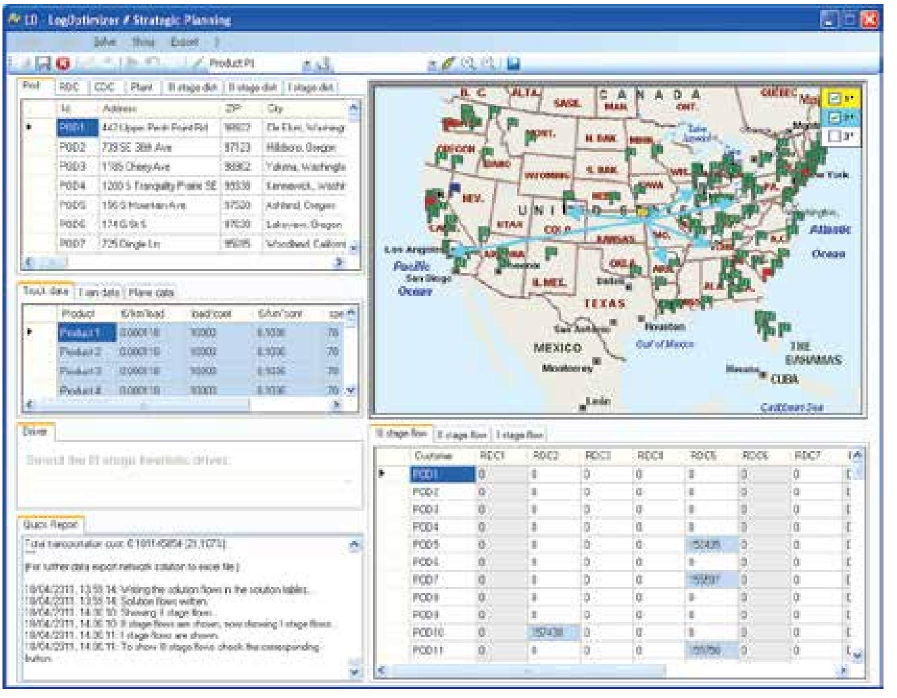

Fig. 12. Results, strategic planning

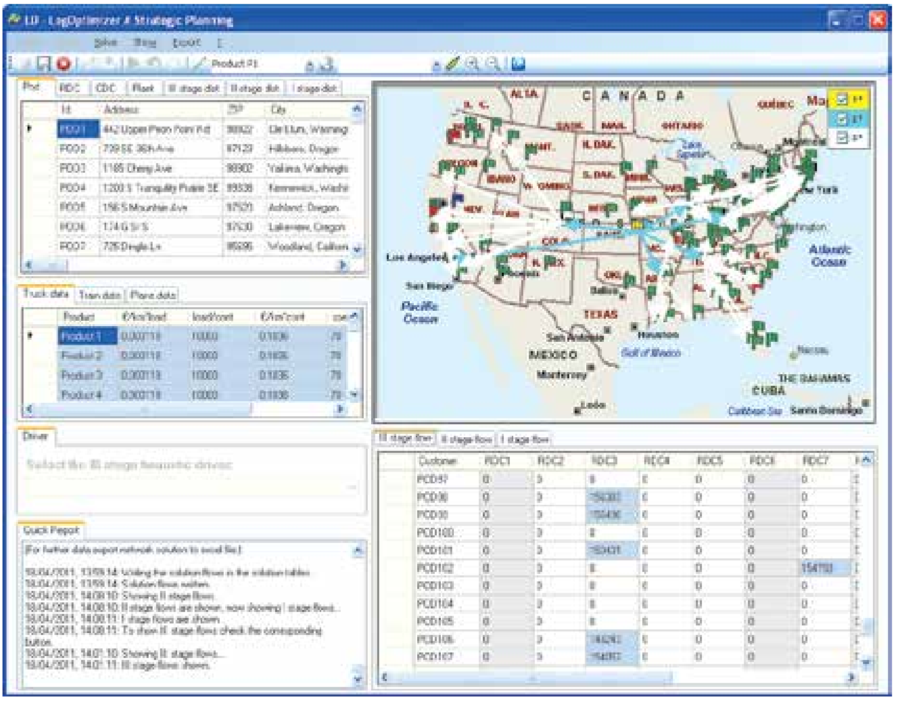

Fig. 13. Product 1, strategic planning. Flows at the first stage.

Fig. 14. Product 2, materials flows. Strategic planning.

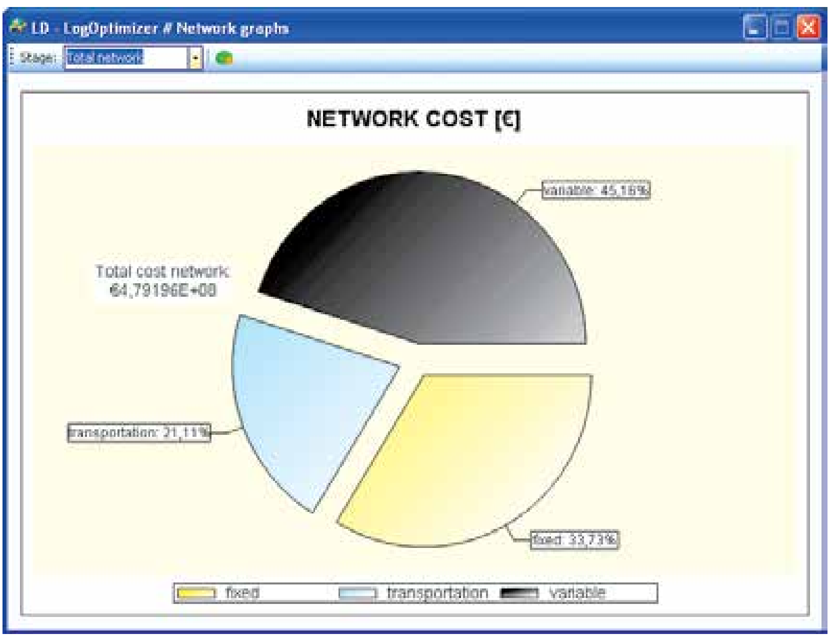

Fig. 15. Strategic planning, network cost.

Figure 16 presents the result of the execution of LD-LogOptimizer on the case study object of the analysis and for the tactical planning. In particular, results in figure refer to the product named P1. The list of deliveries for the active RDCs to the Pods in the point in time T1 is also reported: this is the input for the operational planning illustrated in next subsection. Flows of product P1 between active facilities in T1 are shown.
Figure 17 shows the material flows of another product, P2, for the period of time T1.

KPI Strategic Planning	Value
Points of demand	120
RDC	12
CDC	3
Plants	3
RDC activated	6
CDC activated	1
Plants activated	1
TOTAL COST [€]	479196000
RDC cost [€]	98235760
CDC cost [€]	37760600
Plant cost [€]	242053800
3° stage trasportation cost [€]	42149040
2° stage trasportation cost [€]	53662470
1° stage trasportation cost [€]	5334346
Average n° of points of demand served by a regional distribution center	10.24
Average n° of regional distribution centers that serve a point of demand	0.51
Average n° of regional distribution centers served by a central distribution center	5.97
Average n° of central distribution centers that serve a regional distribution center	0.99
Average n° of central distribution centers served by a plant	1
Average n° of plants that serve a central distribution center	1
Average 3° stage distance [km]	835.03
Average 2° stage distance [km]	1175.36
Average 1° stage distance [km]	103.78

Table 2. Strategic planning, KPI

Fig. 16. Tactical planning, case study

Fig. 17. Tactical planning (P2 in T1)

Table 3 presents the obtained results in terms of KPI for the tactical planning. In particular, the expected costs significantly differ from the strategic planning costs because they refer to the planning period made of 20 units of time. The activated facilities are: 6 of 12 RDCs, 1 of 3 CDCs, 1 of 3 production plants. An RDC serves about 10-11 Pods.

KPI Tactial Planning	**Value**
Points of demand	120
RDC	12
CDC	3
Plants	3
RDC activated	6
CDC activated	1
Plants activated	1
TOTAL COST [€]	19584910
RDC cost [€]	3542925
CDC cost [€]	1197645
Plant cost [€]	9232994
3° stage trasportation cost [€]	3171216
2° stage trasportation cost [€]	2227638
1° stage trasportation cost [€]	212496
Average n° of points of demand served by a regional distribution center	10.26
Average n° of regional distribution centers that serve a point of demand	0.51
Average n° of regional distribution centers served by a central distribution center	5.96
Average n° of central distribution centers that serve a regional distribution center	0.99
Average n° of central distribution centers served by a plant	1
Average n° of plants that serve a central distribution center	1
Average 3° stage distance [km]	834.07
Average 2° stage distance [km]	1174.56
Average 1° stage distance [km]	103.78

Table 3. Tactical planning, KPI

4.3 Operational planning, case study

The operational planning can be applied to plan and schedule the vehicle routing at the each stage of the network and in particular from RDCs to Pods and from CDCs to RDCs. The first of this stage usually involves trucks as transportation modes; while CDCs-RDCs shipments can be executed also adopting one of the other available modes (e.g plane and train).
Figure 18 presents a result obtained by the execution of the operational planning on the case study. A list of clusters is reported and for each cluster it is possible to generate the optimal route as the minimum Hamiltonian circuit visiting all the members grouped in a cluster.
The route ID 173 is shown. It is made of the following sequence of visits: RDC4, Pod106, Pod110, Pod111, Pod109, Pod108, Pod107, RDC4. Another detailed route is exemplified in Figure 19. The groupage strategy can reduces the cost of travelling of about 55% if compared with direct delivery, i.e. direct shipment from a generic supplier to a point of demand.
Figure 20 exemplifies another route (named ID 109) departing from Chicago and generated by the operational planning.

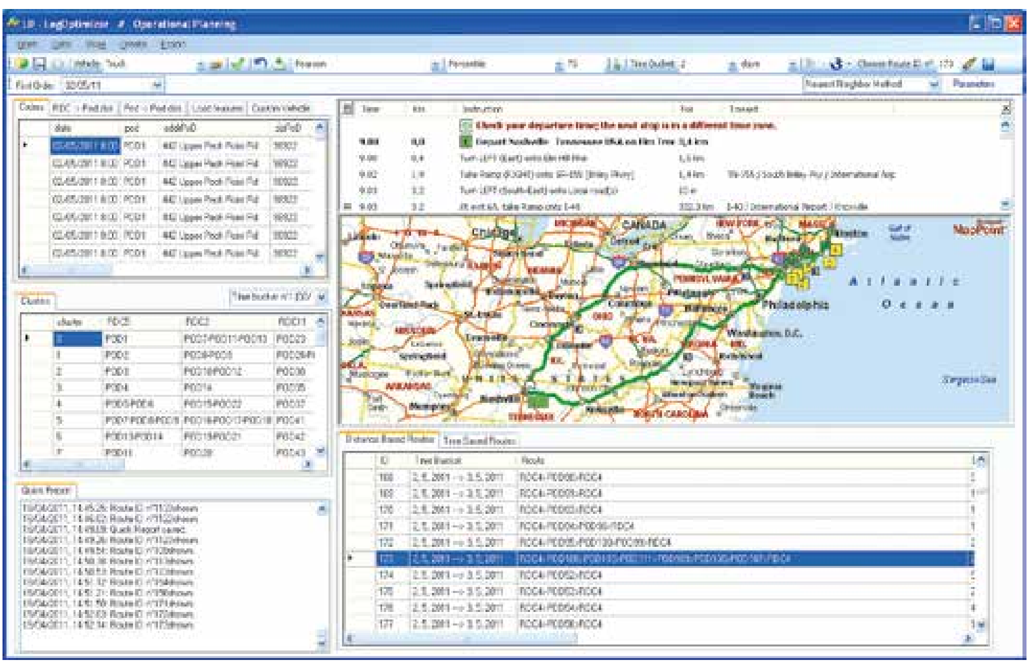

Fig. 18. Operational planning, route ID 173

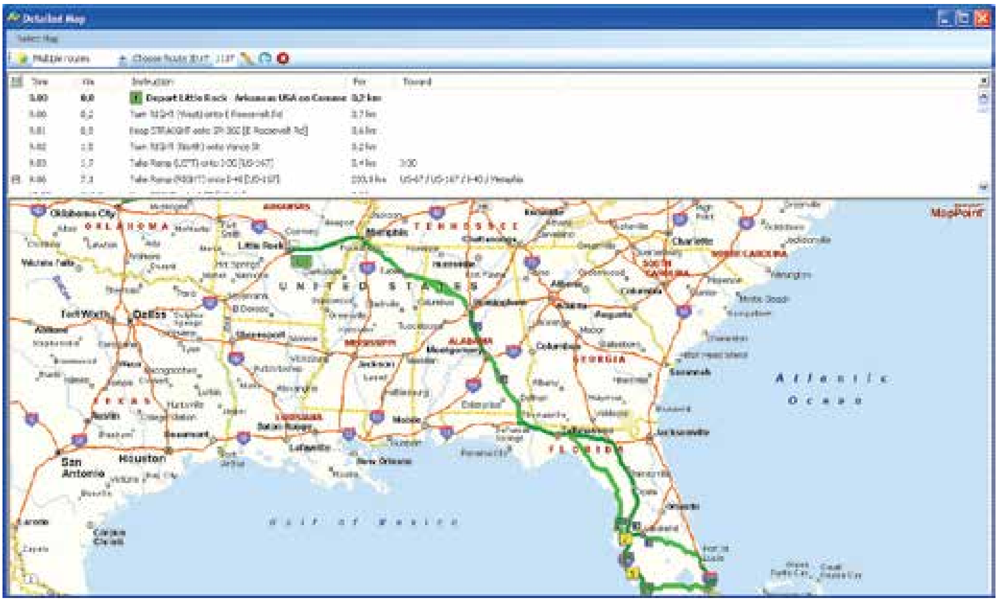

Fig. 19. Operational planning, Route ID 1137

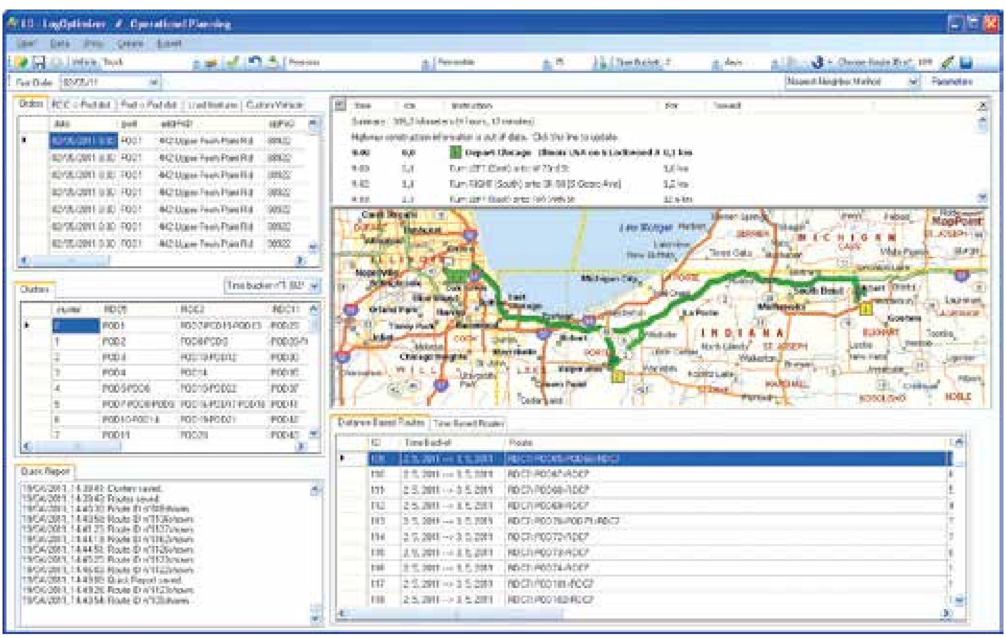

Fig. 20. Operational planning, an example

4. Conclusions and further research

This chapter illustrates an original framework for the design and planning a production-distribution logistic network by the integration of the strategic planning, the tactical planning and the operational planning. This framework has been implemented by a supporting decisions platform, a software tool, named LD-LogOptimizer. The discussed case study demonstrates the effectiveness of the proposed models and automatic supporting decisions tool. The tool supports the manager in configuring the system by the determination of the number, location and capacity of the generic facility, e.g. a distribution center and a production plant. Further research is expected on the development of new models, new effective solving methods and procedures/algorithms, experimental multi-scenario what-if analyses conducted on significant case studies. New applications and benchmarking are also expected. Finally, the development of reverse logistic flows and issues and the integration in LD-LogOptimizer tool are expected. The new platform will support managers in the design, optimization and management of direct and return flows in a multi-level logistic network, minimizing the global logistic cost and/or maximising the customers' service level by the joint optimization of strategic, tactical and operational issues, including vehicle loading and routing. Models and tools for electronic data interchange between the planner, as a controller (the server), and vehicles (the clients) executing the transportation missions are expected. The generic vehicle can also communicate its location during the routing and visit of a set of Pods adopting the groupage strategy: the server can update the planned routes and eventually modify them accordingly.

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14

Development of a Cost Model for Intermodal Transport in Spain

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1. Introduction

For several years, the promotion of intermodal transport has been a priority for the Spanish and European authorities (Cuerda et al., 2003; Conseil National des Transports [CNT], 2005) but the importance and the recent growth of rail transport in Spain is extremely small compared to road transport. This is more so in the case of small and medium-size companies shipping general (non-bulk) cargo, which almost exclusively use the road (Ministerio de Fomento, 2004). The establishment of a network of intermodal freight transport centres connected to the main railway lines and close to the main cities is viewed as an opportunity for the modal shift, and also the establishment of relevant intermodal corridors dedicated to specific freight purposes (ore, agricultural products), to be defined at a European level, should improve the overall figures. But nevertheless, there is the feeling in Spain that more attention should be given to general traffic issues, facing the needs of the great amount of small companies moving small amounts of freight, but with an enormous aggregate effect.

Thus the strategic objectives of our work lie within the rationalization of mobility and the improvement of intermodal accessibility. They concentrate on establishing the basis for a higher participation of small and medium-size companies in intermodal transport by analyzing the specific experiences of an individual transport company, based in the city of Seville, seeking an enhancement of the modal shift within its logistic operations.

This work is organized as follows: In section 2 we describe the role of intermodal transport in the supply chain. In Section 3 we list the actors involved in all phases of intermodal transport to then show the decision-making model for each one of these actors. In Section 4 we apply this model to the case of a transport company based in the South of Spain, describing all the shipment and cost data. Finally, in section 6 we explain our conclusions drawn from the decision making model in general and in particular for the case-study company, and analyze the effect of additional factors (other than cost) in the decision-making process with respect to intermodal transport.

2. Intermodal transport and the supply chain

The role of intermodal transport in supply chains is clearly described by Ramstedt and Woxenius (2006). According to them,

- A supply chain focuses a product and extends back over the integrated chain of actors, activities and resources required for making it available at the place of consumption.
- A logistics chain focuses an item and extends from when the article number is created until it is dissolved (article consumed or becoming a part of another article).
- A transport chain focuses a consignment and extends over movement, physical handling and activities directly related to transport such as dispatch, reception, transport planning and control.

Thus, the transport chain is a relevant component of logistics chains, which in turn compose supply chains involving many different actors which can act as logistics service buyers or logistics service providers. For these three types of chains, it is essential, but complicated, to define the exact configuration and roles of the actors. Different actors involved in an intermodal transportation chain are:

- Ship-owner: the real owner of the ship. The owner may use the ship for his own benefit or may rent it for external use.
- Charterer: an individual or legal entity who hires or charters a ship for their own profit. For example, an operator who hires the use of a ship from the ship-owner is known as the charterer of that ship.
- Shipper: a person or company who entrusts his goods to a third party (which may become the charterer with regard to the sender) who will deliver them to their destination. In the example being used, when the transport agency contacts the shipping company, the transport agency becomes the sender in relation to the shipping company.
- Forwarding agent: an individual or legal entity responsible for coordinating the carriage of goods according to the client's needs. The forwarding agent contacts all companies providing services involved in the carriage. They may also act as the Customs Official. The intervention of the forwarding agent is quite useful in large operations. They are transport specialists who will closely monitor the selected operation and the costs incurred.
- Consignee: is an individual or legal entity acting in the name of the ship-owner, in terms of administrative and technical procedures, port activities, fees incurred by ship-owner for docking and services provided while in the port terminal, etc... The consignee also carries out the procedures required for customs clearance, when importing or exporting is involved, and may also negotiate with stowing companies on behalf of the ship-owner.
- The stowing company is responsible for handling goods within the port during:
    - Loading: reception, loading and stowing.
    - Unloading: break bulk, unloading, delivery.
    - Emptying and filling containers.
    - Sorting goods.
    - Horizontal movements to position goods in inspection areas.

All these different links in the transport chain can be managed by the shipping company itself, directly contacting operators and arranging transport and storage operations. However, and more so in the case of small and medium companies, this management requires an enormous effort, and the preferred option is often the subcontracting of different actors, or a single actor who manages the whole process.

3. Modelling the decision-making process

The intermodal chain connects the origin and the destination of goods through a series of links, some of which are decision-nodes, that is, decisions have to be made in terms of how to proceed from them, or what option to choose in order to carry the freight to the next node. The stakeholders involved in the intermodal chains will therefore have to take a series of decisions regarding what intermodal operators will be involved in the delivery, taking into account factors like time, cost and route choice.

This is the type of decisions that was brought into the model. In any case, the transport modes considered were rail, vessel and road, excluding air transport due to its totally different characteristics, which cause it not to be a competitor for road transport in terms of general cargo. The possible intermodal operators to be considered were logistic operators, forwarders, the rail operator (Renfe), and the ship companies.

Different models have been formulated in the literature to optimise the efficiency of intermodal transport (Arnold et al., 2004 ; Ballis & Golias, 2004 ; Barthel & Woxenius, 2004 ; Li & Tayur, 2005 ; Macharis & Bontekoning, 2004). In this case, a cost model was derived in order to assess the effectiveness of intermodal transport in terms of costs. The objective was to represent all the possible options and alternatives that companies have when shipping or transporting a given delivery. Three different decision-making models were therefore built, one for each decision-making stakeholder in the intermodal chain:

- The shipper: generates and sends the goods, and is therefore in charge of deciding how and by what means those goods are going to be handled and transported.
- The forwarder: instead of organizing the delivery himself, the shipper can subcontract a forwarder to do it, thus passing the responsibility and the decision-making process to it. The forwarder acts as an intermediary, making all the necessary arrangements but not necessarily taking actual hold of the freight.
- The logistic operator: it can be subcontracted by either the shipper or the forwarder, and will then decide on the transport mode to use.

In each model, the different choice options for the corresponding stakeholder were linked.

3.1 The shipper's decision making process

The first decision (see Figue 1) that the shipper will have to take will depend on whether they have the appropriate fleet for the journey and the connections between the point of origin and destination. If they have the appropriate fleet available and they are able to transport the goods themselves by land, then they need to decide whether to do the job themselves or subcontract it. If the job requires other transportation modes, the only decision possible is to contract out the service. It is in the latter case that the concept of the intermodal transport chain is introduced.

The reasons for contracting out the service may be:

- Lack of means available to carry out the job themselves.
- Have means available, however do not wish to use them.
- Another transportation mode is necessary due to existing connections between the origin and destination points.

In all three cases, the shipper will have to decide which operator to contract and how. This decision will depend on existing connections between the point of origin and destination. Connection types:

- Direct road connections between both points. In this case, an intermodal transport chain is not necessary since land carriage is the only transportation mode required.
- Rail connection: goods must be transported in part by rail. As a result the respective carriages will have their point of origin and destination in the corresponding rail terminals.
- Sea connection, in which part of the journey must be done by ship.

There will be different diagrams representing the operator's decision making process depending on the connection types between the points of origin and destination.

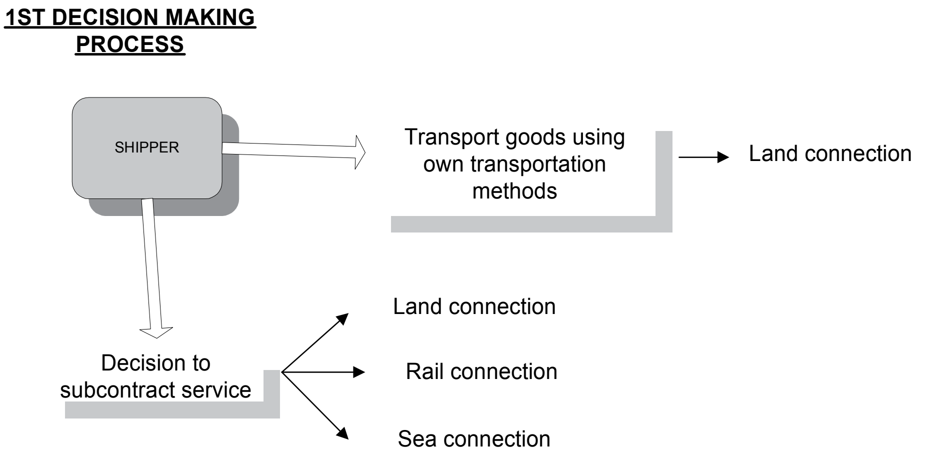

Fig. 1. Shipper's first decision making process

3.1.1 Direct connection by road

Land carriage is the only transportation mode required. In this case, the intermodal operators who may participate are:

- Transport company
- The forwarding agent

Since there are neither sea nor rail routes respectively, neither the shipping nor rail company will gain from providing land carriage and therefore will not provide their services to the shipper. In cases where rail and/or sea carriage are required, these operators will offer their transportation services even if it is only over a short distance. In this way the client receives a more comprehensive and better quality service.

The hypotheses involved are the following:

- The distance covered during the journey is less than 300 km.
- The distance covered is greater than 300km and the only transportation method available is by land.

Bearing these hypotheses in mind, the following diagram (Figure 2) may be followed:

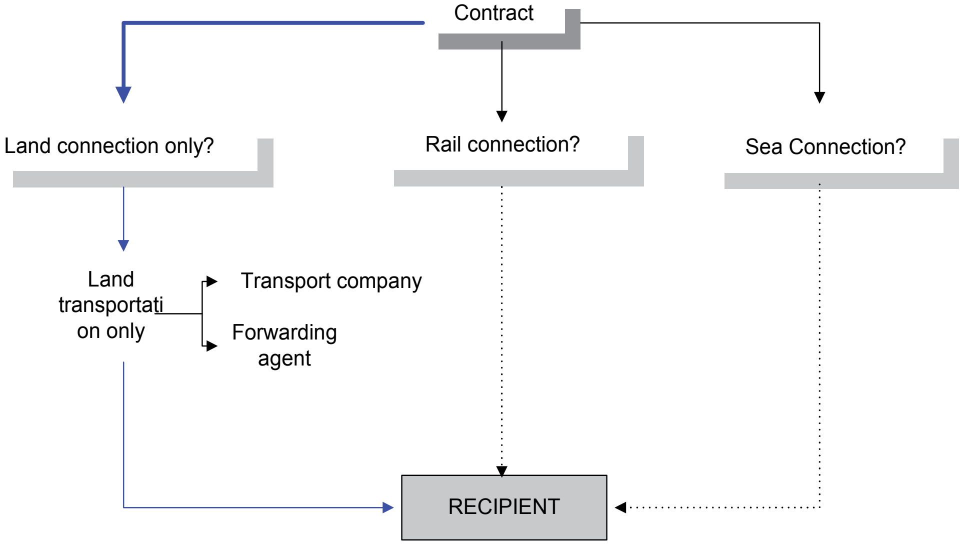

Fig. 2. Shipper's decision making process.

3.1.2 Connection with rail carriage

In this case, the rail company acts as a possible intermodal operator since a section of rail network is found along the established route. Two types of rail connection are possible (see Figure 3):

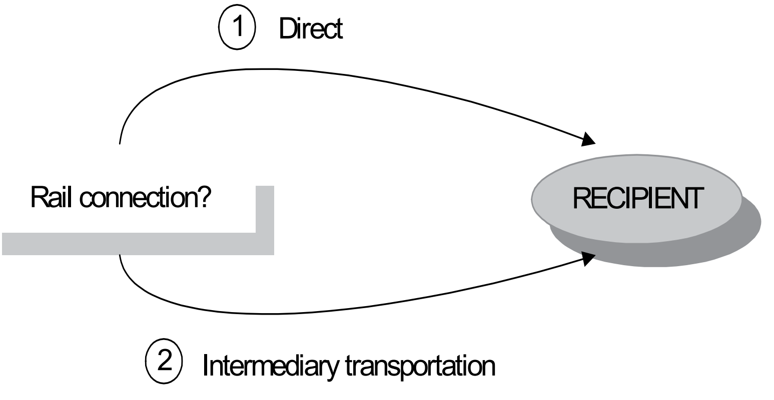

Fig. 3. Possible rail connections.

1. A direct rail connection means that the point of origin and destination are connected by one railway line. This may be a main line or a secondary one. Based on the hypothesis that it is the shipper who chooses the transportation mode and the route, the only operators who are able to participate are the railway company and the forwarding agent. This must be pointed out as the shipper may contact his usual transportation company and contract the service to them, even though the goods will not be transported by land.

2. A non-direct rail connection means that an intermediary section of the journey will be made by land. The possible transportation routes may be: the first stage from the point of origin to the train departure terminal, from the train arrival terminal to the destination point or both.

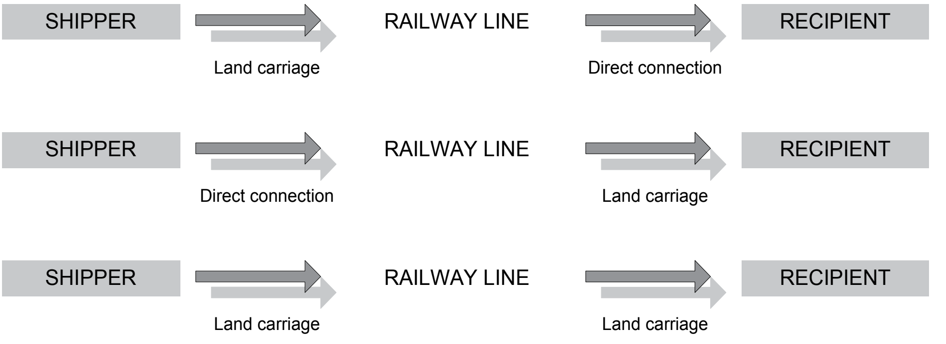

Fig. 4. Land transportation.

In the previous diagram (Figure 4) direct connection was used when the point of destination had some type of railway access, whether it is a secondary or a main line.

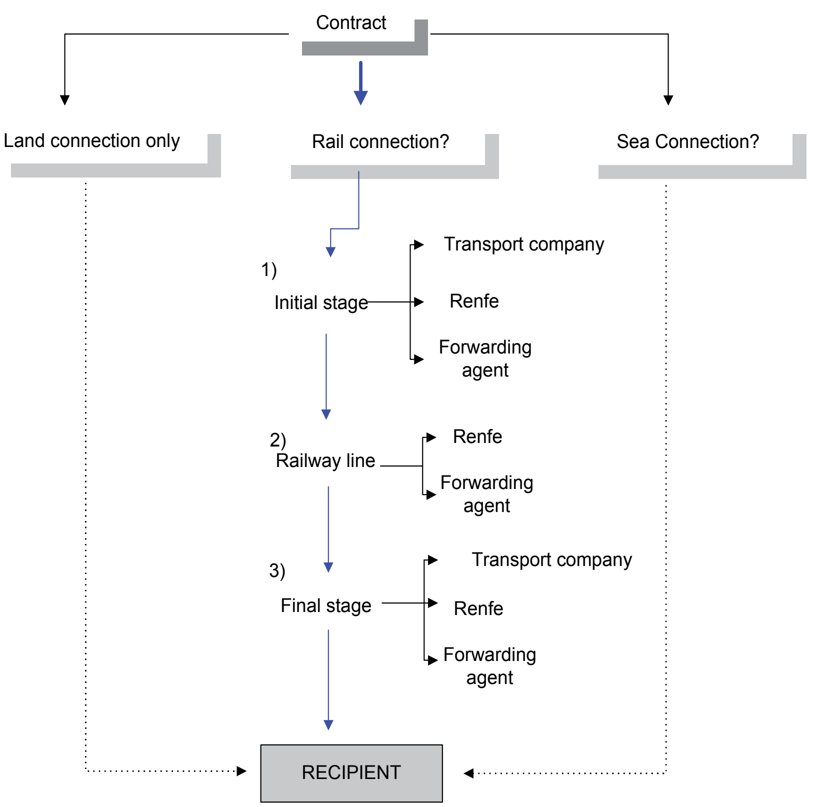

Fig. 5. Shipper's decision making process.

In order to outline the shipper's decision making process, let us look at the most complicated scenario. This would occur when, in addition to rail carriage, two stages of the chain are to be completed by land, i.e., the first stage from the point of origin and the final stage to the point of destination.

The intermodal operators who may participate are:

- The transport company.
- The rail company.
- The forwarding agent.

Each of them may manage the entire route and act as the sole intermodal operator for the shipper (see Figure 5).

3.1.3 Connection with sea carriage

Up until now we have mentioned three operators, the transport company, the rail company and the forwarding agent. In cases of sea carriage, the shipping company acts as an intermodal sea operator. Three different scenarios may be identified depending on the established connections between the point of origin and destination (see Figure 6).

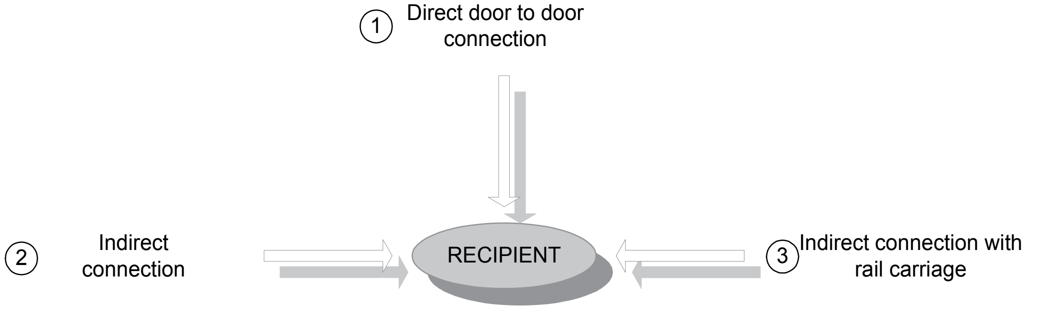

Fig. 6. Possible sea connections.

3.1.3.1 Direct connection from port to port

The shipper and the recipient are situated within the departing and arrival ports respectively. This means that the only land journeys to be made are due to the intermodal handling and moving of the load units within the port terminals. These movements are carried out by the ship's stevedores (personnel dedicated to carrying out this type of service) or by those in the port terminal. As a result, the transport company cannot act as a possible intermodal operator for this type of connection. The intermodal operators who may participate are:

- The forwarding agent
- The shipping company

3.1.3.2 Indirect connection

Indirect connection means that the intermodal route includes a stage to be completed by road, for example, outside the port terminal. This means that the origin and/ or destination point are not located within the port. As a result, transportation by land is required. In this case, in addition to the operators already mentioned, the transport company may also act as a possible intermodal operator.

3.1.3.3 Indirect connection with rail carriage

There is a section of railway along the route by which the goods will be transported. Here we have the most complicated scenario since it involves three types of transportation modes: land, rail and sea.

If a section of the journey is to be completed by land, then the road transport company may once again act as an intermodal operator. Usually the shipper or docker contacts one intermodal operator only or two at the most. This does not mean that they cannot contact a different one for each section of the journey. However, this rarely happens and it would most probably be very a very laborious task for the shipper. If they decide to contact one intermodal operator only, this may be the:

- Transport company.
- Rail company.
- Shipping company.
- The forwarding agent.

As long as they are duly authorised, all operators are capable of managing the entire intermodal chain.

The following figure shows the decision making process:

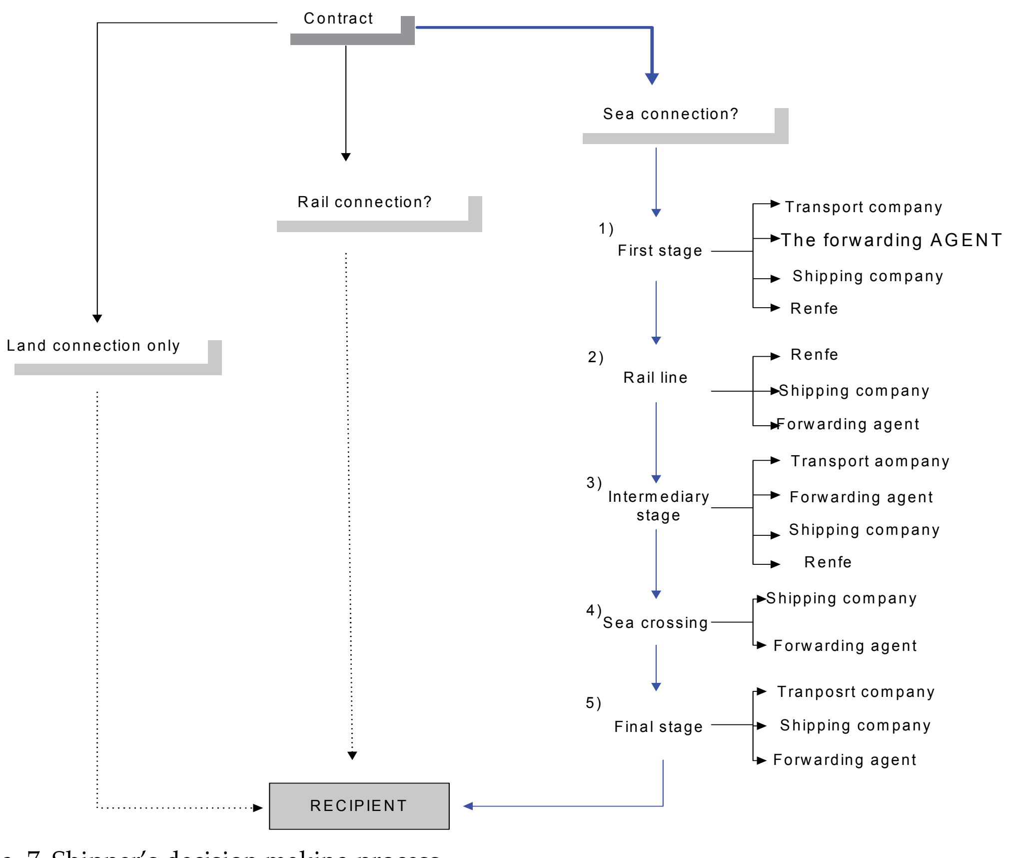

Fig. 7. Shipper's decision making process

The last scenario represents the most extensive example of an intermodal chain since it includes three different transportation modes. We will therefore look at how this process develops in more detail.

- If the goods are to be transported via a route such as the one above, the shipper will normally assign management of the entire route to one operator only. The forwarding agent, the shipping company, the transport company and the rail company are all able to carry out this task. In Spain, the rail company with the greatest influence up until now is Renfe. In some cases, although not many, Renfe has provided the entire service, including management of sea carriage. In this study and for this reason, we will work under the hypothesis that Renfe does not provide the complete service in cases where sea carriage is necessary. As a result the number of operators is reduced to three.
- A more detailed study is required in cases where the shipper contracts the shipping company as the only intermodal operator. In general, the shipping company will manage all aspects of the process except for customs procedures which will be carried out by the forwarding agent or a customs official. The shipper will contract a customs official to carry out all necessary tasks. Alternatively, the shipping company may be responsible for contracting the customs official. In this case the shipping company will subcontract a customs official to perform all duties. Since the shipping company is not responsible for customs processes, it is normally the shipper who will contract the customs official.
- Once this decision has been made, the shipping company is responsible for contracting the shipping company to load a certain type of goods at the point of origin and transport it to the destination point. If the point of origin is inland and not a port, then the goods must be transported to the port. This may be done by land or by rail. In both cases the shipping company will have to subcontract the transport company for land carriage and the rail company for rail carriage. The latter may also provide land carriage.
- Once the goods are in the port and are ready for loading onto a pre-assigned vessel, they need to pass through customs before loading.
- As already mentioned, the client has two possibilities available to him. He may either contact the customs official directly or he may contact him through the shipping company. In both cases, a series of data included in the commercial invoice for the goods must be provided.
- Once the necessary documentation has been signed and dispatched, it should be delivered to the shipping company's premises within the point of origin. With this documentation the shipping company is now able to load the goods into the pre-assigned vessel.

  Once the shipper in origin has paid the costs agreed with the shipping company, the shipping company should send the shipper a Bill of Lading (B/L) proving that the shipper is the owner of the goods.
- Once the docker has received this document, it is sent to the destination client or consignee who will need it to unload the goods at the destination port.
- The transit will take a specific amount of time. It will follow a specific route and may have several ports of call or transhipment ports before arriving at the destination port.
- When the goods arrive at the destination port, the client in origin should have paid the shipping company a series of costs already agreed in the commercial invoice. These costs will depend on the terms of sale agreed by the shipper or docker and the shipping company. It is at this point that the Incoterms come into effect. For example EXW, FAS, FCA, FOB, CFR, CPT, CIF, CIP, DAF, DES, DEQ, DDU, DDP.

- When importing, in order to unload the goods, the destination client should have the documentation proving that he is the owner of the goods, i.e., the B/L. He should also reimburse the shipping company for any costs, according to the terms of sale set out in the contract drawn up between the two contracting parties. Depending on Incoterm, the docker should pay some of the costs or all of them (the recipient also pays). In this way the recipient of the goods is able to receive the goods in their factory.
- If the goods are to be delivered to a point inland after the destination port the transport company at the point of destination or the rail company comes into play again. The process may be carried out in the same way it was for the point of origin.
- At this point the recipient of the goods should contact the customs official or the forwarding agent so that they can perform the customs importation process. Alternatively they may contact the shipping company who will subcontract the service to a forwarding agent or a customs official.
- Once the customs process has been completed, the goods may be transported by land or rail. This will depend on what the recipient or shipper deems appropriate. Depending on their decision they will contact the transport company or Renfe.
- The shipping company may offer door to door service to the shipper or, as already mentioned, the door to door operation may carried out by a combination of both. Normally the shipping company is responsible for the complete door to door intermodal transportation. In this way the shipper receives a better service and problems are avoided.

Once the possible decisions have been looked at individually, we can see the entire shipper's decision making process in the following figure:

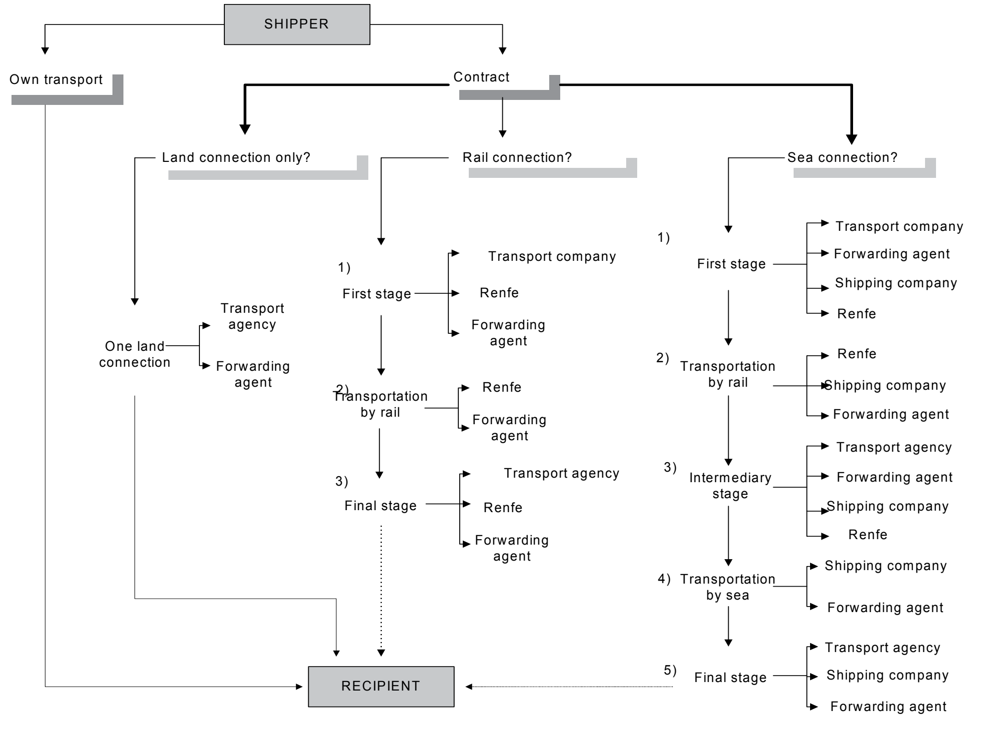

Fig. 8. Shipper's decision making process, depending on the intermodal chain used.

3.2 Forwarding agent´s decision making process

The forwarding agent organises and coordinates transportation. The forwarding operator chooses and contracts the transportation modes for the transportation of goods. The forwarding operator must control and coordinate goods during all of the transportation stages, whether this is by land, rail, sea or air.

In practice, the forwarding operator also takes care of transportation involving land carriage only and acts as a Transport Agency in such cases. However, if land carriage only is required, it is not common for a shipper to contact a forwarding agent if they have the option to contract the land transportation company directly. If this does occur, it may be due to the fact that the shipper is using this forwarding agent to transport other goods and decides to assign them this land carriage as well.

When the client contacts the forwarding agent, they look at the most appropriate itineraries and the different transportation modes available. The best solution in terms of costs, time and security is always selected.

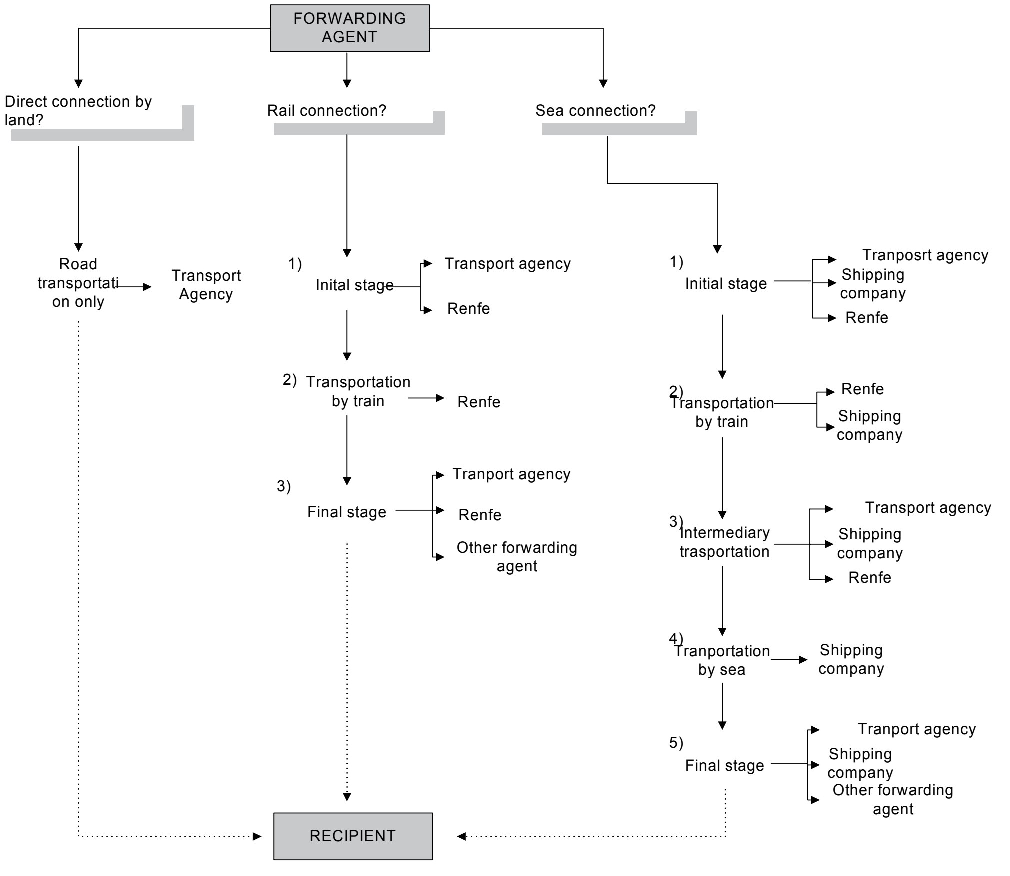

Fig. 9. Shipper’s decision making process, according to the intermodal chain used.

There may be occasions when the forwarding agent has to subcontract the services of another forwarding agent to manage a certain part of the intermodal transit in origin or destination. This may be due to the fact that they do not have links with any other transport agencies in the area. In cases where agreements between forwarding agents are made, we refer to this as "collaboration between agents".

The forwarding agent's decision making process may be presented as follows (Figure 9):

Hypothesis used to complete the table:

- We have not considered the scenario where there is no door to door rail connection between the point of origin and destination, either on main or secondary lines.
- The forwarding agent does not collaborate with another forwarding agent in the initial nor intermediary stages, nor the rail nor sea carriage since all of the transportation means fall under its trading area.
- When goods are transported by sea, once they reach the destination port they are then transferred to the point of destination by land. In other words, there is no rail connection point between the destination port and the point of destination. This is not to say however that in reality there may be. This is simply a means of creating a table which is less complicated and easy to follow.

The shipper usually contacts the forwarding agent who will take care of the entire operation (land carriage and sea and rail carriage if required).

When the forwarding agent makes decisions regarding shipping he reaches an agreement with the shipping company so that they perform all procedures required by the type of cargo. At this point there are a number of possibilities. The shipping company regards the forwarding agent as a client or shipper and determined terms of sale are established between the two, according to the service offered by the shipping company:

- Sea carriage along with one or all other stages done by land, whether they be in origin or in destination and rail carriage if available.
- Sea carriage only.
- Sea and rail carriage (if available).
- Sea carriage and others.

When goods are being transported by sea it is important that they are cleared by customs so that they may be unloaded.

Regarding the customs clearance at the point of origin, the forwarding agent is responsible for carrying out the necessary customs processes and will act as a customs official. On some occasions the shipping company may take care of customs clearance. However, this is not common since it incurs an added expense for the forwarding agent. If the forwarding agent deals with this, costs will be centralised and reduced. If the forwarding agent carries out the customs clearance it will cost approximately 30 euros. In comparison, if this is done by the shipping company it would cost 35-40 euros. Centralising costs results in a more favourable quality-price relationship.

Customs clearance at the point of destination cannot be carried out by the forwarding agent at the point of origin. It is always done by the goods recipient. The recipient may contract another forwarding agent or a shipping company at the point of destination to take care of customs processes relevant to the destination.

Depending on the shipper's turnover, they may contract the transport agency or the shipping company to transport the goods by land. The shipping company subcontracts certain transport agencies and will normally have a fixed price agreement with them ensuring lower prices than those charged to a shipper or a forwarding agent (client). This is due to the fact that shippers or forwarding agents only require the services of the transport agency for a small amount of transportations while the shipping company will always require a huge amount of transportations per year.

The shipping company is not always able to manage transportations. There are countries in which transportation services cannot be subcontracted because this service is not offered due to its lack of profitability.
As mentioned earlier, the forwarding agent may also act as a customs official. As soon as the goods arrive at the port terminal, whether it be at the point of origin or destination, they should pass through customs so that they can be unloaded and leave the port. If they fail to do so the goods will be stored in a warehouse until a new customs clearance is requested (see Figure 10).

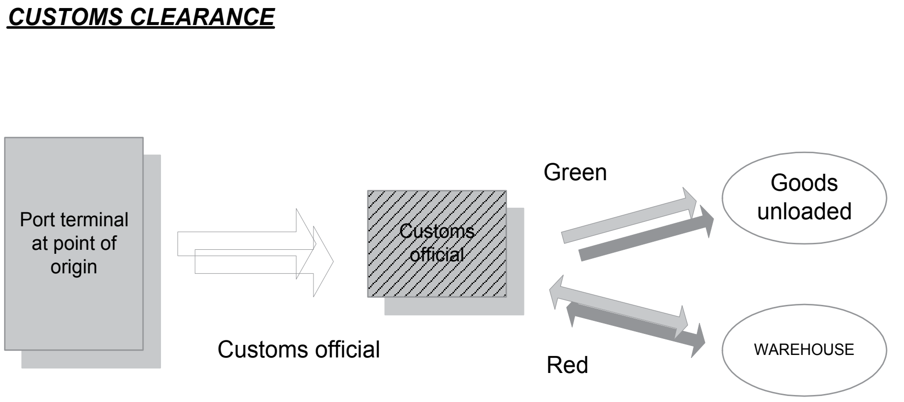

Fig. 10. Customs clearance process.

There are different types of customs clearance:

- Shipments within the European Community.

Shipments carried out in countries belonging to the European Economic Community. A customs document is required to transport goods by sea within the geographical area of the Economic Community.
The TL2, as it is referred to, is one single document, which once presented to and sealed in customs, should be delivered to the shipping company's premises within the port of loading. The shipping company arranges the unloading of the goods into the previously assigned vessel and sends the document to the client in the destination country. This, together with the B/L should be sent to those responsible for unloading the goods.

- The DUA (Documento único aduanero)

Single customs document (copy) produced on green paper and containing a series of numbered pages on which information on non-EU goods should be entered.
Each sheet has a specific purpose. For example, page three is the copy to be retained by the person sending the document. In this case it is the customs official. With this document the official or the forwarding agent can control the company's turnover and in addition to sending this to the customs officials every year, it must also be sent to Inland Revenue. There are nine pages in total and every page has a different function.
As with the T2L, without this document the goods cannot be unloaded and transported to their destination. Failure to pass through customs (which is necessary for the balance of payment) before unloading goods will be treated as an offence and customs will report the incident to the appropriate authorities and a fine will be imposed. This fine should be paid by whomever responsible for the goods having been loaded without previous clearance.

Moreover, under normal circumstances the goods are returned to the port of origin. Once they are cleared by customs they can be loaded once again.

3.3 Transport company´s decision making process

The transport company's decision making process is similar to that of any other intermodaltransportation operator (see Figures 11 and 12).

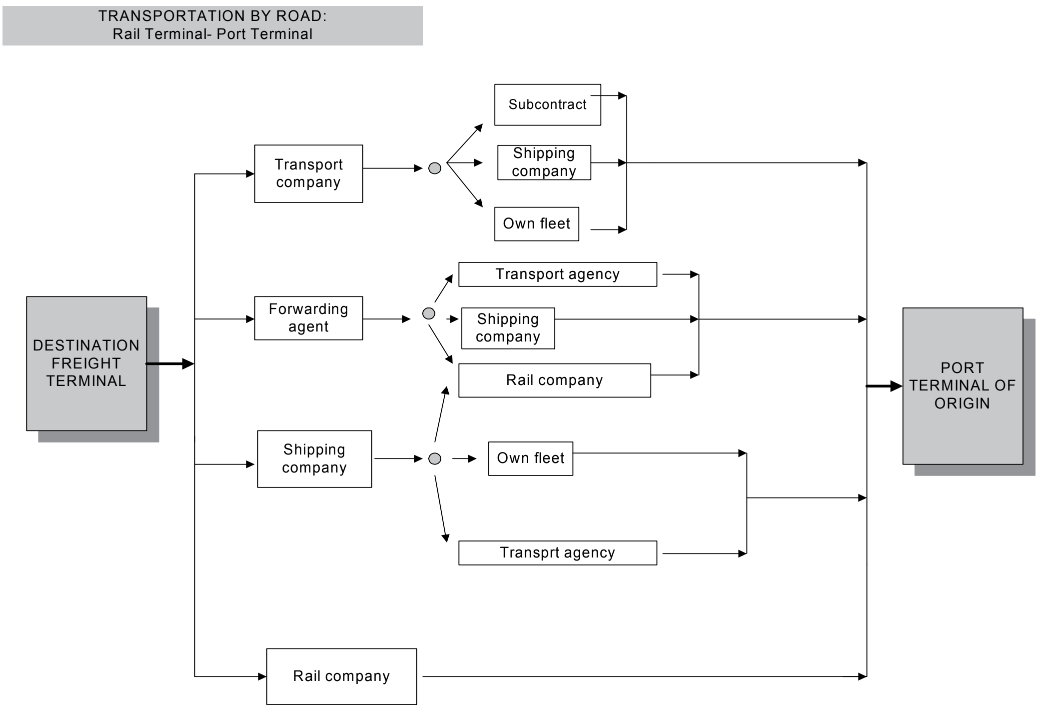

Fig. 11. Transport company's decision making process regarding transportation by land between the rail or port terminal.

The company aims to meet customer demand and considers service quality their number one priority. Enabling factors for ensuring quality service are:

- Regularity.
- Frequency.
- Flexibility.
- Availability.

The transport company offers a wide range of business services, thus providing the client with a better service and maintaining costs as low as possible.

They must take into account the selected route and the transportation modes available. They will then have to study the quotes received from the operators able to participate in the transportation chain. If we assume that we are dealing with the most extensive intermodal transportation chain in which sea, land and rail carriages are included, the operators which may participate are the same as before: the forwarding agent, the rail and shipping company. Each one puts forward a different quotation and the company will decide which one most suits their needs.

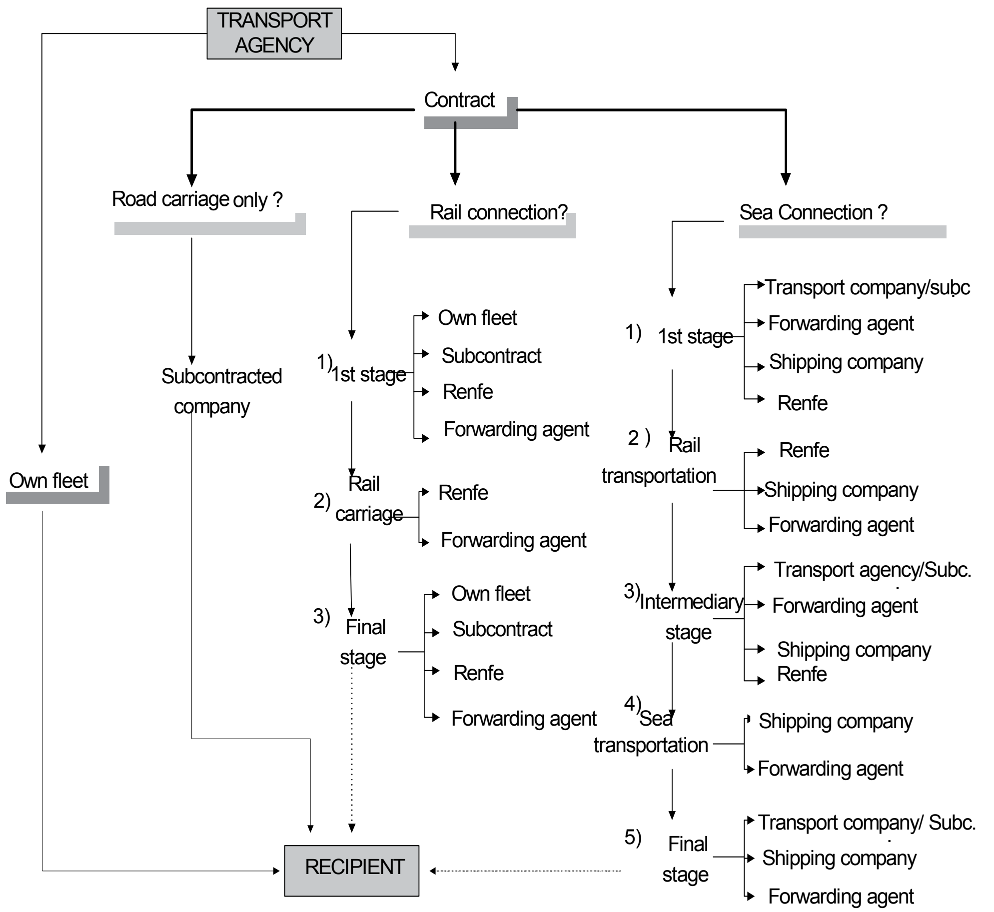

Fig. 12. Transport agency's decision making process within the intermodal transportation chain.

A detailed study of all the quotations is carried out, bearing in mind the following:

- The selected operator(s) is able to comply with the established timetables and schedules, i.e., the frequency of services set out by the company.
- Reliability in terms of continued compliance with schedules, avoiding changes and delays. This is important as interrupting the intermodal chain will incur losses.
- The cost of the service provided and amount saved by choosing one or the other.

Goods may be transported by land using the company's own fleet or by subcontracting the service to another transport company, depending on whichever option is most suitable. If goods need to be transported by sea and/or rail, this may be done by the shipping company or the rail company respectively.

With respect to customs clearance, the companies may take care of this by themselves if they are certified to do so. If this is not the case, they should contact a forwarding agent who can carry out the necessary procedures.

4. Case study

To test our decision-making model, we applied it to a transport company located in Seville, in the south of Spain, managing intermodal shipments from the local port and intermodal rail terminal. The Port of Seville is located 80 kilometres from the mouth of the river Guadalquivir, and is the only commercial inland port that exists in Spain. Its geographical location is perfect for access from both the Mediterranean and Atlantic, with several factors that position it as a first-rate logistical and commercial node. Traffic at the Port of Seville is around five million tonnes annually (Table 1). Regular lines stand out with the Canary Islands for container and ro-ro traffic, which makes the Port of Seville the main maritime gate between the Canaries and the Iberian Peninsula.

	2008	2009	2010
Goods (Tn)	4,584,671	4,504,647	4,365,589
Containers	130,452	129,736	152,612
Boats	1,278	1,242	1,181
Passengers	166,990	149,646	123,025

Table 1. Traffic at the port of Seville.

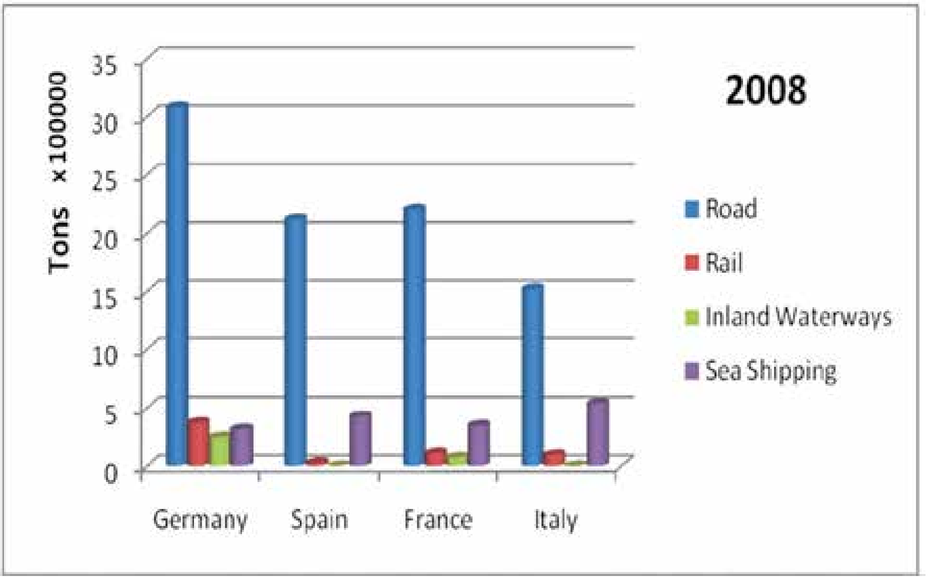

Fig. 13. Movement of freight in Spain, France, Germany and Italy on each transport mode for year 2008.

With respect to rail transport, whereas the total amount of freight moved in Spain is comparable to other European countries, the amount of freight moved by train is significantly lower (see Figure 13 and Figure 14). Specifically, the modal distribution of freight transport in Spain is as follows: road: 82%; water: 12% (and this mainly due to the shipments to the Spanish islands, with a negligible relevance of short sea shipping); rail: 4%; pipeline: 1.97%; air: 0.03%. Moreover, while the increase in the amount of freight on roads is steady, rail-based transport has shown little or no increments in the recent years.

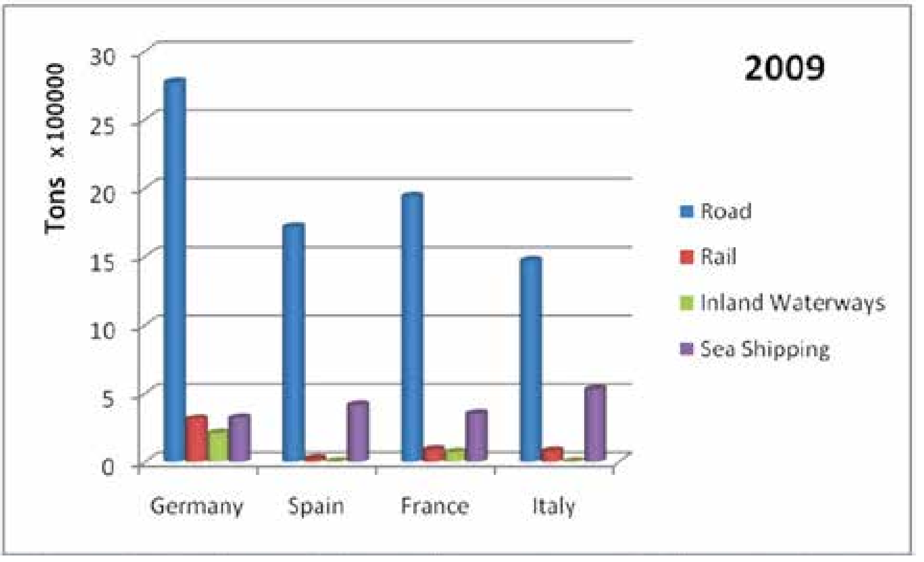

Fig. 14. Movement of freight in Spain, France, Germany and Italy on each transport mode for year 2009.

The only rail operator in Spain is Renfe, the national railway company. Renfe operates a freight division, where other shippers or carriers of general freight may subcontract the delivery of a less-than-wagon load or a whole wagon for a container. The network of freight terminals distributed throughout Spain is depicted in Figure 15.

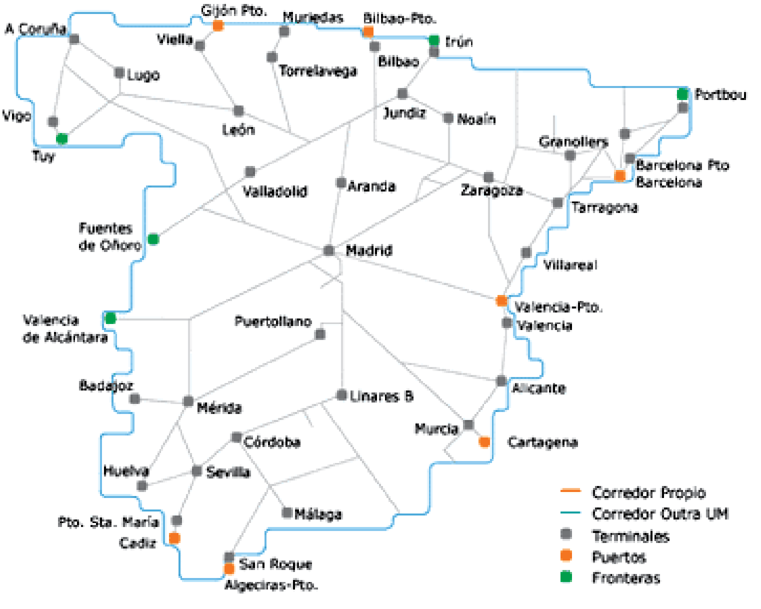

Fig. 15. Freight terminals operated by Renfe in Spain.

The intermodal shipments run by the company during the two-month period selected for the case study are shown in Tables 2 and 3.

Distance (miles)	Time Taken (days)	Time Expected (days)	Distance (miles)	Time Taken (days)	Time Expected (days)	Distance (miles)	Time Taken (days)	Time Expected (days)
1134	21	6	**1504**	11	5	**540**	30	
1134	14	6	**1504**	14	5	**540**	30	
1134	11	6	**1504**	14	5	**540**	17	
1134	10	6	**1504**	14	5	**540**	22	
1134	10	6	**1504**	11	5	**540**	31	
1134	10	6	**1504**	9	5	**540**	18	
1134	14	6	**1504**	14	5	**540**	22	
1134	10	6	**1504**	18	5	**540**	30	
1134	14	6	**1504**	14	5	**540**	30	
1134	11	6	**1504**	14	5	**540**	17	
1134	21	6	**1504**	14	5	**540**	22	
1134	21	6	**1504**	14	5	**540**	31	
1134	11	6	**1504**	14	5	**540**	18	
1134	14	6	**1504**	14	5	**540**	22	
1134	11	6	**1504**	14	5			
1134	9	6	**1504**	13	5			
1134	14	6	**1504**	14	5			
1134	11	6	**1504**	11	5			
1134	13	6	**1504**	10	5			
1134	11	6	**1504**	10	5			
1134	10	6	**1504**	10	5			
1134	10	6	**1504**	10	5			
1134	14	6	**1504**	14	5			
1134	11	6	**1504**	18	5			
1134	11	6	**1504**	10	5			
1134	10	6	**1504**	10	5			
1134	14	6	**1504**	10	5			
1134	15	6	**1504**	17	5			
1134	14	6	**1504**	14	5			
1134	11	6	**1504**	10	5			
1134	14	6	**1504**	32	5			
1134	10	6	**1504**	11	5			
1134	11	6	**1504**	14	5			
1134	14	6	**1504**	10	5			
1134	14	6	**1504**	10	5			
1134	14	6						

Table 2. Data on the intermodal waterborne shipments delivered by the case-study company.

Distance (Km)	Time Taken (days)	Time Expected (days)	Distance (miles)	Time Taken (days)	Time Expected (days)
1099	2	1,5	**570**	3	1
1099	2	1,5	**570**	2	1
1099	2	1,5	**570**	3	1
1099	2	1,5	**570**	2	1
1099	2	1,5	**570**	4	1
1099	10	1,5			
1099	2	1,5			
1099	2	1,5			
1099	2	1,5			
1099	3	1,5			

Table 3. Data on the intermodal rail shipments delivered by the case-study company

4.1 Cost data

In order to represent the decision-making process of companies involved in intermodal transport, we gathered all the cost-related data for each link of the intermodal chain. This included vehicle cost components, rail and ship tariffs, intermediary supplements, etc. The data collection was carried out by accessing the appropriate statistical sources in each case, or by direct consultation to the involved stakeholders.

4.1.1 Road transport

The Spanish Ministry of Public Works publishes a yearly report (Ministerio de Fomento, 2009) for road transport companies providing them with reliable criteria upon which they may establish the price of the service offered. This publication contains average cost data related to the different concepts involved in road transport, and has become a capital reference for the establishment of transport rates in the country. An example of the type of data provided is shown in Table 4. The cost data was then translated into prices by adding the average commercial margins in the sector.

4.1.2 Rail transport

Every year the rail company Renfe offers its clients rates depending on the origin and destination terminal. The rates data for haulages departing from Seville is shown in Table 5. On top of these rates, clients must pay a surcharge for the different additional services (road haulage, container storage, etc.) offered by Renfe.

4.1.3 Waterborne transport

The rates charged for the waterborne transport of a container correspond to the transport itself, which is often negotiated between the shipper and the carrier, plus the port charges. The concepts normally included in a vessel transport invoice are:

	ANNUAL DIRECT COSTS	
	Euros	**Distribution (%)**
Direct costs	119,420.84	100.0%
Costs per time	65,274034	54.7%
Vehicle depreciation	13,844084	11.6%
Vehicle financing	1,302.69	1.1%
Drivers	28,384073	23.8%
Insurance	6,848.08	5.7%
Tax costs	928.00	0.8%
Expenses	13,966.00	11.7%
Kilometric costs	54,146.50	45.3%
Fuel	41,619.83	34.9%
Tyres	6,730.67	5.6%
Maintenance	2,088.00	1.7%
Repairs	3,708.00	3.1%
Annual distance travelled (km/year)	120,000	
Annual distance travelled for loaded vehicles (km/year)	102,000	
Direct Costs (euros/km covered)	0.995	
Direct Costs (euros/km covered by loaded vehicle)	1.171	

Table 4. Average cost data for a vehicle containing a normal load (420 HP, MAM = 40,000kg and payload of 25,000kg). Base hypothesis: 20,000 km covered every year, 85% loaded and 15% empty. (Source: Spanish Ministry of Public Works).

- The haulage rate (BAS) for sea transportation and the previous procedures associated with ship operations.
- Obtaining the necessary currency for payment of freight.
- THC for handling of goods in port terminals. This is called the OHC in the terminal of origin and DHC in the terminal of destination.
- The goods rate (PTD) for use of port facilities. This depends on the weight of the goods and the container.
- Management of the consignee (shipping company) for port operations between them and the forwarding agent, the customs official, recipient/shipper, port terminal and carrier. This involves the notification of arrival, the B/L (bill of lading) and the delivery and acceptance order. A sum is paid for the processing of documents. In the origin this is called the ODF and in the destination the DDF.
- Management of the Customs official for goods clearance procedures (presentation of DUA, customs release, closing of DUA, and/or presentation of additional documentation, physical inspection, representation and obtaining of customs release - document or physical inspection) which will be explained later.
- IHE Inland Haulage Export (TTE)/Import (TTI).
- Warranty of article 102: warranty to respond as a whole to deferment of payment of the customs debt in accordance with the Customs Code.
- BAF. This is the amount to be paid depending on the cost of fuel.
- CCN is the surcharge for cleaning the container (this varies according to terminal).
- Occupancy: this is the amount to be paid for temporary storage of goods in the terminal port and for any delays caused as a result of container occupancy.

DESTINATION	CH	LOADED				EMPTY		
		20' <12 Tonnes	20'> 12 Tonnes	30'	40'	20'	30'	40'
A CORUÑA S.D.	*	404.2	504.21	615.29	779.75	270.02	403.05	452.37
BARCELONA MORROT	*	410.74	514.19	625.19	792.22	274.38	409.52	459.54
BILBAO PORT	*	376.79	477.74	558.96	703.34	262.19	377.92	423.86
GIJON PORT	*	370.3	467.5	577.57	686.53	263.77	378.98	428.72
IRUN	*	368.56	452.52	560.77	710.33	246.66	367.95	412.72
JUNDIZ	*	340.21	439.61	517.54	655.63	227.72	339.82	381.03
LEON	*	316.97	388.88	469.22	591	229.29	328.51	375.74
MADRID ABROÑIGAL		178.92	224.45	272.39	344.91	119.11	177.41	199.14
MURIEDAS	*	340.21	439.61	517.54	655.63	227.72	339.82	381.03
NOAIN	*	367.19	448.1	546.68	688.36	263.39	379.43	430.92
SILLA	*	266.53	375.62	405.32	517.54	178.24	265.54	298.12
TARRAGONA CONSTANTI	*	383.11	479.12	582.37	738.67	280.76	382.69	429.29
VALLADOLID ARGALES	*	238.61	299.32	356.45	452.01	177.44	245.92	275.79
VIGO GUIXAR	*	380.01	473.94	578.56	733.09	254.38	379.72	426.02
ZARAGOZA	*	346.42	423.33	525.11	668.36	370.74	370.74	446.86

Table 5. Price rates for containers leaving the Seville intermodal terminal on a Renfe train (CH: Container Hire) (Source: Renfe Combined Transport Rates).

The invoice may have a different layout depending on the shipping company. However, the concepts included are more or less the same as those outlined above. Below we have an example (Table 6) of a Spanish port invoice for a 20′ dry container:

Port invoice (euros)	
BAS	400/600
BAF	30/50
OHC	140.04
DHC	140.04
PTD	30
ODF	45
DDF	45
CCN	6
FFC	2.5
Carriages	
- Internal port	62
- 0-10km	100
- over 200	1.03 cents/km

Table 6. Example of a port invoice for a 20′ dry container (€).

Other concepts are included in the invoice but indirectly. These are the services provided directly or indirectly by each Port Authority.

- Direct Services are those services provided to the ship or goods (in accordance with the BOE, Official Gazette of the Spanish State).
- Indirect Services are those provided to the ship or goods by the Port Authority through individuals or third parties (subcontacted or by means of concession).

We will now look at the different components of this service and their corresponding rates, all of which will be looked at with reference to the Port of Seville.

4.1.3.1 Direct services

- Ships accessing the port, berthing or anchoring:
- The rate is 0.04912 euros/GT for short stays of 3 hours (maximum of 4 periods every 24 hours) Reductions are applicable for the use of facilities under administrative concession, for lack of draught in berthing, mooring method and navigation type (cabotage between ports within the European Union).
- For the number of stopovers made (Table 7):
- For long stays a minimum surcharge of 0.009196 and a maximum of 0.055173 euros per GT and day of stay is applied.

Generally Applied Reductions	
From 13 to 24 stopovers	20%
From 25 to 40 stopovers	45%
From 41 stopovers	70%
Reductions for scheduled routes	
From 13 to 24 stopovers	5%
From 25 to 50 stopovers	15%
From 51 to 100 stopovers	25%
From 101 stopovers	35%

Table 7. Applied reductions for the number of stopovers made.

- Goods. Rates for general goods per section (Table 8):

Discount group	**% disc. ***	**Amount discounted (€/Tonne)**		
		UNLD	**Base**	**LD**
First	85	0.565552	0.459774	0.354056
Second	75	0.942567	0.766290	0.590074
Third	60	1.508059	1.226065	0.944070
Fourth	30	2.639104	2.145613	1.652122
Fifth	0	3.770149	3.065162	2.360175
UNLD=Unloading LD=Loading *Based on the basic amount of 3.065162 €/Tonne				

Table 8. Rates for general goods per section.

- Other services. Scales:
  - For lorry: €1.664804

- For loaded wagon: €5.709615
- For empty wagon: €3.305567

4.1.3.2 Indirect services

Pilotage: Services to facilitate entry to and departure from the port and manpower within the boundaries where such activity takes place. According to National Ports Authority Law, Merchant Navy regulations and the General Regulations of Pilotage, Some of the discounts applicable are:

- For ship type:
  - Passenger and Ro-Ro ships: 5%
  - Scheduled Ro-Ro ships: 8%
  - Scheduled Ro-Ro ships which stopped at Seville before 01/06/99 and whose GRT was less than 3000 and GT more than 6000 units: 13%
- Scheduled routes:
  - More than 40 annual stopovers: 47%
  - More than 24 annual stopovers: 35%
  - More than 10 annual stopovers: 20%
- Ships who berth outside the dock: 20%

5. Results and conclusions

5.1 Assessment of the company's operations

After having applied the decision-making model to the company's intermodal routes, (road-rail-sea and road-rail), the following observations can be made:

- Road-rail-sea-route: Although the decisions taken illustrate how the model may be most effectively implemented, they do not reduce costs. The company is not 100% efficient, since the initial road carriage is subcontracted. The least expensive option is to contract this through Renfe, provided that they also manage the rail carriage. As our results have shown, contracting Renfe for the road carriage would be less expensive than using the company's own fleet, at least for the first 70 km. Besides, if as a result of the liberalisation of the rail market, Renfe loses its monopoly in this sector, the market will be more competitive and costs will be reduced. In this way, having the rail operator manage the road carriage, as indicated by the model, will be less expensive.
- Road-rail route: The company has been able to optimise the costs incurred in this route by implementing the decision-making model and has therefore made the right decision. The figures show that using intermodal transport, rather than road transport only, considerably reduces costs by 50%, which confirms that intermodal transport is more cost-effective than road for distances greater than 500 km.

Besides, in addition to making its business more economically efficient, the company also aims to maintain customer loyalty and service quality. The introduction of intermodal transport therefore widens the range of services offered to its clients and as new routes open, the incorporation of other services is also possible. As borders are opened up, the company is able to reach other destinations that were previously limited to road transport.

5.2 General conclusions for intermodal transport in Spain

Besides using the developed model to assess the specific intermodal operations of the case-study company, it was also used to analyse transport routes from Seville to the rest of Spain. Depending on the location of intermodal terminals throughout the national territory, and on the distances to these terminals and from Seville, it was possible to determine which transport option would be cheapest for hauling a container from Seville to all the other Spanish provinces.

The result is shown in Figure 16, and comes to confirm the generally accepted statement that intermodal transport is only cost-effective for distances longer than 500 km. In the case of Spain, road transport to the East coast would still be the preferred option due to the existence of a highway along the coast, while rail shipments have to pass through Madrid. It is also significant to mention that, even though waterborne transport is only cost-effective for shipments to the islands, it is the second cheapest option, after rail transport, for shipments from Seville to the coastal areas in the north of Spain.

It has been noted that in long distance and intercontinental routes, although the use of intermodal transport improves the relationship between time taken and distance covered, it may also have a negative impact due to periods of unproductivity when goods are stationary and the mode used for the carriage is unavailable. It is therefore necessary to dedicate resources to avoiding any negative impact from factors such as these. For example, this can be done by improving data exchange and compatibility between the different agents' schedules, among others.

Although intermodal transport is much more developed in other countries than in Spain, as time passes and borders are opened up and the market becomes more global, intermodal transport may establish itself as the most efficient solution, thus making it much easier for small and medium enterprises to enter the market.

Fig. 16. Cost-effectiveness borders for the different transport modes in Spain for shipments from Seville, as obtained from the decision-making model.

5.3 Effect of additional factors

The analysis was also be extended to other non-monetary effects, such as time and shipment reliability, which play a very important role in making the road more attractive to freight transport than other alternative modes (Modenese Vieira, 1992). One of the objectives of the paper was thus to gain some insight about the importance of these non-monetary effects on the decision-making process related to intermodal transport, as it might sometimes be cheaper than road transport but is also often less reliable. Two additional factors were considered in the analysis:

- The time taken for the delivery, measured as average of time taken. (Table 9 and 10)
- The reliability of the delivery, measured as standard deviation of the time taken. (Table 9 and 10)

Distance (miles)	Time Expected (days)	Time average (days)	Standard deviation (days)
1134	6	12,72	3,09
1504	5	13,24	4,07
504		24,29	5,73

Table 9. Data analysis on the intermodal waterborne shipments delivered by the case-study company.

Distance (Km)	Time Expected (days)	Time average (days)	Standard deviation (days)
1099	1,5	2,90	2,51
570	1	2,80	0,84

Table 10. Data analysis on the intermodal rail shipments delivered by the case-study company.

The procedure followed consisted in registering data on the intermodal shipments delivered by the case-study company (Table 9 y 10).

In terms of the time taken for deliveries, the high values of the time average of the waterborne case may be explained by the fact that it includes an intercontinental route, and therefore rotations are higher due to port of calls and procedures for entering port areas. As a result, although the distance covered is less than other routes, the time taken is greater. It may also be due to the time taken to load and unload in the port of destination. In the case of rail transport, the time average values are greater than time expected but not as the waterborne case.

In terms of reliability, the data for waterborne transport shows an increased standard deviation with the distance of the trip, international case except for the reasons previously exposed. In the case of rail the trend is the same, which highlights the fact that unexpected delays take place in the distance between origin and destination, and are therefore independent of terminal operations rather than during the movement process itself.

The standard deviation is high. This means that time and reliability vary a lot over the same distance. It would have been useful to look at more routes; however, no more data was available, so the results are not very reliable. However, this type of analysis is useful since it allows us to measure the importance of these additional factors in intermodal transport. With more data, more sophisticated analysis may be carried out and more reliable data obtained.

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15

Location Problems for Supply Chain

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1. Introduction

A typical supply chain is a materials and information network composed by supplier, manufactures, logistics agencies, distribution center, warehouse, retailer and consumer. It involves all enterprises and departments throughout the whole product life-cycle from the material gaining, production to semi-finished products or finished products, assembly, transportation, consumption till disposal. Supply chain management is the term used to describe the management of the flow of materials, information, and funds across from those enterprises and departments. It has been proved to be an effective way to enhance enterprises' adaptive ability and viability in the market by collaborating with the upstream and downstream enterprises in the competitive market.

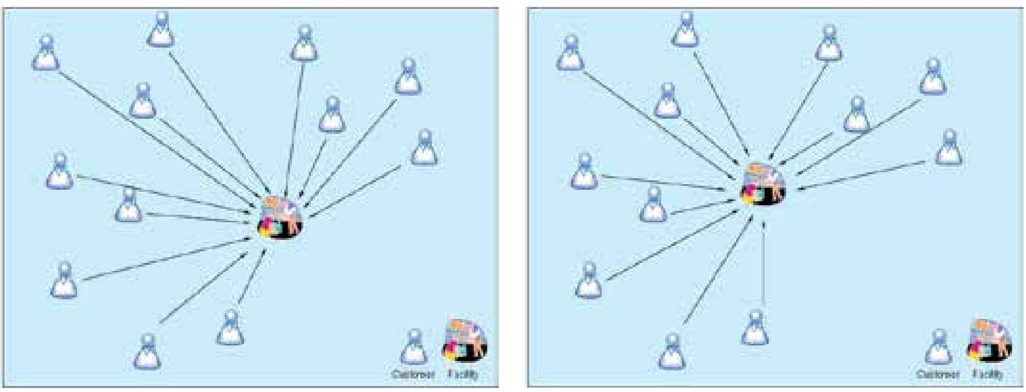
Traditionally, location problem is a branch of operations research concerning itself with mathematical modeling and solution of problems concerning optimal placement of facilities in order to minimize transportation costs, avoid placing hazardous materials near housing, outperform competitors' facilities, etc. Location problems in supply chain management is to find the ideal locations for suppliers, manufactures, distribution centers and warehouses to achieve different objectives by using mathematical modelling, heuristics, and mathematical tools such as, ILOG CPLEX, LogicNetPlus etc.

With the increased environment pollution concerns of people, organizations and governments, enterprises are facing pressure to protect and improve the environment, such as decreasing environment pollution, reducing waste cites and using green raw material etc. In order to solve this problem, enterprises begin to integrate Supply Chain Management (SCM) with the thought of environment protection. With the development of researches on this problem, it naturally comes green supply chain management Stevels (2002). Presently, green supply chain management are mainly focused on the following two aspects: 1) green technology, such as green design, green manufacturing and remanufacturing, waste management, and green logistics and green management Wang et al. (2005). 2) green materials flow, it is to make material flow effective and green by the management of material flow, for example, using green materials, recycling disposal products etc Srivastava (2007). Among those technologies, the approaches for location problems play key roles in green supply chain management.

Motivated by the above problems, we will firstly review the traditional location problem in supply chain management from the following three views: modelling, solving algorithms and mathematical tools, then we will demonstrate the development of location problem in supply chain and propose mathematical model for distribution center location problem in green supply chain. Finally we will illustrate the proposed problem by using IBM Watson Implosion Technology.

2. Literature review

Location theory was first formally introduced in 1909 by Alfred Weber, who considered the problem of deciding a location in the plane to minimize the sum of distance from the distribution center to all demand consumers/retailers. A typical location problem and its solutions are shown in the following two figures. Obviously, the above problem can be



(a) Facility Location Problem (b) Solution for Facility Location Problem

Fig. 1. Facility Location Problem and Its Solution

described as following mathematical model:

$$\text{Geometric Solution} = \arg\min_{y \in \mathbb{R}^n} \sum_{i=1}^{12} \|x_i - y\|_2 \tag{1}$$

Where $x_1, x_2, \cdots$ and x_{12} are the points where the twelve customers locate, y is position where the facility located.
Based on the simple model provided by Alfred Weber, researchers had proposed lots of models to describe complex location problems for different industries. In fact, location theory is not only a pure mathematical problems, it comes from application, and it also has lots of applications in different industries, such as logistics, public fire protection, manufacture etc. For example, when a supply retailer is thinking to open a new outlets, he will consider customer demands and related costs for different locations. When a manufacturer chooses where to position a warehouse, he will consider customer demand, cost, inventory and cost and market trends of targets locations. When a city planner selects locations for fire stations, he will consider the requirements and constraints for fire fighting. Obviously, those problems are typical location problems.

Although all of those problems are called as location problems, there are many difference in constraints and objectives. Those constraints and objectives are coming from factors/decisions for specific industries Li et al. (2007). For different industries, the factors/decisions are different. For instance, customer demand, population shift and market trends evolve will be considered for a logistics planner when he determine the location for distribution center, minimum transportation time and district coverage rate will be thought for a city planner when he selects locations for fire stations. Because those factors will have impact on the constraints of location model, they will result in lots of challenges for models and algorithms for location problems. According to the objectives of those problems, we can classify those problems as the following six groups,

1) Minimize average travel time/average cost or maximize of net income,
2) Minimize average response time,
3) Minimize maximum travel time/cost,
4) Minimize maximum response time,
5) Maximize minimum or average travel time/cost,
6) Problems with other objectives.

According to the characteristics of those problems, we can identify them as, static and deterministic location problems, dynamic location problems and stochastic location problems. Distribution center location is a typical location problem. Choosing the proper location for a distribution center has developed into a specialized, scientific process. Cost and non-cost factors such as efficient customer access, infrastructure availability, proximity to qualified labor, variable operating costs, incentive availability, and environmental impact are all part of the scientific equation. As a supply chain planner begins the location selection process, the following two questions are very important for him:

1. What are the factors that will control the supply chain decision?
2. What are the steps to properly select a location?

Transportation, the largest location-dependent cost factor, is addressed first. After transportation, labor cost/ productivity, quality, work ethic, and supply, available or develop-able land, power needs, water and waste water supply and capacity, and building costs are considered. Moreover, as basic energy costs have continued to rise, utility costs have become a more important element in the site selection process. Besides those factors, inventory and services costs will also be taken into accounts. When we determine the locations of its distribution centers for a green supply chain, we will consider the other important factor, carbon emissions, besides those factors mentioned above.

2.1 Models for location problem

In order to formulate this problem mathematically, the following notations are necessary:
Inputs:
i = index of customer,
j = index of potential location for distribution center,
k = index of manufacture,
R_i = product requirement for customer i,
P_i = sale price for customer i,

I_j = maximal inventory for potential distribution center location j,
C_j^o = total cost for opening a distribution center at location j,
C_k^p = production cost of manufacture k for single product,
C_{ij} = transportation cost from location j to customer i for unit product,
$\bar{C}_{jk}$ = transportation cost from manufacture k to location j for unit product,
Decision Variables

$$x_j = \begin{cases} 1, \text{ if open a distribution center at location } j, \\ 0, \text{ otherwise.} \end{cases}$$
$$y_{ij} = \text{product transport volume from } j \text{ to } i,$$
$$z_{jk} = \text{product transport volume from } k \text{ to } j,$$

Using these definitions, the model for distribution center location can be described as follows,

$$\begin{aligned} \max & \sum_j \Big\{ \sum_i (P_i - C_{ij}) y_{ij} - C_j^o x_j - \sum_k (\bar{C}_{jk} + C_k^p) z_{jk} \Big\} \\ s.t. & \sum_j x_j \cdot y_{ij} = R_i, && \forall i, \\ & \sum_i y_{ij} - \sum_k z_{jk} \le 0, && \forall j, \\ & \sum_k z_{ij} - x_j \cdot I_j \le 0, && \forall j, \\ & x_j \in \{0,1\}, y_{ij} \ge 0, z_{jk} \ge 0, && \forall i, j, k. \end{aligned} \tag{2}$$

In model (2), the first constraint is to satisfy each customer demand, constraint from is to meet the requirement that the supply volume of the product at each distribution center should be greater than the demand volume of the product, the third constraint is to limit the total stock volume less than the maximal inventory of each distribution center, the forth constraint is to restrict the decision variable x_j be 0 or 1.

2.2 Algorithms for location problem

In order to solve those problems, the researchers also proposed dozens of exact optimization algorithm and heuristics Brandeau & Chiu (1989); Owen & Daskin (1998); Rosing (1992). The most popular used exact optimization algorithms go as follows, branch-and-bound, branch-and-cut, column generation, and decomposition methods. Where branch-and-bound algorithms sometimes combined with Lagrangian relaxation or heuristic procedures to obtain bounds.

Normally, static and deterministic facility location problems are attractive to be solved by exact optimization algorithms. However, in the real world, the number of decision variables is large and the models are comparatively more complex, it is hard to obtain optimal solution by exact optimization algorithms. There comes the heuristic method. Lagrangian relaxation, linear programming based heuristics and metaheuristics are among the most popular techniques. In fact, most of time the dynamic location problems, stochastic location problems and problems with multiple objectives can only be solved with some specific methodology, heuristics. At the same time, researchers had created and built some useful and innovative tools to help us solve the location problem in supply chain.

2.3 Tools for location problem

The most famous tools for the location problems is IBM ILOG LogicNet Plus XE and Watson Implosion Technology. Below we will illustrate them one by one.

2.3.1 IBM ILOG LogicNet Plus XE

IBM ILOG LogicNet Plus XE is a software for supply chain network optimization and supply chain design, an off-the-shelf decision support solution for ongoing strategic planning. It is for network design and production sourcing. It determines the optimal number, location, territories, and size of warehouses, plants, and lines. It also determines where products should be made and optimizes the carbon footprint. Figure 2 give a typical case for using IBM ILOG LogicNet Plus XE.

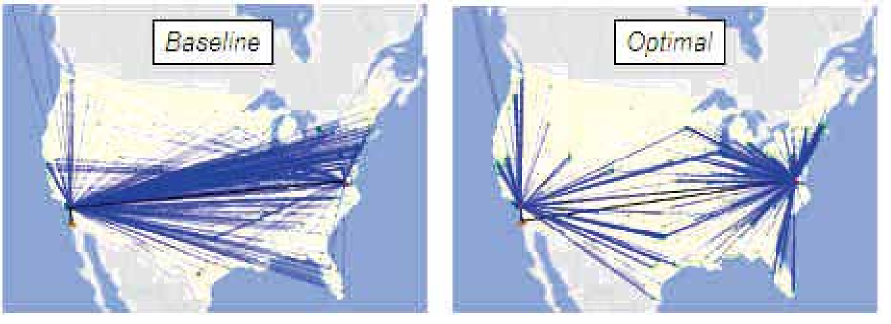


Fig. 2. Typical Case for ILOG LogicNet Plus XE

IBM ILOG LogicNet Plus XE can solve the following typical applications:

1. *Distribution Network Design*, Determine the optimal number, location, and size of distribution facilities to meet customer service requirements at minimum cost.
2. *Manufacturing Network Design*, Determine the best number, location, and capacity of plants, lines, and processes to maximize asset utilization, minimize total cost, and align capacity with business growth projections.
3. *Manufacturing Sourcing Strategy*, In a multiplant environment, determine which product should be made at which plant, trading off manufacturing costs and economies of scale with transportation costs.
4. *Shipping Territory Realignment*, Determine the best service territory for each DC (Distribution Center) to improve service levels and reduce costs.
5. *Network Transition Planning*, Make the transition to a new supply chain configuration focusing on various asset, capacity, inventory and transportation lane requirements.
6. *Seasonal Supply Chain Design*, In a highly seasonal business, determine the appropriate trade-off between capacity and inventory prebuild and the use of overflow facilities.
7. *Contingency Planning*, Understand how unexpected events in the supply chain will affect the costs, service levels, and potential revenues. Develop plans to mitigate the risks.

The major inputs for this tool includes

1. Customer locations and demand by product and time period.

2. Locations, costs, and capacities for plants, suppliers, and production lines for existing and potential sites.
3. Locations, costs, and capacities of existing and potential warehouses.
4. Transportation costs for each lane.
5. Service level requirements.
6. Carbon emissions data.
7. Tax rates.

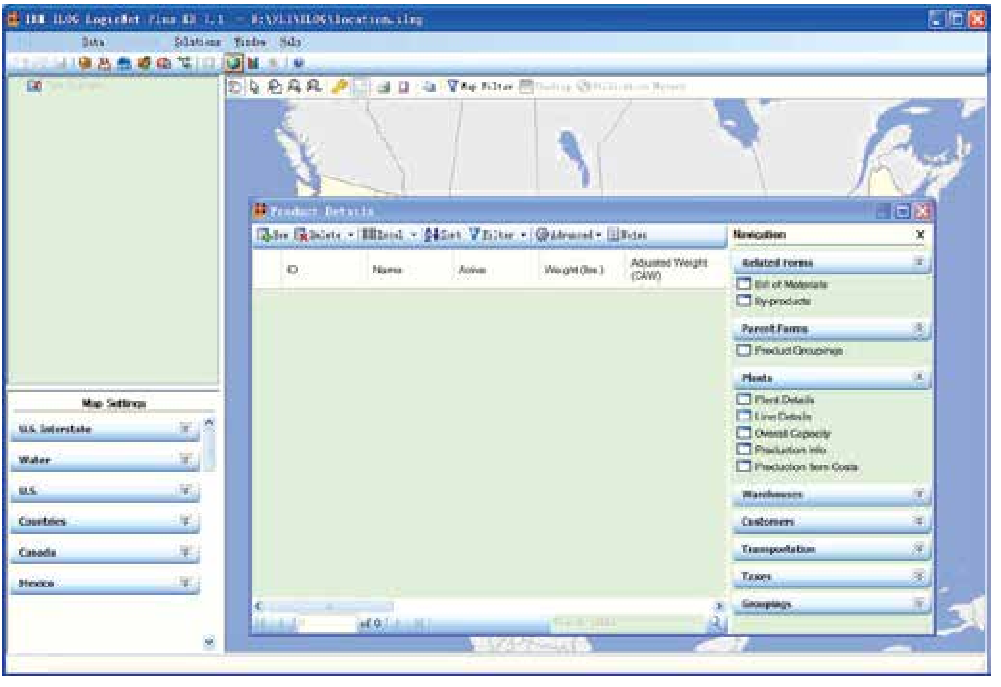


Fig. 3. Screen Shot for ILOG LogicNet Plus XE

Figure 3 is a screen shot for the tool of IBM ILOG LogicNet Plus XE. It will help you to build supply chain for your problem by tables. By using those tables, we can input the data and their relationships for products, by-products, bill of materials, plants, warehouses (distribution centers), customers, transportation, and taxes etc. Once we've finished building the model, we can click on the "Optimize" button to obtain solution for our problems. Integrating with geographic information map, the tool can help us to review the solution through a map. It will visualize the locations for the customer, plants, and distribution center (warehouses). The tool also provide summary report for the solution, including the various input and output parameters for the latest optimization run, such as run time, optimization gap, and the total cost of the solution. This report also has sections on financial summary, cost totals, transportation summary, variable cost details, holding cost details, and manufacturing cost details. Meanwhile we can use the tool to do sensitivity analysis for the model by adjusting the parameters of the model. Although IBM ILOG LogicNet Plus XE has powerful function and can solve several kinds of problems in supply chain management, it cannot support graphical mode to build models.

2.3.2 Watson Implosion Technology

Watson Implosion Technology (WIT) tool is a graphical modeling tool Wittrock (2006), it was generated to solve particular kind of production planning problem, especially for constrained materials management and production planning problem. It utilizes an analytical decision making approach to determine if equipment is worth selling as whole or if it should be dismantled for service parts, which can often yield better returns. It can describe the planning problem as an optimization model by using visual predefined components, and the optimization model will further calculate the number of products to disassemble in a given time period to fulfill the demand for various components. A typical WIT model is should as following Figure 4

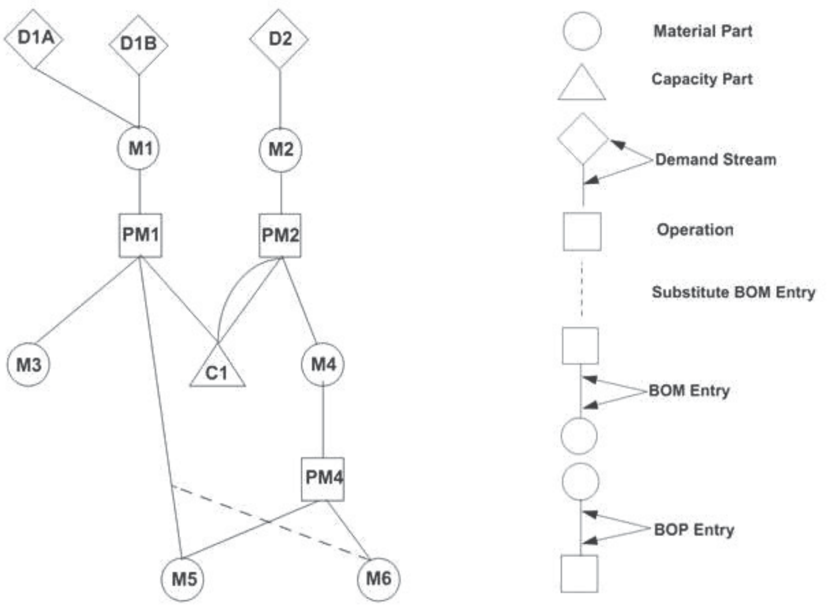


Fig. 4. Typical WIT Model

Table 1 defines all of the manufacturing terms for WIT. The primary data for this software tool is a list of demands for products, a list of supplies for components, and a multi-level bill-of-manufacturing (BOM) describing how to build products from components. Ordinarily, it takes many components to build a single product, and so the list of supplies is much larger than the list of demands. A traditional use of a BOM to perform production planning is Material Requirements Planning (MRP), in which the list of demands for products is "exploded" (via the BOM) into a much larger list of requirements for components. The main capability provided by WIT is, in some sense, the reverse of an MRP explosion: the WIT "implosion". The list of supplies of components is "imploded" via the BOM into a relatively small list of feasible shipments of demanded products. The assumption is that not all demands can be met, and therefore the idea is to make judicious trade-offs between the different demands given limited supplies to best satisfy the manufacturing objectives.

In general, optimizing implosion is used to find the best possible implosion solution according to some well-defined criterion. We can use WIT tool to determine the best possible distribution

Period	The time bucket for production plan.
Part	WIT's concept of a part is very general. A part is either a product or anything that is consumed in order to build a product. This includes both materials and capacities.
Part Category	Parts are classified into two categories: Material and Capacity
Operation	An operation is the means by which parts are dismantled. Specifically, a part is dismantled by "executing" an operation. When an operation is executed, some parts (machines) are consumed, while other parts are produced.
Material	A material part is either a raw material or a product. Any quantity of a material part that is not used in one period remains available in the next period. In other words, material parts have stock.
Capacity	A capacity represents some limitation on the quantity of one or more operations that can be executed during one period. We assume no capacity limitation at dismantling or refurbish centers.
BOM (Bill-of-Manufacturing /Materials)	Each operation has a bill-of-manufacturing that specifies the how parts (both material and capacity) are consumed when the operation is executed. In MRP terms, this is roughly equivalent to a combined bill-of-material and bill-of-capacity.
BOM entry	A BOM entry is the association between a particular operation and one particular part in its BOM. Each BOM entry represents the consumption of some volume of a part in order to execute some operation.
BOP (Bill-of-Products)	Each operation has a bill-of-products that specifies the how parts are produced when the operation is executed. Production rates indicating how much of the part is produced, and so on.
BOP entry	A BOP entry is the association between a particular operation and one particular part in its BOP. Each BOP entry represents the production of some volume of a part as a result of executing some operation.
Product	Any part that appears as the produced part of a BOP entry.
Demand	Each material part may optionally have one or more demands associated with it. A demand stream represents an external customer who places demands for the part.

Table 1. Definition of WIT Terms

center locations and transportation modes for delivering the products given a defined set of criteria. In the following section we will use this tool to illustrate the proposed models.

3. Distribution center location in green supply chain

The concept of green supply chain was first introduced in 1996. Since green supply chain was given it has been getting a lot of attention. It aims to not only synthetically consider the environment impacts and resources utilization in the manufacturing supply chain but improve good business sense and obtain higher profits Wilkerson (2005). Green supply chain

management involves a fundamental rethinking of supply chain management practices and how they can be integrated with your company's environmental strategy, such as, carbon emission and power consumption etc.
Distribution center is a core part for a supply chain. A typical structure is shown in Fig.5, while warehouses are distribution centers which connect factories and retailers. A suitable distribution center location can help us reduce the transportation cost, operation cost of the supply chain and improve the operation efficiency and logistics performances . It is a crucial question in the design of efficient logistics systems to identify the distribution center location Blanchard (2010). Currently choosing the proper location for a distribution center has been developed into a specialized, business and scientific process. It will consider cost and non-cost factors such as efficient customer assess, infrastructure availability, proximity to qualified labor, and variable operating costs. With the increasing concerns on global warming of environmental challenge, the decision to curtail carbon emission become more and more serious for all of the poor and rich countries Akerlof (2006). That makes reducing carbon dioxide emission become a key problem for green supply chain, especially for the distribution center location problems.

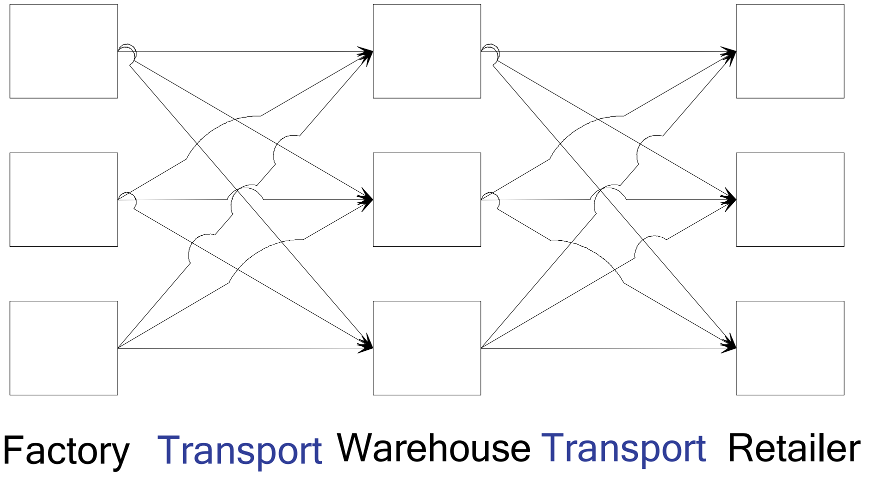


Fig. 5. Typical Distribution Center Location Problem.

3.1 Problem statement

As shown in Fig.5, distribution center location for green supply chain is to determine several locations for distribution centers in a supply chain while pursuing minimal operations cost, carbon emission, maximal profits, considering inventory constraints and satisfying customer demands.

3.2 Mathematical model

Model (2) is a typical description for distribution center location problem. It is to maximize its profits and minimize operations costs while considering inventory and customer demand constraints. However it has ignored an important factor for green supply chain. That's the carbon emission. Carbon emission is related with the manufacture and transportation. Carbon dioxide will be generated during the production and transportation process, and energy will be consumed during those process. Below we do not consider how to improve the production technology of each manufacture in order to reduce the carbon emission. We suppose the carbon emission for producing a product are fixed for every manufacture, and they can be different for different manufactures. Using the above notations, we can get the following multiple objective mathematical model,

$$
\begin{aligned}
&\max \sum_j \Big\{ \sum_i \left(P_i \cdot y_{ij} - \sum_m C_{ij}^m \cdot u_{ij}^m\right) - C_j^o \cdot x_j - \sum_k \left(C_k^p \cdot z_{jk} + \sum_m \bar{C}_{jk}^m \cdot v_{jk}^m\right) \Big\} \\
&\min \sum_m \sum_j \Big\{ \sum_k v_{jk}^m \cdot (\bar{E}_{jk}^m + V_m \cdot E_k) + \sum_i u_{ij}^m \cdot E_{ij}^m \Big\} \\
&s.t. \;\; \sum_j x_j \cdot y_{ij} = R_i, \qquad \forall i, \\
&\qquad \sum_m V_m \cdot u_{ij}^m = y_{ij}, \qquad \forall i, \forall j, \\
&\qquad \sum_m V_m \cdot v_{jk}^m = z_{jk}, \qquad \forall j, \forall k, \\
&\qquad \sum_i y_{ij} - \sum_k z_{jk} \leq 0, \qquad \forall j, \\
&\qquad \sum_k z_{ij} - x_j \cdot I_j \leq 0, \qquad \forall j, \\
&\qquad x_j \in \{0,1\}, y_{ij} \geq 0, z_{jk} \geq 0, \qquad \forall i, j, k.
\end{aligned} \tag{3}
$$

where, m represent the number of types for transportation mode used to transfer product from manufactures to distribution centers and from distribution centers to customers. u_{ij}^m and v_{jk}^m denote the transportation round times of mode m from the j-th distribution center to the i-th customer and from the k-th manufacture to the j-th distribution center, respectively. C_{ij}^m and $\bar{C}_{jk}^m$ denote the cost of mode m for single transportation round from from the j-th distribution center to the i-th customer and from the k-th manufacture to the j-th distribution center, respectively. E_k denote carbon emission for producing single product at the k-th manufacture, respectively. E_{ij}^m denote carbon emission of mode m for a round transportation from the j-th distribution center to the i-th customer, $\bar{E}_{jk}^m$ denote carbon emission of mode m for a round transportation from the k-th manufacture to the j-th distribution center, V_m denote volume of mode m for single round transportation.

Model (3) is a bi-objective mathematical programming, the first objective is to maximize the profits of the supply chain, the second objective is to minimize the carbon emission of the supply chain. At the first glance there is no relationship between these two objectives. In fact, these two objective are dependent. For example, if we decrease the transportation cost, let's say, decrease the gas consumption, we will cut down the carbon emission of the transportation. In this paper, we will assume the the carbon emission for transportation is a function of the transportation cost and the carbon emission for different manufacture is also a function of the manufacture cost for that factory.

3.3 Algorithms and experiments

Using WIT tool, It is easily for us to translate the model (2) from mathematical equations into a visual WIT model. The WIT model is shown as Fig.6, where,

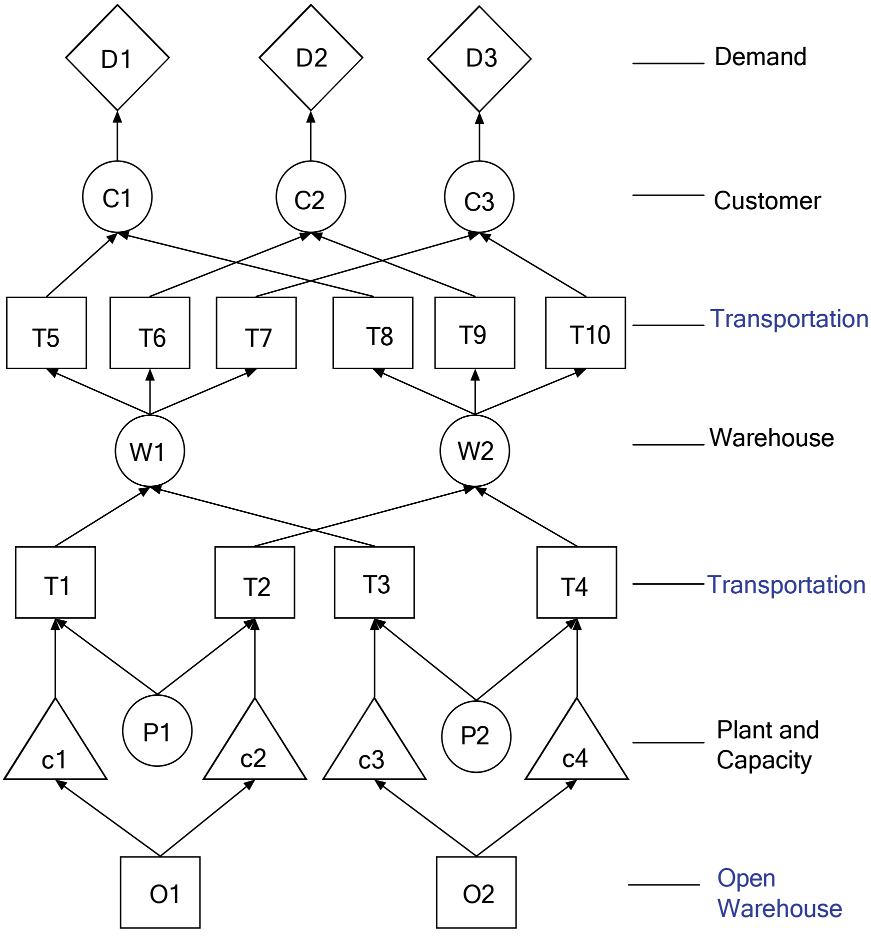


Fig. 6. WIT Model for Model 2

- P1-2: products in factory, defined as materials;
- W1-2: products in warehouse, defined as materials;
- C1-3: products for customer, defined as materials;
- D1-3: demands from customer;
- T1-10: transportation defined as operation, which move products from factory to warehouse, or from warehouse to retailer/customer;
- O1-2: open warehouse/(distribution center) defined as operation. Once a open warehouse operation is executed, the warehouse can be used;
- c1-4: capacity, which is generated only when the warehouse is opened. Specially, it is consumed by each transportation operation.

In the WIT model for model 2, we suppose that all potential distribution center locations can be used for storing products and while we open a distribution center it will have a capacity for transportation. It will be consumed for each transportation. If the warehouse is not opened, the capacity is zero which prevent the products to be transported to this warehouse. There is a solid fee to open a warehouse, which is modeled as the execution cost of the open warehouse operation. Perfect locations of warehouse are near to both factory and customer, and they are influenced by the production supplying from factory, demands from customer and transportation fees. Our WIT model can optimize the warehouse location given all these information. If we suppose that production supplying and demands are fixed, how will the transportation fee influence the location of distribution center? We will demonstrate the influence in the following experiments.

Just as we mentioned above, distribution center locations are influenced by transportation fees if product supplying from factory and demands from customer are fixed. Transportation fee is closely related with the crude oil price, and we can conclude the transportation fees' change from the crude oil price change. In order to illustrate the impact of the variation of the crude oil price on the distribution center location and transportation mode option for green supply chain, we increase the price of the oil from 75$ to 200$ and here is the numerical examples and their result we have. For this case, we have 3 factories located at different places, where the production cost are different because of the raw materials supply and labor supply, we have 15 potential locations where we can open a distribution center/warehouse, 200 customers/retails at different locations. While we increase the crude oil price we found we will open more distribution center in order to decrease our operation cost, especially for the transportation cost. In Fig. 7 we have shown the relationship between the number of opened distribution centers and the crude oil prices. In Fig. 8 we have shown the relationship between profits and crude oil prices. From those two above figures we can easily found that as the increase of the

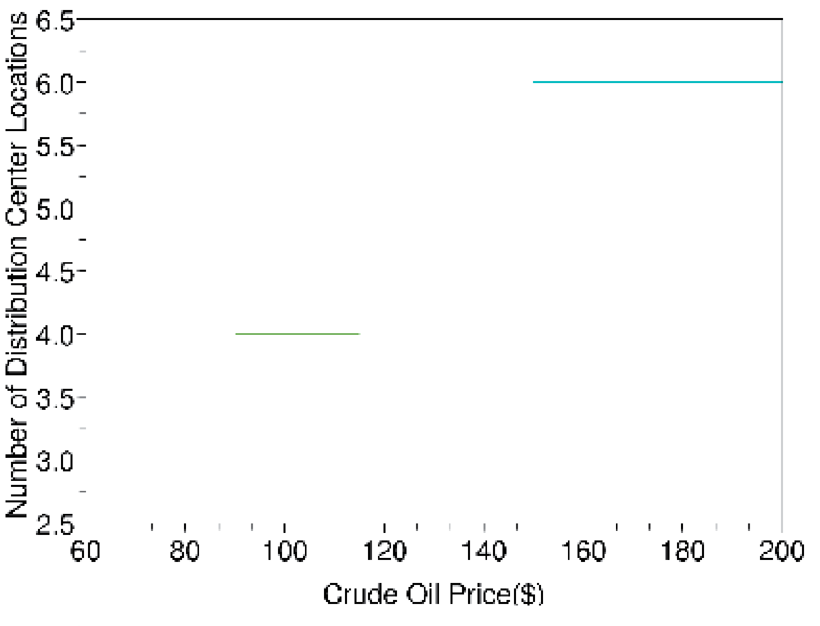


Fig. 7. Number of Distribution Center Locations

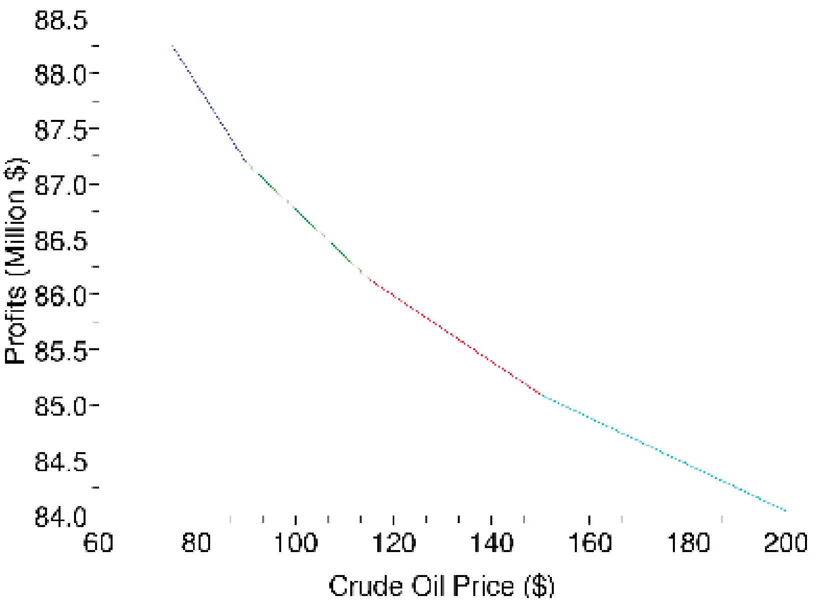


Fig. 8. Profits

prices of crude oil the profits decrease and we will open more distribution center. While we open more distribution center, it will help us to slowdown the decrease of profits.
Since we've considered different transportation modes in model (3). These modes have different transportation capacity and cost, and another key constraint come from different carbon emission. The multiple objective optimization problem, model (3), is transformed as a single objective optimization problem which can be resoled by WIT tool well, and we must balance between profits and emission. A price is suppose for each unit emission, then the minimizing emission problem can be redefined as minimizing cost problem which can be combined with the maximizing profit objective function. As described in Liu et al. (2010), the emission price can be get from the market. WIT tool can be used to optimize this combined optimization problem. Based on the model in Fig. 6, complex model divide each transportation rectangle into multiple rectangles, which correspond different transportation modes. This complex structure exceed the range limit of this paper, and we can describe the differences as follows:

- Each transportation rectangle splits into multiple rectangles which correspond different transportation modes;
- Following Liu et al. (2010), a material called emission is generated by a purchase operation, while each purchase operation has a executing cost corresponding the unit emission price.
- Each transportation operation has a unit executing cost which correspond the total fee from distance and oil price;
- Each transportation operation will consume another material called emission;
- Each product in factory is generated by a manufacture operation which will consume emissions;

With this model, emission constraints can be well integrated in our basic model. Based on the number example above, we suppose there are only two transport mode to move products from the factories to distribution centers and from distribution centers to retailers/customers. While we increase the crude oil price from 75$ to 200$, we can get the following results,

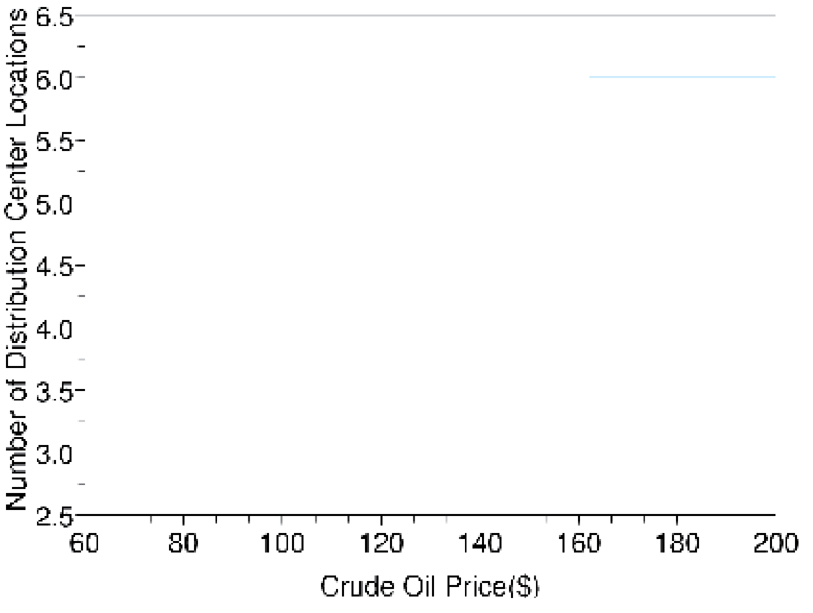


Fig. 9. Number of Distribution Center Locations

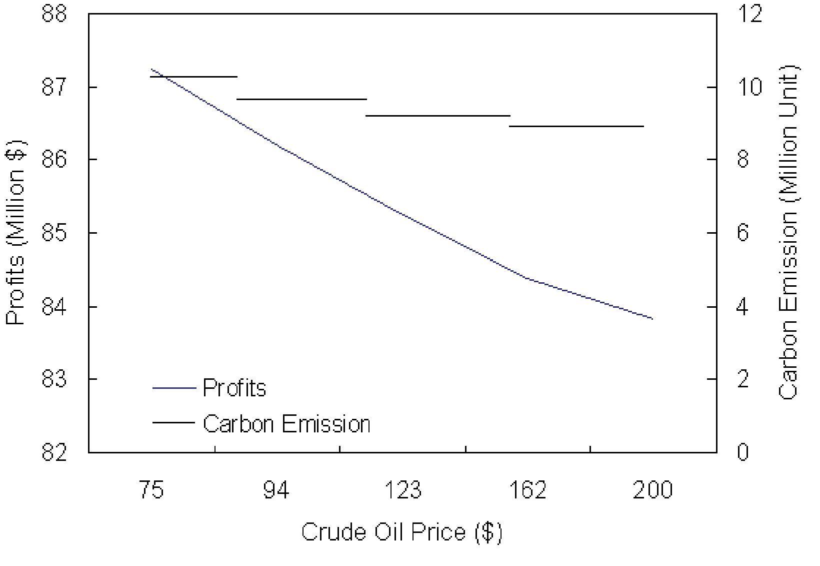


Fig. 10. Profits and Carbon Emission

1. As the crude oil price increasing, we need to open more distribution center in order to decrease the impact on the increase of the transportation cost. Compare Fig. 7 and 9 we know the factor of carbon emission will reduce the impact on the transportation cost of the increase of crude oil prices.
2. As the crude oil price increasing, the profits and the carbon emission will decrease. Compare Fig. 8 and 10 we also can get that the factor of carbon emission will slowdown the decrease of profits. Thanks for opening more distribution center we can decrease the carbon emission to some degree.

4. Conclusion

Location problem is a well established research area within Operations Research (OR). Numerous researchers and engineers have done lots of work for it. The American Mathematical Society (AMS) even created specific codes for location problems. In fact, the problem comes from industries and is created to model real problems in logistics, supply chain, city planning etc. It has played a key role in supply chain management. With the increased environment pollution concerns of people, organizations and governments, enterprises are facing pressure to protect and improve the environment, such as decreasing environment pollution, reducing waste cites and using green raw material etc. Naturally, there come the location problems for green supply chain. The objectives are to improve the performance of supply chain management and to protect the environment.
In this chapter, we firstly reviewed the traditional location problem in supply chain management from the following three views: modelling, solving algorithms and mathematical tools. Then a mathematical model is proposed to describe the distribution center location and transportation mode option for green supply chain. Based on this model, we illustrate the crude oil price impact on the distribution center location and transportation mode option by using IBM Watson Implosion Technology tool. However, there are still several issues to be studied: 1) the product supplying and demands from customer will be influenced by many factors and they always changes especially in developing countries or regions. 2) emissions from each operation are usually estimated in experiments, and more precise method must be proposed.

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16

Traffic Congestion Effects on Supply Chains: Accounting for Behavioral Elements in Planning and Economic Impact Models

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1. Introduction

As traffic volumes and congestion grows on highways and urban roadways, freight and delivery service operators become increasingly challenged to maintain dependable and reliable schedules. This affects supply chains and truck-dependent businesses both of which are of increasing importance for both public policy and private sector operators. From the public perspective, there is a need to make investment, financing and policy decisions based on an understanding of public infrastructure needs, costs and broader economic stakes involved. From the perspective of shippers and carriers, there are the day-to-day cost implications of delay and reliability as it affects supply chain management, and well as a longer-range need to assess opportunities, risks and returns associated with location, production and distribution decisions. Both perspectives need to be recognized when considering the full range of impacts that traffic congestion can have on the economy.

A barrier to considering these two perspectives together is the gap that exists between theoretical simulation modeling and real world observations of business responses to congestion. A review of research literature reveals a number of theoretical models which posit that the generalized growth of traffic congestion adds to total transport costs for delivered products, causing firms to shift location and shipment size configurations to re-optimize net revenues. However, industry publications and business interviews reveal a wider variety of behavioral responses that depend on the type and timing of congestion delays (bottlenecks at specific ports, intermodal facilities, highways or urban road networks) and their frequency, leading to a range of operational responses as a hedge against both expected and unexpected delay. The nature of the affected parties, and the form of operational responses, can vary widely by industry. The impacts can span different supply chain configurations – including not only the movement of material and parts to producers and then to distributors, but also local distribution and delivery of finished goods to retail markets, and even local delivery of parts and repair services to businesses and households. For service-oriented economies, more sophisticated changes in operations – especially those that depend on efficiency of over-the-road operations – can be limited or entirely foreclosed by congestion. In a broad sense, all of these forms of movement have supply chain elements. And they share a common factor, which is that they are very much affected by the degree of of unpredictability and variation in delays associated with growing congestion.

While there is also a separate line of research on bottlenecks at ports, this chapter focuses on the most ubiquitous and fastest growing form of congestion delay, which is that occurring on urban roads and highways. It examines how growing traffic congestion on urban roads and highways leads to delays for the delivery of both goods and services. It also shows how impacts on urban goods delivery and worker commuting can become interrelated. It covers two forms of congestion delay: (1) *recurring daily traffic delay* that occurs as vehicle speeds are reduced and vehicle queues are increased due to a high volume/capacity ratio on specific corridors at specific times, and (2) *non-recurring traffic delay* that occurs when there are incidents such as collisions, medical emergencies and vehicle breakdowns. These two forms of congestion are related, for the same incidents that would cause little delay at off-peak times can lead to substantial traffic backups during peak commuting periods. In addition, rising traffic volume typically increases the frequency of collisions.
Here, we draw on information from business interviews and findings from prior studies conducted by the authors for North American regional organizations in Portland, OR, Vancouver, BC and Chicago, IL, which examined the business and economic implications of alternative scenarios for future growth of traffic congestion. We provide a framework for defining the different forms of impacts that urban traffic congestion can have on various types of supply chains affecting different industries. We then discusses how performance indicators and economic modeling approaches can be applied to better inform industry and transport planners of the broader consequences of growing congestion so that they can take steps to either minimize it or mitigate its adverse consequences.

2. Past research: Traffic congestion impacts on business and the economy

2.1 Transportation literature

Traffic congestion has been defined as "*a condition of traffic delay (i.e., when traffic flow is slowed below reasonable speeds) because the number of vehicles trying to use a road exceeds the design capacity of the traffic network to handle it*." (Weisbrod et al., 2001). Most transportation literature and transportation impact models treat congestion as a cost factor, comprised of time delay and operating expense (Cambridge Systematics, 2008; Short et al., 2010). However, a premium is often added in recognition of the variability aspect of congestion delay that is masked by focusing just on average delay statistics. Indeed, there is also a growing base of research on freight logistics and time-sensitive delivery which attempts to estimate the magnitude of cost premium associated with travel time reliability and the avoidance of delay for this class of travel (Rao & Grenoble, 1991; Small et al., 1997; Cohen & Southworth, 1999; Grant-Muller & Laird, 2006).
Another line of transportation research has highlighted the business productivity impact of growing traffic congestion. A US study laid out a framework for defining congestion and then viewing the ways in which it can affect regional economic competitiveness and growth by nullifying some of the agglomeration benefits (returns to scale) associated with operating a business in larger urban markets (Weisbrod et al, 2001, 2003). More recent work in the UK has shown how urban road traffic congestion, by constraining the benefits of agglomeration, can serve to reduce achievable levels of productivity in congested urban areas (Graham, 2007). However, all of these studies focused at a general level when discussing productivity and accessibility, and none of them investigated the "micro-level" mechanisms by which businesses actually see their productivity eroded by traffic congestion.
Most of the existing research literature on economic costs of urban traffic congestion is at a very broad-brush level, demonstrating that increased congestion can affect business

productivity by increasing operating costs and reducing the size of market areas served from any given business location. However, there is little information beyond that level to explain the ways in which congestion affects different types of freight movement, different types of businesses, or the ways in which businesses can respond to those conditions. These issues and their economic consequences can only be addressed through more detailed micro-level analysis of business processes and business decision-making.

2.2 Supply chain literature

A separate line of research studies on supply chain behavior have used systems dynamics models to show how traffic congestion can change the optimal decisions of producers, distributors and retailers along a supply chain. The most basic impact is that congestion delay and uncertainty increases requirements for (and hence costs of) product inventory (Disney et al., 1997; Mason-Jones et al., 1997). That, in turn, can affect supply chain behavior by encouraging shipment of smaller lot sizes to reduce cost risk (e.g., Moinzadeh et al., 1997). More recent research has extended this beyond delivery lot size, to also affect delivery frequency, spread of deliveries over time of day, and also total trips made per day (Sankaran & Wood, 2007). Surveys of corporate managers confirm that there is a range of ways in which traffic congestion can affect delivery decisions for retail (Fernie et al., 2000) and trucking industries (Golob & Regan, 2003).

Simulation modeling has also been used to show how traffic congestion can lead to fluctuations along a supply chain, as retailers adjust their inventory which in turn "reverberates upstream" via a "bullwhip" effect on inventory requirements for distributors and suppliers (Lee et al., 1997). However, since significant congestion delays may occur on a non-predictable basis, the optimal responses of affected parties may critically depend on both where they are in the supply chain and the probability of occurrence (Wilson, 2008). In the longer run, firms may also change their location decisions to minimize congestion impacts (Guenes & Konur, 2009). Yet most of these studies are based on simulations, and there has been relatively little attention to the question of how business decisions regarding location, scheduling, and deployment of vehicles and labor resources can also contribute to congestion or be used to minimize the effects of rising traffic congestion.

2.3 Public policy perspective

From a business development and economic growth perspective, concern about congestion impacts on supply chain flows is seen as introducing growing risk for maintaining regional competitiveness in a global economy. This risk is magnified as the move from push to pull supply chains depends on tight schedules and reliable performance, both of which can be threatened by flow uncertainty and variation that occurs as congestion grows (Colledge, 2007). As a result, it becomes important to recognize that decisions made by public planners of transportation facilities and business supply chain planners can interact and involve tradeoffs related to congestion. This becomes most critical as failure to adequately address congestion impacts can cause business relocation away from congested areas (see Geunes & Konur, 2009, for discussion of congestion impacts on business location).

These business cost and location issues have raised concern by various regional business organizations about the future viability of critical industries and freight transportation functions in the face of growing traffic congestion. That has led to a number of studies of the business impacts of urban traffic congestion across North America, including three by the authors of this chapter – conducted for the Gateway Council of Vancouver, Canada

(Delcan and Economic Development Research Group, 2003), Chicago Metropolis 2020 (Economic Development Research Group, 2004) and the Portland Business Council and Oregon Business Alliance (Economic Development Research Group, 2005 & 2007).

These studies are notable because they focused on business and economic impacts, emphasizing need to better understand the economic role of freight movement and its sensitivity to rising traffic congestion. In each area, local business organizations helped to bring in the perspective of senior managers who had a history of dealing with transportation and logistics operations. Many of these businesses had long experience in their region, and were able to provide valuable insight into how their operations had adapted to congestion over time. The Vancouver and Chicago studies included meetings with business organization representatives, while the Oregon study included in-person and telephone interviews with executives of the region's largest manufacturers and distributors. These experiences made it possible to better identify and classify the ways in which traffic congestion affects businesses, their locations, operating procedures and freight shipping patterns. Findings are reported in the rest of this chapter.

3. Categorizing facets and mechanisms of business impact

3.1 General model

Using a wide range of business interviews and studies of facilities and corridors with the most impact on business operations, the three studies pointed to a series of ways in which the growth of traffic congestion affects sectors of the economy. A key finding from all three studies is that the consequences of congestion go far beyond just the travel time and travel cost factors associated with delay and reliability. They also include fundamental impacts on the size of business markets, the scheduling of business processes, the deployment of personnel and vehicles, dispersion of business locations and use of intermodal connections. All of these issues bear directly on either the competitive cost of doing business in a region, or the ability to expand business operations to meet the demands of a growing region.

Although there are many ways of categorizing the impacts of congestion on businesses and the metropolitan business environment, we have defined a taxonomy for describing the ways in which congestion can lead to changes affecting businesses and their operations. It is based on seven types of congestion impact: (a) market & fleet size, (b) business & delivery schedules, (c) inventory management, (d) use of intermodal connections, (e) worker travel, (f) business relocation and (g) localized interactions with other activities. Within each of these seven classes, there are broader aspects of impact on business and the economy, as shown in Table 1. These broader impacts affect public policy insofar as they shift the locations, times and scale of business activities and traffic generation. Each of these impact classes is discussed in greater detail later in this section.

These categories of business and economic impact occurs as the logical consequence of a sequence of conditions, which are illustrated by flowchart in Figure 1. The top of the flowchart shows that congestion effects on delay and its uncertainty have four key elements: (1) they have a spatial pattern of occurrence at sites and routes with a high volume/capacity ratio, (2) they add a level of unreliability to travel times that depends on the degree of congestion and extent to which alternative routes are available, (3) they occur with severity that varies by time of day and is usually most severe during peak commuting periods, and (4) they affect different freight modes (and choices among those modes) depending on the extent to which traffic congestion occurs along truck corridors or access routes to major commercial and industrial clusters, seaports, airports or intermodal rail terminals.

Class of Congestion Impact	Implication for Business and the Economy
Market and Fleet Size	delivery area, market scale, fleet size/type, delivery & reliability cost, assignment flexibility
Business & Delivery Schedules	delivery time shifts, truck dispatch, backhaul operations, relief drivers, operating schedules
Intermodal Connections	access to truck/rail/air/sea interchange terminals
Business Inventory and Operations Management	inventory requirements, stocking costs, inventory management/control, cross-docking opportunities
Worker Travel	worker time/expense; worker schedule reliability, service delivery cost
Business Relocation	distribution from smaller, more dispersed locations, consolidation of production sites
Externalities: Interactions with Other Activities	land use & development shifts, costs passed on to workers and customers

Table 1. Seven Classes of Congestion Impact and Potential Business Responses

Those four elements of congestion affect different aspects of business decision-making, as shown in Figure 1. We can view the business decision process as a sequence moving from fundamental long-term decisions to more flexible short-term decisions, as indicated by arrows moving from left to right on the flowchart. One of the most significant long-term decisions made by a firm is the location decision, followed by the scale of operations at that location. Both can involve significant capital investment. Those decisions, in turn, influence business requirements for workers, logistics of incoming materials and production/ inventory technologies. Outputs and final product distribution depends on the efficiency of the ground transport network (including connections to air and sea ports) to serve existing and future markets.

Of course, short-term adjustments to minimize costs of congestion are typically made in an opposite sequence, starting from the easiest to change, shown on the right side of the flowchart -- shifts in fleet deployment, shipment size and delivery schedules. When necessary, businesses can also move to more capital intensive decisions on the left half of the sequence, such as business size, location and operating model. Ultimately, all of these business location and operation decisions can affect broader changes in land use patterns, transportation demand and public infrastructure performance.

The rest of this section provides a more detailed discussion of each of the seven types of congestion impact, and the ways that these congestion effects influence business decisions and the resulting effects on broader regional development. These discussions draw from findings and examples that emerged from the previously-cited regional business studies, as well as research studies by other authors (as cited in Section 2.3). Examples are provided primarily from a detailed set of interviews with corporate executives that were conducted as part of the Oregon study. The overall objective here is not to quantify or measure the severity of these impact elements, but rather to illustrate the wide breadth of different forms of impact that can occur, and the ways in which they interact with other elements of business decisions and public policy.

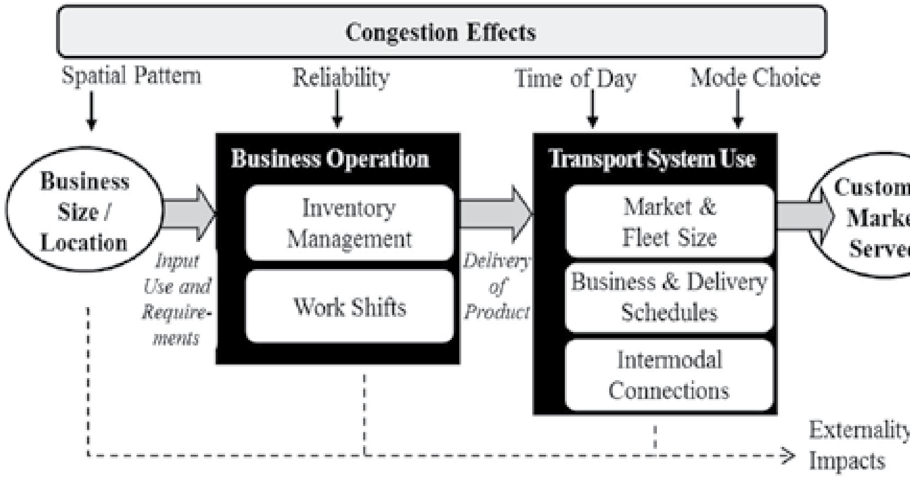

Fig. 1. Conceptual Model of Processes by Which Traffic Congestion Leads to Impacts on Business Activity

3.2 Market & fleet size

Two fundamental decisions for any delivery operation are the market area to be served and the vehicle fleet to serve it. Growth of traffic congestion can affect those decisions and lead to changes in a variety of related cost elements. These impacts can be viewed in terms of: (a) delivery area definition, (b) scale of markets served and (c) fleet size and type of vehicles used. These decisions also affect (d) delivery unit cost, (e) reliability cost and (f) route/ assignment flexibility.

Delivery Area Served - With rising congestion, the time it takes for a truck to get from the warehouse to the first stop/delivery (stem time) has increased in most urbanized areas. In the Portland region, some businesses estimate that it has increased by as much as 50% in the past 8 years. As the peak hour spreads beyond one or two hours, cross-region movements to subsequent delivery stops become more difficult than they have been in the past. In effect, congestion shrinks the delivery area that any one driver and vehicle can serve. This means that there is a need to have more vehicles on the road (to maintain and grow distribution and trucking markets), and routes need to be changed more often. Beyond adding direct driver and vehicle costs, these changes bring added costs for continuing adjustments in scheduling drivers and deliveries.

Market Scale - In addition to increasing the cost of product and service delivery within a core region, the cumulative effects of congestion on the entire distribution network effectively shrinks the boundaries of the area that can be served from any one warehouse or manufacturing plant. This affects the size and dispersion of these facilities, as addressed in the later discussions of business operations (Section 3.5) and business location issues (Section 3.7).

Fleet Size and Vehicle Type - Increasing congestion can mean that it is not possible to make as many deliveries within a shift or delivery run as had been possible in the past. (This was also noted in prior work by Sankaran & Wood, 2007.) The problem is multiplied for distributors of retail products in growing regions, where there are continuing increases in the number of stores to be served. Together, both congestion growth and market growth call for more inventory as well as more drivers and vehicles. The reduction in driver productivity increases costs to distributors, and it adds more trucks and delivery vans to the mix of vehicles already on a region's roads. For many types of product and service deliveries, an increasing number of firms are thus responding to congestion delays by adding smaller and more numerous delivery vehicles and also relocating warehousing and distribution centers to reduce stem times. That solution also provides both flexibility and an enhanced ability to provide rapid delivery of urgent or missed orders. However, it also adds vehicle cost and increases the volume of truck traffic on roads.

Delivery Costs – Congestion directly affects the cost of deploying crews for delivery of products and services. These effects can include labor and fuel costs due to longer truck operating hours, fewer deliveries or completed jobs per crew trip, and/or greater reliance on added truck and van trips when limits are reached on allowable daily hours of service (for individual drivers).

Reliability Costs - Reliable delivery schedules allow for efficient "just-in-time" processing, but delays effectively undo those opportunities for business efficiency. As a result, Oregon businesses with chronic delivery problems reported that they have had to increase inventories by as much as 5% to 8% compared to 5 years ago (Economic Development Research Group, 2007). Studies in other regions have put the figure in the 8% to 11% range (Netherlands survey in Bozuwa & Hoen, 2005), while others have noted it can be as high as 15% (UK study cited in McKinnon, 1999). Of course, wide differences in reliability costs will always occur, as such costs vary by location (reflecting severity of local congestion) and by industry (reflecting sensitivity to congestion delays at peak times).

Flexibility for Route/Shipment Assignment - Many firms are involved in on-going review of routings and have developed methods for "on-the-fly" rerouting or regular adjustment of departure times, loading and preparation of loads for delivery and other measures. However, some firms – particularly those with large, heavy loads moving between established manufacturing operations, do not have the flexibility to make these adjustments. Slower turn-around between plants requires either adding more vehicles to sustain production, adding shifts, or cutbacks in production schedules. Past surveys of trucking companies have confirmed the interest in enhanced routing and scheduling which becomes particularly critical as congestion grows (Golob & Regan, 2003).

3.3 Business & delivery schedules

In theory, businesses can minimize congestion costs by rescheduling deliveries to avoid peak traffic periods, which are principally morning and evening commuting times. However, in practice, various factors can either limit the ability of delivery operations to adjust schedules or add to adjustment costs. These limitations and costs can be viewed in terms of implications associated with changing: (a) afternoon deliveries, (b) shift starts and relief drivers, (c) morning deliveries, (d) backhaul operations, (e) truck dispatch schedules, and (f) business operating schedules.

Reduced Afternoon Deliveries – The growth of PM peak traffic congestion has reduced, and in many cases even eliminated, late afternoon stock/merchandise deliveries in some larger urban areas. It has pushed starting times into the early morning hours for some businesses involved in transportation and distribution. In large cities, a growing number of businesses (irrespective of sector), now face restricted operations after 3 PM. Many transportation and warehousing operations have adjusted scheduling so that most vehicles return to the warehouses or distribution centers by the early afternoon. Most consignees have been able to accommodate these early shipping deadlines into their operations. However, if afternoon congestion trends continue, with the implied shortening of the time window for final outbound shipments, manufacturing and transportation operations could find it difficult to maintain current levels of productivity and current final outbound shipment schedules.

Shift Starts and Relief Drivers – For many transportation and warehousing industries, first shift start times for drivers have been moved to very early in the day – often 4 AM to 6 AM. This is because afternoon congestion has become a problem for firms with scheduled deliveries or routes, and most firms want to avoid overtime pay or violating regulations on truck driving hours. (in the US, hours of service requirements are currently under federal review). Some firms have begun to rely on "rescue drivers" to avoid those situations. In addition, evening swing shifts have been instituted in many warehousing and distribution businesses so that returning trailers can be loaded for the next mornings deliveries.

Increased Morning Deliveries - The shift towards very early morning (4-6 AM) deliveries in the retail sector of some larger cities means that larger stores are sometimes now required to have staff loading and stocking in the very morning (2-3 AM) or during swing shifts. Most retailers and produce consignees are reluctant to allow "drop shipments," especially of perishables or high-value retail merchandize. As a result, some retail businesses need to bring staff in earlier in the morning to receive deliveries, adding to business operating cost and imposing burdens of adjustment on affected workers. Some retailers must also accommodate "push" shipments from manufacturers in situations where improved logistics and manufacturing efficiencies have now made order fulfillment a matter of days.

Backhaul Operations - Backhaul efficiencies are important to many transportation and logistics operations as the ability to support efficient backhauls reduces the number of vehicles, number of operators and time required for normal operations by these firms. Backhaul opportunities and efficiencies are more significantly impacted by afternoon congestion than outbound shipments. Thus, the vulnerability of backhauls to afternoon traffic congestion is also greater. Firms that developed sophisticated routing and logistics management practices integrating backhaul management into their processes have more recently noted increased overtime and the need for "rescue drivers" to conform to the new "hours of operation" requirements.

Backhauls are of growing importance in a number of businesses – not just those involved in commercial distribution and retailing operations. Many businesses with their own fleets that are not in these sectors depend on backhaul operations to support various business activities. In Oregon, for example, Providence Health Systems [PHS] generates significant amounts of recycled materials (surgical and non-surgical), plastics and paper. Collection and recycling of these wastes and potentially toxic materials has depended on backhaul for efficient recovery of recyclables. Congestion during backhaul operations is becoming a growing problem because it limits loading times for the evening delivery cycle. As a result, smaller vehicles in greater numbers are now being used to service evening deliveries to the 29 clinics and hospitals served by PHS. Yet impacts of this type, which put more vehicles on roads, are most often not considered in public decisions about infrastructure investment.

Truck Dispatch Schedules - Truck dispatch times are limited by the ability to prepare and load trailers from the time they arrive in the afternoon to the time that they are scheduled to depart in the early morning. The ability of warehouse operations to assemble loads and stage them for loading in the evening shifts, reposition trailers based on available dock/door capacity and stage trailers for departure is constrained by available time between drop off and whenever trailers with backhaul materials are ready. Increasing the number of trailers on-site is limited by available space and adds costs for redundant equipment. Very early dispatch times also are limited by the ability of businesses to receive goods in early morning hours (e.g., stores in urban areas or manufacturing operations).

Business Operating Schedules – As urban traffic volumes grow, time periods of congestion and associated delay also widen. Delivery operations that start by avoiding the afternoon peak may then move to start shifts earlier in the morning. However, as morning traffic volumes continues to grow in what were traditionally considered shoulder time periods later in the day, available highway capacity limitations start to increasingly affect the operations of businesses that have become dependent on efficiencies of operating in this time period. Ultimately, businesses can experience a shrinking "window of opportunity" to adjust activity schedules and avoid congestion. The combination of avoiding evening peak, experiencing a saturated morning peak and shoulder times that are also operating at capacity can together leave no other feasible time periods to operate and thus result in more serious impacts on the overall scale and cost of business operations.

3.4 Intermodal connections

The impact of congestion delays can be magnified for intermodal freight movements that depend on truck deliveries meeting scheduled connections at: (a) intermodal rail terminals, (b) air cargo terminals or (c) marine terminals. The resulting impacts tend to be concentrated on specific classes of cargo and business locations.

Access to Intermodal Rail Yards and Associated Industrial Park Facilities - Rail yards and rail-dependent industrial parks typically depend on having good truck access. Increasing congestion in core urban areas is a growing concern, as it leads to increasing operating costs and reduced productivity for businesses located at affected industrial parks. This can occur in two ways. First, missed trans-loading schedules add to the time of trucking and unloading crews, and require trucking firms to reschedule their operations. These costs are not immediately recoverable and must be internalized in most businesses as charge-back to missed rail deliveries is not possible. Second, use of broadened pickup and delivery schedules to avoid missed deliveries also carries a cost of vehicle and driver time.

A longer term response being observed in large urban areas such as Chicago is a movement of rail-dependent manufacturing industries to outlying areas, which in turn is also leading railroads to open new intermodal facilities in those same outlying areas. A consequence of this trend is that manufacturing and distribution services are becoming more dispersed, and drays to and from the intermodal facilities are becoming longer. The end result is that there is a growth in total freight vehicles and average distances traveled to support freight intermodal freight movement. This becomes visible as growth in total vehicle-miles (or vehicle-km) of truck traffic.

Access to Air Cargo Terminals - Access to scheduled air cargo services is an important issue for businesses involved with high value cargoes (such as computer chips) and/or time-sensitive cargoes (such as perishables or replacement parts). Access to air cargo services is also important for just-in-time production sites that typically require access to an airport for periodic "emergency" shipments of incoming parts (Hoppin, 2006).

The issue of air freight schedules and capacity is also complicated by access time – especially for those businesses located some distance away from regional airports. Many businesses also rely in inbound shipments from global sources for materials and components involved in manufacturing. Both in-bound and out-bound shipments are consolidated at large airports offering belly capacity or airfreight service at the most competitive costs. Increasingly, time-sensitive imports and exports are being trucked long distances between origin/destination locations and the large international gateway airports. The primary reason for choosing longer and a more costly ground component of the air freight movement is avoidance of congestion (both on major highways and at the airports themselves) occurring at the times that products are ready to ship.

As most air freight is time sensitive, congestion on roads to/from airports can have major economic consequences. For regions served by international air freight gateways, the stakes are even higher, since ground access constraints (caused by traffic congestion) can lead to diversion of demand to other airports further away. While that solution allows businesses to minimize schedule uncertainty, it also comes at a cost of reduced productivity.

The reliance on air-truck transfers makes roadway congestion a particularly critical issue affecting scheduling for international air shipments, such as “high tech” manufacturing that relies on US-Asia production processes. For these shipments, congestion on routes to airports can also affect production schedules. That is because a missed flight can mean loss of inventory and production at the receiving location and the potential imposition of significant cost penalties if production of chip cutting and testing operations is affected.

Congestion on routes to airports also affects business and financial services. For instance, the pickup at overnight courier drop boxes in downtown Vancouver had been moved up two hours, partly in response to growing delay along the congested truck route between downtown Vancouver and its International Airport. Proposals to reduce congestion in major urban areas are focused specifically on addressing these types of problems affecting key freight corridors.

Access to Marine Ports - Major seaports serve as important international gateways for the import and export of goods moving between overseas locations and a broad hinterland. As a result, rail cars and trucks from distances of as far as 1,000 miles or more may converge on port facilities and their access routes. This presents a congestion challenge for ground access routes servicing many major seaports (and was an issue identified in the Oregon and Vancouver studies).

The stakes for trucks delivering containers to port are substantial. A truck that is delayed and misses closing time at the port’s truck gate must wait till the next day. Depending on the day, it is possible that the container may miss its scheduled ship and have to several days or longer to get picked up on another ship heading for that same port. If a driver cannot ensure arrival time early enough to prevent that possibility, then it may be necessary to arrive earlier in the morning or one day earlier. Either way, there can be additional driver and vehicle scheduling, time reservation and operating costs incurred because of the congestion delay uncertainty. Some ports are trying to reduce the severity of this problem by extending their hours of operation at truck gates. Some are also instituting truck reservation systems at their container facilities, to even out the truck arrival times.

3.5 Business inventory and operations management

When schedule and fleet adjustments cannot mitigate rising congestion costs, shipper or consignee operations are likely to be directly affected. This may occur in the form of: (a) increased inventory requirements, (b) added retail stocking costs, (c) added cost of inventory management and control and/or (d) reduced cross docking opportunities.

Increased Inventory - Throughout the 1990s, reductions in inventories increased efficiencies in the manufacturing and transportation sectors. (See Mason-Jones et al., 1997, for a discussion of these efficiencies.) Many economists believe that enhanced inventory management and increasing efficiencies in logistics and supply chain management in that last decade also helped to lengthen economic expansion and moderate business cycle corrections, which were often driven by the need to "work off" excess production and accumulated inventory.

These efficiencies are beginning to erode due to both roadway congestion (on highways) and reduced levels of service at intermodal carriers (primarily major railroads and ocean shipping services). Increased variation in delivery times attributable to congestion, more missed deliveries, and other uncertainties related to maintaining services tied to rail service and maintenance of delivery routes has contributed to keeping more inventory on-hand – both in distribution warehouses and in manufacturing operations.

Most retailers and distributors are faced with rapidly growing inventory management issues. Besides to having to move more of a particular item due increased sales volumes (often with shrinking profit margins), they are also stocking a larger number and greater diversity of items in order to remain competitive with large, "big-box" operators. Increases in volume and mix of products mean space constraints have become critical factors in their ability to serve customers and retail outlets. Inventory management and distribution efficiency are the most important factors in achieving the levels of productivity needed to remain competitive.

Both limited space inside existing warehouses and lack of expansion space encourage just-in-time inventory systems, which are highly dependent on reliable deliveries. Congestion delays can significantly diminish the ability to manage the flow and inventory required in businesses that have rapid inventory turnover. This results in potential lost sales in addition to the costs of managing inventory and receiving emergency, unplanned, or late night/early morning shipments.

Retail Stocking Costs – Many large retail operations depend on high volume sales, especially because margins for competitive retailing operations are constantly being reduced. The primary factors driving higher throughput are the need to offer a greater range of products and the need to provide continuous availability of retail stocks in the face of uncertain delivery delay. Timing of deliveries is critical because it is related to stocking time – the ability to get products on shelves, or from loading docks to in-store storage. Stocking and transfers involving in-store storage often involve shift workers who are at either the beginning or end of their shifts. Delays in receiving deliveries due to highway congestion can result in overtime payments for deliveries at distribution warehouses operated by a retail chain, or in refused deliveries in the case of vendors or third party delivery. In either case, congestion imposes costs that are often unmeasured and unrecognized in traditional modeling or by current cost analysis.

Costs of Inventory Management and Control - Most of the efficiencies in supply chain management over the past decade have been attributable to advances in inventory control and management of materials, components, and finished goods in the supply chain. (Wilson, 2008 illustrates this point by showing how inventory changes can ripple across all elements of a supply chain). Tight inventory controls and accurate accounting for inventory flows are a factor in both achieving profit margins and, arguably, also a factor in the ability of the national and regional economies to weather business cycles.

Squeezing as much efficiency as possible through high levels of automation in warehousing and load management has produced significant efficiencies in warehousing and distribution industries. However, the effects of congestion are eroding the significant progress that has been made in inventory management and warehouse control. Two types of changes appear to be happening simultaneously. First, reductions in labor costs attributable to in-warehouse efficiencies are being absorbed by the costs of the over-the-road operations (more equipment and drivers to deal with congestion and driver hours of service limitations). Second, by re-introducing uncertainty in shipping and receiving attributable to the over-the-road and "last mile" portion of the supply chain system, businesses are forced into looser scheduling , setting lower delivery targets, and adding additional inventory (a reversal of recent trends in lowering inventory) to allow for uncertainty in delivery times.

Impaired Cross-Docking Operations – Congestion impacts are particularly notable for cross-docking operations. Both the efficiency and feasibility of cross-docking operations are tied to the ability of originators to deliver inbound loads within a given window of time needed to reposition loads for outbound customers – typically very early in the morning. Late inbound delivery creates storage and loading problems. As the communications and inventory control infrastructure required to support cross-docking operations becomes more widespread and more critical to improving efficiency and lowering costs of transportation and logistics, delivery reliability will become an even greater issue in the successful adoption of cross-docking in warehouse and logistics management. Insofar as this practice becomes more integrated into transportation and warehousing operations, consideration will be given to locating new facilities in places where congestion is less of a factor in creating uncertainty about delivery times.

3.6 Work shifts

While discussions about optimizing supply chains typically focus on cargo movement, labor is also an input to production processes and a significant component of delivery and distribution services. And in that sense, it can be useful to consider worker travel related costs as part of a broader and more comprehensive view of supply chains. The associated costs may occur as a result of changes in: (a) commuting time and expense, (b) worker schedule reliability or (c) service delivery related travel.

Commuting Time and Expense –Most employers require employees to bear the costs of commuting longer travel times to, from and through congested areas. However, there is also growing evidence that some employers offset some of these higher commuting costs by offering higher wage rates. And yet an even more problematic situation is now occurring –- the change towards earlier start times for shift workers, especially in the warehousing and distribution industries. This is occurring in many congested metropolitan areas to facilitate continued freight operations that rely on over-the-road movements. In some areas, shifts are now being staggered to allow for more efficient operations and these staggered shifts begin as early as 2:00 AM for distribution and warehousing operations attempting to serve areas where congestion is growing. This constitutes a major change in working conditions. In addition, it often reduces the ability of workers to use public transit or ridesharing options, thus representing yet another form of cost increase for workers.

Worker Schedule Reliability - As congestion in larger and rapidly growing metropolitan areas increases, many businesses have noticed an increase in congestion-related delays for scheduled start-times. While such incidental (although increasing) arrival delays can generally be accommodated in service and professional occupations and work environments, it can pose a more serious problems for production, manufacturing and transportation industries.

The costs of start-time delays and arrival reliability are difficult to quantify and have not traditionally posed a noticeable problem for businesses. However, the increasing frequency of start-time delays and the cumulative burdens of congestion on business operations are beginning to focus management attention on all aspects of congestion and its costs for business operations. This trend is illustrated by a recent US national survey of 1,200 construction contractors, which found that 93% of responding firms reported traffic congestion is affecting their operations, 64% reported at least one day of productivity loss per worker annually due to congestion, and 73% reported that congestion adds more than 1% to their total cost of doing business (Associated General Contractors, 2010). While the survey respondents may not be a totally random sample, the results nevertheless underscore the importance of traffic congestion as a source of loss for construction firms.

Service Delivery Related Travel - Increased traffic congestion can also affect vehicle movement during business hours. Such impacts have been reported by larger businesses including utility companies, the insurance industry and major regional-serving businesses such as hospitals and medical facilities. The Oregon study found that business travel between offices, for meetings and for project-related team conferences is also becoming adversely affected by growth in traffic congestion. This has resulted in more “on-the-clock” (employer paid) travel time for senior managers as well as project and departmental staff, and therefore less productive time spent managing and addressing operational issues. While conference calling and virtual meetings are being pressed into service more frequently, each of these options has distinct disadvantages that have become evident with their use over time. Transition from historical multi-site operations for larger, more concentrated operations centers imposes significant costs for businesses, and compounds the commuting time/expense burdens borne by workers in these industries.

3.7 Business location

Site location and expansion decisions typically shift as products, markets, technologies and input requirements evolve over time. As traffic congestion can effectively constrain both labor markets and freight delivery markets, it can also be a factor affecting the location or relocation of both: (a) distribution center sites and (b) production sites.

Relocation of Distribution Centers - Increased travel times that result from congestion can effectively shrink the distribution radius of existing distribution operations, making both existing service and expansion into new regional markets more difficult. In addition, a major factor in providing logistics support outside of a metropolitan area can be the effect of congestion on limiting outbound (morning) truck trips and the timing of afternoon return trips. Afternoon returns, which often include backhauls, can create an overtime/over-hours situation for the drivers involved, thereby increasing costs and reducing productivity for both the vehicles and the drivers. This further cuts into the cost-effectiveness of distribution operations because efficient backhaul management is one aspect of logistics management that traditionally provides competitive advantages to these firms.

As a consequence of these congestion effects, many new warehousing, distribution and transshipment facilities locate far from the metropolitan areas traditionally “home” to such operations. In the New York metropolitan area, warehousing serving the ports of New York and New Jersey are currently operating in central New Jersey. In several regions, major manufacturers and food distribution businesses have located new distribution and warehousing operations further away (as much as 200 miles or 320 km) from the core metro markets in order to remain competitive in serving multiple markets.

Relocation of Production Facilities - The location of production on the part of most manufacturing companies is a complex decision that is based on a unique combination of factors such as labor, materials and markets. However, transportation has historically played a role in these decisions. In the Oregon study, almost all of the businesses interviewed and several of the retailers involved in manufacturing also operate globally – with manufacturing spanning multiple continents and regions of the globe (including Africa and the mid-East). This means that for manufacturers, levels of traffic congestion and the ability of transportation infrastructure to support efficient production processes is an important factor in their decisions about where to locate new product lines, how and where to position various aspects of intermediate and final production, and where they may best serve growing or emerging markets for their products.

3.8 Externalities: Interaction with other activities

As production and distribution activities shift location, partly in response to growth in traffic congestion delay, those decisions also lead to "externality impacts" – i.e., impacts on outside parties including (a) residents of urban areas and (b) workers at affected industries.

Localized Effects of Land Use and New Development - Warehousing has traditionally located at the edge of cities, and it continues to be located in "edge" areas of many urban regions. In regions experiencing population growth, though, firms that originally located in relatively low-density areas in the past may now be facing higher levels of congestion on crowded segments of highways and arterial roads that they depend upon for serving their customers. The result can be not only congestion delay, but also increasing difficulty with access to major arterials (such as turning movements from warehouse gates onto local roadways) due to infill and "densification" in areas that were once semi-rural. Expansion, especially of warehouse and distribution facilities, is often limited both by new and proposed non-commercial land uses and by significantly higher land costs. Using existing facilities with greater intensity may also be limited to the existing footprint for some transportation and warehousing operations.

For manufacturing businesses with regular, high-volume movements between intermediate and final production sites, a series of factors may significantly increase the time needed to move intermediate products, partial assemblies and raw materials. This may occur as a combination of generalized highway system congestion and specific bottlenecks where there is reduced capacity on elements of the arterial roadway system (such as bridges and viaduct underpasses). In some urban areas, especially where older manufacturing sites have been incorporated into new mixed use developments, the associated gentrification and conversion of older and unused warehousing space has combined with traffic congestion to compound delays in routine shipment patterns.

Externalizing Congestion Effects on Workers – As businesses make adjustments to minimize congestion costs (such as shifting hours of operation or site locations), one obvious way that they can "externalize" their costs is by passing on requirements to employees to change their work hours and/or commuting distances. As previously noted, workers asked to shift to early or late work times may find that public transport is unavailable or poorly supported at those times. And when distribution sites are moved to outlying areas, workers may also find that their commute travel times and costs are also increased, while their options for alternative forms of transportation are reduced or eliminated.

While providing adequate alternative transportation is clearly not a traditional role of private businesses, the effects of congestion expansion across the workday, operational decisions required to address the business costs of congestion, and business location decisions can together shift the cost and time burden of maintaining job access to employees. These effects also tend to be most pronounced for longer-term employees who have worked at the same location and in the same industry for many years.

4. Implications for transportation & economic modeling

4.1 Transportation modeling

The preceding discussion, covering seven classes of economic impact, indicates the importance of distinguishing key dimensions of congestion in transportation forecasting and impact models. This includes the composition of affected traffic (distinguishing trucks and service vehicles for supply chain impacts), time of day and spatial pattern of congestion, and effects on intermodal connectivity. There are several key reasons:

- *Time Periods* – Congestion can affect both truck and service delivery travel at specific times of day. For industries that are most affected by congestion delays and schedule unreliability, there are important differences in the extent of their options to modify work shifts and delivery schedules. These options vary by industry depending on abilities to operate and ship during morning, afternoon and/or evening periods.
- *Spatial Patterns of Congestion* – For industries that are most dependent on closely integrated logistics, congestion can affect deployment and use of truck fleets, and that can lead to subsequent changes in the number, location and dispersion of manufacturing and distribution facilities.
- *Intermodal Linkages* – Ultimately, every change in congestion along a segment of the road network is likely to affect access from some areas to airports, marine ports or rail intermodal facilities. Conversely, every change affecting the activity at an airport, marine port or railroad facility is likely to also affect traffic levels on its access routes. Thus, congestion impact analysis calls for an intermodal perspective.

In an attempt to address these key dimensions of impact, all three of the impact studies identified in Section 2.3 (Vancouver, Chicago and Oregon) relied on regional travel demand forecasting systems to assess current and potential future congestion. In each case, the models could distinguish truck movements from car traffic to estimate peak vs. off-peak truck traffic changes and to include intermodal connections. Those analyses were also supplemented by special studies that identified conditions affecting: (a) highway corridors with particularly high levels of truck movement, (b) key rail and truck corridors providing access to industrial zones, and (c) road corridors serving airport, marine port and/or intermodal rail facilities.

4.2 Implications for economic impact modeling

The traffic modeling developed for all three of those studies was used in a transportation economic impact framework now called TREDIS (Transportation Economic Development Impact System). This economic framework incorporates a multi-modal structure that is sensitive to changes in passenger and freight cost, travel time reliability and access conditions by mode and time of day. The access measures include size of labor markets and same-day delivery markets as well as connectivity to intermodal ports, terminals and gateways. Measures of change in transportation system performance and access are applied to information on how various industries rely on different combinations of transportation modes and inter-modal connections for access to supply chain and delivery markets. In this way, changes in modal performance and access conditions lead to different impacts on cost and economic growth opportunities for various industry sectors. (For a summary of TREDIS and discussion of model design policy issues, see Weisbrod, 2008.)

While all three studies required multi-modal analysis, there were very different policy issues in each case. For Chicago, a particularly critical issue was capacity and access for truck movements to rail yards and industrial corridors. For Vancouver, a critical issue was capacity of access routes to seaport and airport facilities. For Portland, Oregon, a critical issue was region-wide truck delivery times for warehousing and distribution facilities. Yet despite differences in local issues, all three cases shared a common need to examine economic impacts of congestion growth, and to do so from a multi-modal perspective.

Another notable element of assessing economic impacts is the ability to distinguish between local-serving industries and "traded industries" (that serve national or international markets). It is important to recognize that even when businesses adjust delivery and worker shift schedules to avoid peak congestion, those activity shifts have some incremental cost for affected businesses. As noted in the Portland report: ". . . *local-serving businesses either absorb added costs and reduce their profits or pass these costs on to people in the region. Trade-oriented businesses though, can and do move their operations to locations outside the region.*" (Economic Development Research Group, 2005, p.10). All three regional studies (Chicago, Vancouver and Oregon) calculated employment and income growth impacts of alternative scenarios involving rates of traffic congestion growth. The estimated impacts calculated by TREDIS varied by industry and over time, but in each region they represented total GDP impacts that are quite substantial – ranging from US $476 million/year in Vancouver to US $2.4 billion/year in Chicago. It is important to note that the variation in impact found in these studies was due to differences in the specific transportation scenarios as well as characteristics of the regional economy and freight infrastructure (sources cited in section 2.3).

5. Conclusion

In examining a range of congestion impacts on supply chains and related business activity, several conclusions arise. First, it is clear that supply chain simulation models based on systems dynamics can be useful to illustrate why congestion delays and uncertainty lead businesses to shift schedules, delivery lot sizes and sometimes even locations. However, the insights provided by interviews and discussions with businesses presented in this chapter show that there can be many more facets of congestion impact and associated change in business organization and behavior beyond those typically identified in such models. Specifically, congestion impacts can go far beyond mere changes in operating cost, to also affect the size and nature of business organizations, production processes and customer markets served. And businesses can have a wide range of responses, depending on the type of affected business activity and the nature of congestion growth.

In this chapter, we described 26 different elements of business impact and response to traffic congestion growth, grouped into seven broad classes. These impact elements are inter-related and they tend to occur as a logical sequence, as illustrated by the conceptual model presented in Section 3.1. They can be important to consider in planning processes, policy development and economic impact analysis models. There are some situations where the economic impacts of traffic congestion can be less than expected because businesses adjust their operations to help mitigate congestion costs. However, in other situations, the economic impacts of traffic congestion can be greater than expected because of additional impacts on workers and on operators of other transport modes. In addition, there are effects on land use and business location patterns -- all of which are unaddressed by models that assess the direct cost impacts of delivery delay. Many of these additional elements of economic impact take place slowly over time and may not be noticed until their consequences are severe (i.e., entire business operations are rescheduled, reconfigured or relocated), at which time it may be too late to reverse business decisions.

Finally, it should also be clear that it can be misleading to focus research and policy attention on the overall incidence and average magnitude of congestion impacts on businesses as a group, since impacts can vary widely depending on the type of affected business activity (location, products or services offered, degree of localization of suppliers and customer base, and modal dependencies) and the nature of local congestion growth (including its severity, spatial and temporal patterns of incidence). In other words, even if only a small fraction of businesses change their fleets, locations or markets in response to congestion growth, the impact can be very important for particular business sectors. This can have significant economic development and public policy implications for some local areas, occupations and industries, especially if these business sectors are those for which future region-wide growth and development are dependent. It can also lead to a much wider and varied set of consequences for regional economies, as demonstrated by the examples of regional economic impact studies. Future policy and planning should consider and account for these distributional consequences.

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Part 4

Sustainability Issues Through the Supply Chain

17

Importance of Reverse Logistics for Retail Acts

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1. Introduction

After 1970 — the energy crisis — the literature began to speak of encompassing logistics materials management and logistics supply production to ensure the efficiency of the procurement of raw materials and production programs were effectively correlated with the market objectives. The participants in the Environment for Europe Ministerial Conference in 1995 adopted a program through which the developed countries agreed to encourage sustainable consumption that translates to the optimum use of resources.

Reverse logistics activities include, collecting useful waste to be returned to the manufacture, purchasing reusable packaging, re-selling components with low wear, the re-sale of consumer goods following refurbishment. In other words, when speaking about reverse logistics we are referring to:

1. a channel conversely, meaning a situation in which a channel or a part of it is designed for the flow of goods or materials moving forward in the opposite direction to the consumer;
2. the many activities being the inverse of transportation, handling, storage that unfolds in reverse channels required for the full use of the products, materials and components throughout the lifecycle;
3. the regulators that are needed to protect the natural environment; they are being increasingly accepted even though this is more than the idea that it would increase the costs of private firms to prevent pollution and to carry out greening actions, thus causing higher prices and decreased competitiveness (Porter & van der Linde, 2008).

As shown by Porter, properly designed environmental standards can stimulate innovations leading to increased resource productivity, thus helping companies become more competitive. The way companies react to environmental problems can be an indicator of their competitiveness, but these rules do not automatically lead to innovations or superior productivity. Companies will realize that successful innovations will benefit (Porter & van der Linde, 2008).

2. Reverse logistics

Logistics is defined by The Council of Logistics Management as the process of planning, implementing and controlling the efficient, cost-effective flow of raw materials, in-process

inventory, finished goods and related information from the point of origin to the point of consumption for the purpose of conforming to customer requirements.
Reverse logistics includes all of the activities that are mentioned in the definition above. The difference is that reverse logistics encompasses all of these activities because they operate in reverse. Therefore, reverse logistics is the process of planning, implementing, and controlling the efficient, cost-effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or for proper disposal.
More precisely, reverse logistics is the process of moving goods from their typical final destination for the purpose of capturing value or proper disposal (Rogers & Tibben-Lembke, 1998). The re-manufacturing and refurbishing activities may also be included in this definition of reverse logistics. Reverse logistics is more than re-using containers and recycling packaging materials. Redesigning packaging to use less material or reducing the energy and pollution from transportation are important activities, but they might be better placed in the realm of "green" logistics. If no goods or materials are being sent "backwards," the activity is probably not a reverse logistics activity. Reverse logistics also includes the processing of returned merchandise caused by damage, seasonal inventory, restock, salvage, recalls and excess inventory. It also includes recycling programs, hazardous material programs, obsolete equipment disposition and asset recovery.
An extended study undertaken in 1998 (Rogers & Tibben-Lembke, 1998) aimed at defining the state of the art in reverse logistics and to determine the trends and best reverse logistics practices. Part of the research charter was to determine the extent of the reverse logistics activity in the U.S.A. Most of the literature examined in preparation for this research emphasized the "green" or environmental aspects of reverse logistics. In this project, green issues were discussed, but the primary focus is on the economic and supply chain issues relating to reverse logistics. The objective was to determine current practices, examine those practices and to develop information surrounding the trends in reverse logistics practices.
To accomplish this task, the research team interviewed over 150 managers that had a responsibility for reverse logistics. Visits were made to firms to examine, firsthand, the reverse logistics processes. Also, a questionnaire was developed and mailed to 1,200 reverse logistics managers. There were 147 undeliverable questionnaires. From among the 1,053 that reached their destinations, 311 usable questionnaires were returned for a 29.53% response rate.

3. Motivators of design for environment-friendly reverse logistics

According to Bras (1997) and Rose (2000), mainly four motivators, involving customers (stakeholders), competition, ISO 14001 system and the most important, legislations, make organizations and corporations more concerned about environment-friendly products and technologies on their own initiatives. The integrated relationship of each factor can be represented in Figure 1. This section provides a brief description of each factor and their impact on a corporation's reverse logistics strategy.
The increasing awareness among customers of the importance of saving the environment will certainly stimulate the corporations to improve their performance in both the green manufacturing procedure and the products design and recycling to satisfy the customer

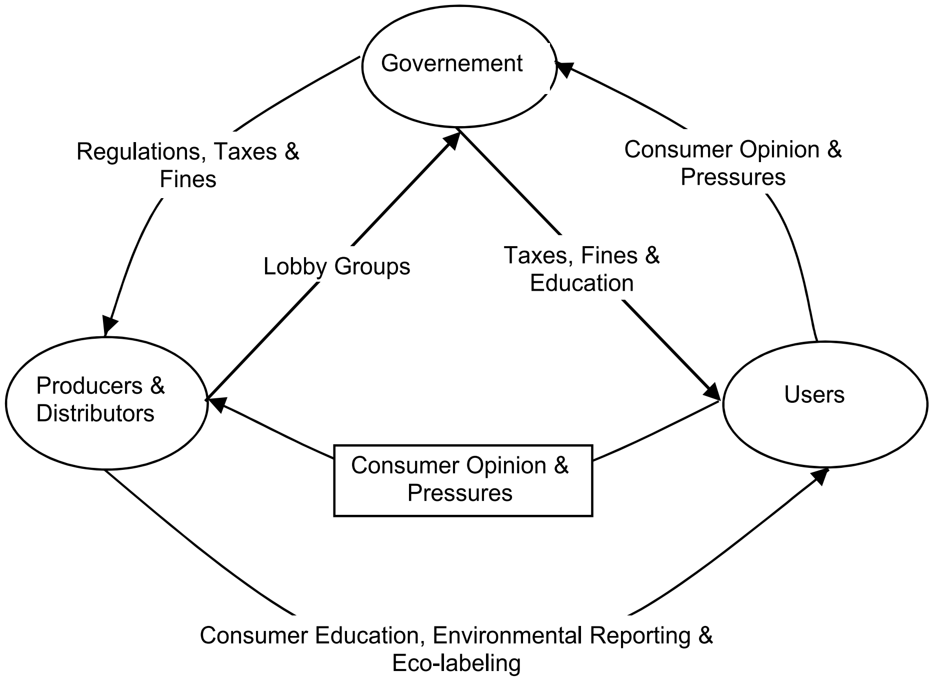

Fig. 1. The Motivators of Design for Reverse Logistics and Their Relationships (Wang, 2008)

demand. The increasingly positive attitudes of consumers on green products, therefore, accelerate the innovation of products and techniques on environmental safety and further stimulate organizations to make designs for a product life-cycle strategy. Another important factor that will influence the consumer's purchasing willingness is the corporations' image, more specifically, the role of the corporation and its contributions for saving the environment. Wal-Mart provided a good example of being publicly boycotted for its un-recyclable products with an environment-friendly label.

Competitors that get ahead in product end-of-life processing will stimulate corporations to make more efforts to recapture the market shares by designing more environment-friendly and recyclable products and processes, and take more responsibilities for the end-of-life products (Rose, 2000). Reverse logistics is a complex and comprehensive system that requires designers to take into account the reusability, disassemble-ability, re-manufacturability, serviceability and recyclability of the returned products. Meanwhile, the marketing, finance, safety, health, functionality and manufacturability aspects should also be considered carefully to obtain a trade-off design for all these factors. Nowadays, many counties have made efforts to improve the reverse logistics using different systems. The EU has made specific regulations for monitoring and inspecting the performances of companies for the treatment and recycling of waste electrical and electronic equipment (WEEE) that has been proved an effective way for implementation. However, the WEEE recycling and disposal in China is facing a dilemma because customers, unwilling to end the life of the products, and the companies doubt the worthiness of an investment in the WEEE recycling system. Through the investigation of two leading Chinese companies in the household appliances industry, Wang (2008) finds that:

1. The financial profit is still the fundamental driving force for companies to integrate reverse logistics into product design process. The management of the companies is reluctant to invest in the programs in which consumers are not interested.
2. The consciousness of the WEEE among the Chinese consumers is still low, which can be proved from their definition of "green" products — low in harm to the healthy people and low energy consumption — which are only a small aspect of environmental protection and are much less than sufficient.
3. The difficulty of a "take-back" is another barrier for a company's initiative to establish a comprehensive reverse logistic system, because they may feel it is not worthwhile investing much on an idle facility.
4. The WEEE reverse logistics design is far too laggard for the innovation in the new EEE in China. Also, Chinese companies are more willing to invest in the improvement of inventory management and customer relationship management rather than obsolete domestic appliances.
5. The Government should play a more active role in encouraging corporations to take more responsibility for the recycling and treatment WEEE, closing down the illegal small warehouses for reselling WEEE after a simple clean and maintenance, and finally, 'propagandizing' the importance of the WEEE recycling and treatment and the harm to the environment caused by illegal recycling.
6. The Haier Co provided a quite new concept — employing sub-contractors to do its take-back, recycling and treatment jobs. This allows it to have sufficient time to estimate the benefits from the reverse logistics and to develop a reverse logistics suitable for its development before investing.
7. There are also some companies that have not even established a WEEE disposal department. This will eventually impact on their export business, because more and more countries have published stricter regulations for companies to take more responsibility for the environment.
8. Integrating reverse logistics into product design, in the long-term view, can shorten the recycling and treatment time and further cut costs.

Supply chain management is the coordination and management of a complex network of activities involved in delivering a finished product to the end-user or customer. All stages of a product's life-cycle will influence a supply chain's environment burden, from resource extraction, to manufacturing, use and reuse, final recycling, or disposal (Zhu et al., 2007). Environmental issues under legislation and directives from customers, especially in the U.S.A., the European Union (EU) and Japan, become an important concern for the manufacturers. As a more systematic and integrated strategy, the Green supply chain management (GSCM) has emerged as an important new innovation that helps organizations develop "win-win" strategies that achieve profit and market share objectives by lowering their environmental risks and impacts, while raising their ecological efficiency.

A research (Zhu, Sarkis, & Lai, 2007) aimed at surveying the current green activities in the computer parts' manufacturers in Thailand and evaluating the green supply chain management. The 11 manufacturers were selected for case studies that provided in-depth interviews about green procurement, green manufacturing, green distribution and/or reverse logistics. Their products or services are related to computer parts that are IC, hard disk drives, power supplies, print circuit boards and monitors. Also, several stakeholders in the EOL electronic parts, used computer stores (second-hand markets), waste collectors (called SaLeng), disassembly/recycle plants and final treatment/landfill companies, are involved. Most of them comply with the WEEE and the Restriction of Hazardous Substances (RoHS) Directive(RoHS) directives to minimize the hazardous or toxic elements in electronic parts[i]. To obtain efficiency and effectiveness in the GSCM, collaboration among the important stakeholders in the electronics industry must be strongly concerned.

4. Reverse logistics activities

Typical reverse logistics activities would be the processes a company uses to collect used, damaged, unwanted (stock balancing returns) or outdated products, in addition to the packaging and shipping materials from the end-user or the reseller. Once a product has been returned to a company, the firm has many disposal options from which to choose. If the product can be returned to the supplier for a full refund, the firm may choose this option first. If the product has not been used, it may be resold to a different customer or it may be sold through an outlet store. If it is not of sufficient quality to be sold through either of these options, it may be sold to a salvage company that will export the product to a foreign market.

If the product cannot be sold "as is" or if the firm can significantly increase the selling price by reconditioning, refurbishing or remanufacturing the product, the firm may perform these activities before selling the product. If the firm does not perform these activities in-house, a third party firm may be contracted or the product can be sold outright to a reconditioning/remanufacturing/refurbishing firm. After performing these activities, the product may be sold as a reconditioned or remanufactured product, but not as new. If the product cannot be reconditioned in any way, because of its poor condition, legal implications or environmental restrictions, the firm will try to dispose of the product for the least cost. Any valuable materials that can be reclaimed will be reclaimed and any other recyclable materials will be removed before the remainder is finally sent to a landfill.

Generally, packaging materials returned to a firm will be reused. Clearly, reusable totes and pallets will be used many times before disposal. Often, damaged totes and pallets can be refurbished and returned to use. This work may be done in-house or by using companies

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[i] While electronic devices have become a way of life for much of the world, their presence have caused adverse effects on the health of many and the environment. We rely on electronics for nearly every aspect of life. They allow us to obtain information easily and they are even used to save lives in hospitals worldwide. However, once these electronic devices become obsolete, their disposal poses extreme health risks due to the hazardous materials commonly found in electronic parts and components. In an effort to fix this problem, the Restriction of Hazardous Substances (RoHS) Directive was created by the European Union and went into effect July 1, 2006.

This directive is intended to regulate toxic materials in electronic devices and electrical systems. In an effort to reduce toxic e-waste and lesson the negative environmental footprint electronic devices have on our planet, the European Union has restricted the use of six materials in electronic parts that are deemed hazardous.

As such, RoHS restricts the use of lead, cadmium, mercury, hexavalent chromium, polybrominated biphenyls and polybrominated diphenyl ether. These restrictions are intended to apply to the production of consumer electronic equipment, appliances, tools, toys and medical devices (http://EzineArticles.com/3940448) whose sole mission is to fix broken pallets and refurbish packaging. Once repairs can no longer be made, the reusable transport packaging must be disposed of. However, before it is sent to a landfill, all salvageable materials will be reclaimed. European firms are required by law to take back transport packaging used for their products. To reduce costs, firms attempt to reuse as much of these materials as possible and reclaim the materials when they can no longer be reused.

4.1 Interest in reverse logistics

Awareness of the art and science of logistics continues to increase. Additionally, great interest in reverse logistics has peaked. Many companies that previously did not devote much time or energy to the management and understanding of reverse logistics have begun to pay attention. These firms are benchmarking return operations with the best-in-the-class operators. Some firms are even becoming ISO certified for their return processes. Third parties specializing in returns have seen a great increase in the demand for their services. Leading-edge companies are recognizing the strategic value of having a reverse logistics management system in place to keep goods on the retail shelf and in the warehouse fresh and in demand (Raicu et.all, 2009). In the case of Romania, the recovery management is limited to the only three products' industries, which are:

1. collecting and recovery of old cars (usual older then 10 years) and parts of them, following some stages of reverse logistics process;
2. collecting and recovery of electronics and electrics products;
3. packaging waste recovering.

For the first products category, the Public Authority supports the fixed cost of car recovery from the public budget and the financial program is well-known as "crock" program. There are some recovery centres, and all stages of the reverse management are accomplished by private operators. The second products category is periodically collected, in front of the final user's house. The obligation for providing location of the recovery centres is on the Public Administrative Authority at local level. According to the Romanian Government Resolution no.448/ 2005, every county has to provide at least one recovery centre for electronics and electrical equipment; as well as each of the city having more then 100,000 inhabitants. In Bucharest, the minimum number of such centre is at least six, one for each of the administrative sector. The producers and distributors support all the involved costs for all reverse management activities.

Besides these product types for the recovery there are no other initiative for materials which still have usage value. Moreover, there is no planning measure to reserve some space for the purpose of the recovery centre settlements into the outskirts of the new urban areas.

4.2 Return percentages

The reverse logistics process can be broken down into two general areas, depending on whether the reverse flow consists primarily of products or primarily of packaging. For product returns, a high percentage is represented by customer returns. Overall customer returns are estimated to be approximately 6% across all retailers. Return percentages for selected industries are shown in the following table. In each case, return percentages were established by several different firms.

Industry	*Percent*
Magazine Publishing	50%
Book Publishers	20–30%
Book Distributors	10–20%
Greeting Cards	20–30%
Catalog Retailers	18–35%
Electronic Distributors	10–12%
Computer Manufacturers	10–20%
CD-ROMs	18–25%
Printers	4–8%
Mail Order Computer Manufacturers	2–5%
Mass Merchandisers	4–15%
Auto Industry (Parts)	4–6%
Consumer Electronics	4–5%
Household Chemicals	2–3%

Table 1. Sample Return Percentages (Rogers & Tibben-Lembke, 1998)

Clearly, return rates vary significantly by industry. For many industries, learning to manage the reverse flow is of prime importance.

5. Reverse logistics – component of environmental sustainability

There are three main principles in sustainable development:

- environmental sustainability, ensuring a tolerable development for all essential ecological processes, especially the diversity of biological resources
- social and cultural sustainability, which guarantees a favourable economic development, members of society, culture and values compatible with the existing culture and civilization, to preserve community identities
- economic sustainability, having a role in ensuring efficient economic development, resources are handled so that it also will exist in the future.

Reverse Logistics is the process of disposing of used products or a new initial point of the supply chain, such as the customer returns, overstock, expired food, also redistributing them using specific rules to collect their management. Reverse logistics refers to recoverable material components after consumption, waste and packaging, which go on backward, from the consumer production that is incorporated into a new economic cycle. Reverse logistics supposes some extra handling operations, which involve certain circuits', and also specific charges for the reception from consumers, sorting, loading and unloading. In attempting to design a total system of distribution, logistics specialists have traditionally approached the distribution process, starting with the manufacturer and the product flow from the producer to the consumer. It is well known that, during accelerated economic growth periods, as emergent economies have known, the urban settlements go to the fringe, creating huge residential areas. These are acquiring in time (in a nonregular environment) new spatial functions such as commercial, educational and social ones. Some of them are set up simultaneously with the residential development stage. This kind of real estate evolution is presented in the recent development of Bucharest suburbs.

The following two types of residential areas rising up in suburbs are distinguished:

- low density zones, with lodgings like villas, having large space and high income inhabitants;
- high density zones, with lodgings on many levels, usually four or eight levels, having large flat surface and inhabitants with high income, at least greater than the average income of the city's inhabitants (Raicu et.all, 2009).

Making a reverse logistics process for a company or a product is very difficult, especially because, in many cases, there is no systematic plan of distribution. In addition, many products reach the retailer and consumer brand identity without any product or provider. Locating these products and sending them back to the producer is a very costly process. Products may be withdrawn by a company for a variety of reasons, poor packaging, improper labeling or delivery methods resulting in improper alteration and contamination. The level of urgency of the withdrawal depends on several factors, most importantly, the gravity product risk.

Three different levels can be identified, depending on the level of penetration of the product in the system. At the first level, the product is still under the manufacturer's control, the deposits under its control or primary distributor warehouses. At this level, the location and recovery of a product is a logistics specialist for the simple matter of rebuilding the stock. At the second level, the product should be located and removed from the intermediaries involved in the product distribution — the wholesalers and retailers. Withdrawal, in this case, becomes a little more difficult. At the third level, the product is in the hands of the consumer. Here, we reach the highest level of difficulty.

6. Opportunities for sustainable management of reverse logistics

Many companies realize that there are large amounts of money that can be recovered by returning the goods. A large number of companies have developed this "recall" business. Logistics service providers have found that up to 7% of company sales are embedded in the cost of the return. This figure is hard to imagine because, as part of the answer, they provide reverse logistics applications worth between US$50,000 and US$500,000 dollars for a single license for a location.

Logistics companies made between 12 and 15% profit from this industry. One of these companies is represented by Unyson, whose CEO, Mr Donald Matlby, explains how companies can do more business if they apply the reverse logistics process. Unyson manages products returned, destroyed (in whole or in part) and the registration of each product defects in a specially-designed transport network on the Internet. This allows an in-transit visibility absolute return, while the returns are forwarded to the center or distribution center to be discarded or repaired. A company that has a logistics service provider can create his own internal platform returns, but its cost may exceed US$1 million.

Another way to get your 'money-back-returns' policy is enforced by the company Bed, Bath & Beyond, which pays much attention to their clients so that they remained loyal to the company's products. BB & B accept products returned by customers who consider them inadequate without further explanation being required. Products will be replaced or a credit will be given to customers buying in other company stores. The return process begins when a customer, vendor, dealer or manufacturer finds something inappropriate in a product (expired, damaged, broken or wet). This finding needs to initiate a response, through

automated processes already established, to determine fault, return the transport, also the eventually physical process of redistribution or recycling and the final payment to the client.
The idea of reverse logistics and return can be difficult, expensive and time-consuming for everyone involved, manufacturers, retailers and consumers. As an example, the Romanian Ministry of Finance announced on a press release that the European Commission, on 4 May 2011, has approved the introduction of reverse charge mechanism for domestic supply of the following products: corn; wheat; rye; sunflower; barley; sugar beet; soya and two-row barley.
The measure has to be further approved by the Council of the European Union, and will enter into force 10 days after such approval. The vendors' and suppliers' aim is to reduce the total cost, while increasing the supply chain visibility, through a management program using the Internet. A company monitoring their returns may reduce between 15 to 30% of loans granted by the correction process. And those savings can be even more significant. Shipping and handling costs may be partially or entirely eliminated by consolidating and also optimizing the delivery, in particular, the elimination of non-returnable products or materials that would be discarded before being loaded into the truck for the long journey home.

7. Threats for reverse logistics due to global instability

The network of facilities, processes and people involved in procurement of raw materials, production, distribution and related information flow are integrated in one complex chain.
However, the consumer is not always the end of the chain and, a return flow of products should be added to forward flow into a closed loop supply chain.
Products that have failed, recalled products or obsolete ones, spare parts that still have some value, waste that must be disposed of and even unsold products become subject of take bake system, as the the responsibility for them shifts back to the producer. Suppliers and producers are facing new and complex challenges determined by several factors:

- Increasing competition in a global environment. Companies adopt more flexible sales policies and agree to take back unsold products from retailers.
- Consumer awareness on companies and their products environmental footprint.
- Legal constraints. Original manufacturer is now responsible for final disposal of the product.
- Shortening product life cycles. Products become obsolete more quickly and returns increase.

There are important characteristics that need to be managed in order to ensure an economically viable reverse supply chain, listed by Blumberg: uncertain flow of materials, diversity of returned products depending on the specific customer, time, value improvement, flexibility of the supply chain, coordination between multiple parties involved into the returning process.
When both forward and backward system are controlled by one company the result is a closed loop supply chain with positive effects on reducing costs of returns, transportation, warehouse expenses and time.
Beyond their choice between compliance with minimum legal requirements and adopt a pro-active green behavior, companies are facing their utmost challenge: survive the global financial crisis.

Aberdeen Group researches propose a holistic approach, integrating supply chain management and financial management of the company through sales and operation planning, in an attempt to resolve complex challenges and changes of global environment. They identify strategies for managing complexity within Global Supply Chains, and define best companies in terms of successful and operations planning and their core capabilities. The capabilities of best-in-class companies are: employees understanding the business strategy, products and processes, high level reporting designed for executive management, ability to consider previous results with regard to forecast accuracy and inventory, capability to express sales and operations planning in terms of revenues and margins. Research group considers key performance criteria to distinguish the best- in- class companies with regard to a successful sales and operations planning :forecast accuracy, complete and on-time orders delivered to customers, decreased cash- to- cash cycle, gross profit margins.

The most companies in best class category are focusing on holistic consideration of supply, demand and finance.

Capgemini Consulting conducted in 2009 a survey on 300 companies reflecting the impact of economic crisis on the activities and projects that supply chain mangers will execute in the coming period. On top of the list are inventory optimization projects, followed by supply chain strategy and improve planning and supply chain visibility projects.

The focus of strategic actions has shifted in 2010 versus 2009 from inventory decrease to management of volatile demand and integrating the financial planning and budgeting process with the sales and operations planning.

Global market and recent effect of economic crisis impose changing the traditional supply chain network required to become more flexible and organized to deliver smaller and more frequent orders. More flexible supply chain could imply adapting manufacturing and packaging process for point of sale customization , outsourcing , regionalization of distribution network and horizontal integration.

Global market in which consumers seek on-demand goods and services can determine breakdowns in complex supply chain management. Consequently, companies should pay closer attention to business environment and asses risks associated with both suppliers and customers. Moreover, global instability and pressure to cut cost can lead to increased risk of supply chain disruptions.

8. Reverse logistics as a strategic weapon

When companies think about strategic variables, they are contemplating business elements that have a long-term bottom line impact. Strategic variables must be managed for the viability of the firm. They are more than just tactical or operational responses to a problem or a situation. Not long ago, the only strategic variables a firm was likely to emphasize were business functions, such as finance or marketing. During the late 1970s and 1980s, some forward thinking companies began to view their logistics capabilities as strategic. Although more and more firms have begun to view their ability to take back material through the supply chain as an important capability, the majority of these firms have not yet decided to emphasize reverse logistics as a strategic variable.

There is no question that the handling of reverse logistics challenges is an essential, strategic capability. In a celebrated case a few years ago, the McNeil Laboratories division of Johnson & Johnson experienced a very serious threat when someone poisoned several people by placing cyanide inside unopened bottles of Tylenol, a Johnson & Johnson flagship product. This horrible act happened twice in the space of a few years. The second time, Johnson & Johnson was prepared with a fine-tuned reverse logistics system and immediately cleansed the channel of any possibly tainted product. Because Johnson & Johnson acted so quickly and competently, a mere three days after the crisis, McNeil Laboratories experienced an all-time record sales day. Undoubtedly, the public would not have responded so positively had Johnson & Johnson not been able to quickly and efficiently handle its recalled product in reverse through its existing system. Clearly, the Tylenol incident is an extreme example, but it illustrates how reverse logistics capabilities can be strategic and how they can dramatically impact the firm.

Another example of how reverse logistics can be used by retailers as a strategic variable is by keeping the consumer product fresh and interesting. According to a quotation from Dan Eisenhuth, executive vice president for asset recovery at the GENCO Distribution System, "Retailers used to liquidate to compensate for 'screw-ups'. Today they do it to stay fresh". The most important asset a retail store has is its retail space. To maximize the profit per square foot of selling space, stores have to keep the fresh goods visible. Grocery stores, with razor-thin profits of one to two per cent, realized long ago that it is critical to keep on the shelf only those products that will sell. Supermarkets have to turn over their inventories frequently to prevent spoilage loss and to maximize the return on their space. Now, non-grocery retailers have begun to adapt supermarket ideas to their own businesses.

Grocery retailers started building reclamation centers in the 1970s. These reclamation centers were places where old and non-selling products would be sent. In many instances, reclamation centers would be attached to a store. Later on, supermarket chains began shipping obsolete or bad product to one central reclamation center for processing. Reverse logistics is strategically used to allow forward channel participants — such as retailers and wholesalers — to reduce the risk of buying products that may not be "hot selling" items. For example, a record company developed a program to adjust return rates for various products depending on variables such as name recognition of the individual recording artist. This program produces a win-win environment for both the producer and the retailer, not to mention the consumer, who gets a broader selection. The program gives the company the ability to develop new artist franchises. Had the record company not implemented this program, its retailers would likely be willing to only carry "sure-thing" products.

Another example of the strategic use of returns is the electronic distributor that, during a period of volatile memory chip prices, created a program to help reseller's better control their inventory and balance stocks. By allowing resellers to return anything within a reasonable time frame, customers were encouraged to keep inventory low and make purchases just-in-time. Strategic uses of reverse logistics capabilities increase the switching costs of changing suppliers. A goal of almost every business is to lock customers in so that they will not move to another supplier. There are many ways to develop linkages that make it difficult and unprofitable for customers to switch to another supplier. An important service a supplier can offer to its customers is the ability to take back unsold or defective merchandise quickly and credit the customers in a timely manner.

If retailers today do not have a strategic vision of reverse logistics, it is likely that they will be in trouble tomorrow. Retailers in high-return categories — such as catalogs, toys and electronics — can easily go out of business if they do not have a strong reverse logistics program. Given the competitive pressure on the North American retailers, the bottom line contributions provided by good reverse logistics programs are important for the firms' overall profitability.

Role	*Percentage*
Competitive Reasons	65.2%
Clean Channel	33.4%
Legal Disposal Issues	28.9%
Recapture Value	27.5%
Recover Assets	26.5%
Protect Margin	18.4%

Table 2. Strategic Role of Returns (Rogers & Tibben-Lembke, 1998)

For more than one mass merchandiser included in the research, the bottom line impact of good reverse logistics was large. Another large retailer found that 25% of the profit of the entire firm was derived from its reverse logistics improvements during its initial phase. In this research project, the research team examined several ways that reverse logistics could be used in a strategic manner. These strategic uses of reverse logistics are presented in Table 2.

8.1 Competitive reasons

Research respondents stated they initiated reverse logistics as a strategic variable for competitive reasons. Most retailers and manufacturers have liberalized their return policies over the last few years owing to competitive pressures. While the trend towards the liberalization of the return policies has begun to shift a little, firms still believe that a satisfied customer is their most important asset. A part of satisfying customers involves taking back their unwanted products or products that the customers believe do not meet their needs. Generally, customers who believe that an item does not meet their needs will return it, regardless of whether it functions properly or not. In an interesting example of this behavior, one retailer recently reported the return of two Ouija boards. Ouija boards are children's toys that, supposedly, allow contact with the spirit world. On one Ouija board, there was a note describing that it did not work because "… no matter how hard we tried, we could not get any good answers from the 'other side'…" The other Ouija board returner said that the reason for return was, "too many spirits responded to the Ouija board session and things became too scary". In both cases, the consumers were allowed to return these "defective" products. These competitive pressures appear to be, in large part, cultural. North American consumers and businesses are much quicker to return goods than those in most other countries. In fact, in many other countries, returns are never allowed. Some of the international managers and academics interviewed in the course of this research believed that if liberal returns were ever allowed in their country, both businesses and consumers would abuse them. However, it is clear that, in some countries, business return models are moving closer to the North American models. Over the next few years, it is likely that international firms will feel a strong pressure to liberalize their return policies and improve their reverse logistics capabilities.

8.2 Good corporate citizenship

Another set of competitive reasons is those that distinguish a firm doing well for other people. Some firms will use their reverse logistics capabilities for altruistic reasons, such as philanthropy. For example, Hanna Andersson, a US$50 million direct retailer of infants and toddlers clothes, developed a program called Hannadowns. In the Hannadowns program, customers are asked to mail back their children's gently worn Hanna Andersson clothes. The company then will give those customers 20% off the purchase price of new Hanna Andersson clothes. For Hanna Andersson, this program has been very successful. In 1996, 133,000 garments and accessories were returned. These returns were then distributed to schools, homeless shelters and other charities.

In a second example, a shoe manufacturer and retailer, Kenneth Cole Productions, encourages consumers to return old shoes to Kenneth Cole stores during the month of February. In return for bringing in an old pair of shoes, the customer receives a 20% discount on a new pair of Kenneth Cole shoes.

In Figure 2, an advertisement for the Kenneth Cole shoe donation program is depicted. This program has been very successful in providing shoes to those in need. Nike also encourages consumers to bring their used shoes back to the store where they were purchased. These shoes are shipped back to Nike, where they are shredded and made into basketball courts and running tracks. Instead of giving consumer discounts, like Andersson or Kenneth Cole, Nike donates the material to make basketball courts and donates funds to help build and maintain those courts. Managing these unnecessary reverse flows is costly. However, these activities enhance the value of the brand and are a marketing incentive to purchase their products.

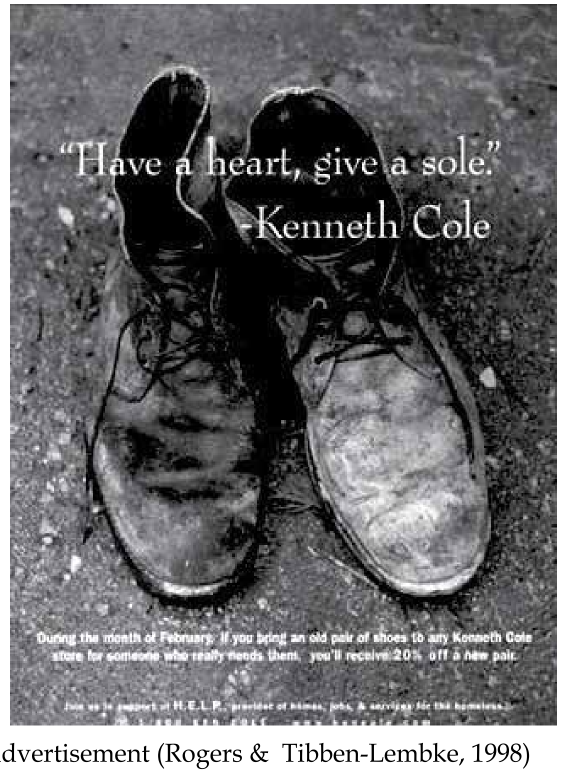

Fig. 2. Shoe Return Advertisement (Rogers & Tibben-Lembke, 1998)

Firms are using reverse logistics strategically. They are acting as good corporate citizens by contributing to the good of the community and assisting people who are probably less fortunate than their typical customers. While these policies may not be the reason all customers purchase their products, they are considered a marketing incentive. It is using reverse logistics to not just be environmentally friendly, but to promote customers at a real cost to their businesses.

8.3 Clean channel

Reverse logistics competencies are also used to clean out customer inventories, so that those same customers can purchase more new goods. Auto companies have fairly liberal return policies in place and a large reverse logistics network that allows them to bring back parts and components from their dealers. These parts are often remanufactured, so that value is reclaimed. If new parts held by the dealer are not selling well, the auto companies will give the dealers a generous return allowance, so that they can buy new parts that they really need, and therefore, better service the ultimate consumer. Most auto dealers, and many dealers in other industries, are family-based businesses with limited supplies of capital to invest in inventories. They often have less than state-of-the-art inventory management capabilities. It is in the best interest of the parts suppliers to clean out these inventories, reduce credit-line constraints and improve customer satisfaction.

8.4 Protect margin

Nearly 20% of the firms included in the research use their reverse logistics capabilities to protect their margins. This strategic usage of reverse logistics is closely related to "cleaning out the channel". Firms cleanse their inventories and the inventories of their customers and their customers' customers by using reverse logistics processes. Some firms are proactive in their management of the downstream inventory, as opposed to merely being reactive. These firms have programs in place that maximize inventory freshness. Fresher inventories can demand better prices, which in turn, protect the margin. While many companies have yet to recognize the strategic potential of efficient reverse logistics, it is clear that the tide is beginning to turn. There is more interest in reverse logistics now than ever before. Firms are beginning to make serious investments in their reverse logistics systems and organizations. One clear indication of the strategic importance of a business element is the amount of money spent on managing that element. Given the volume of returned products experienced in some industries, it is not surprising that the firms in those industries consider returns a strategic and core competency. It appears likely that companies in industries that generally do not place much value on good reverse logistics practices, will, over the next few years, find that making investments in their return systems will enhance their profitability. It is clear that for many firms, excellent reverse logistics practices add considerably to their bottom line.

One of the difficulties in managing returns is the difference in the objectives of the manufacturers and retailers. The distance between them on many issues can make the difference seem like a chasm. Whenever a retailer wants to return an item, the retailer and the manufacturer may disagree on any one of the following:

- condition of the item
- value of the item
- timeliness of the response.

Often, from the retailer's perspective, every product was sent back in pristine condition and any damages must have occurred in transit or must be manufacturing defects. The manufacturer may suspect the retailer of abusing the return privileges because of poor planning or of returning a product damaged by the retailer.

Once the condition of the item is agreed upon, the value that the retailer should receive must be determined. The retailer may claim full credit and the manufacturer may have a dozen reasons why it should not receive full credit. These issues can be difficult to sort out. After they have all been decided, the refund never comes quickly enough to suit the retailer.

Retailer returns to the supplier are a method of reducing inventories near the end of a quarter. Retailers may suddenly move material back to the supplier, or at least notify the supplier that they are going to do so, and negotiate the details later. For similar reasons, manufacturers can be slow to recognize returns as a subtraction from sales. They may want to delay returns until a later accounting period or they may not want to credit the returned items at the full price. Sometimes, the retailer simply deducts the cost of the items from an invoice. Often, that invoice is not the same one for the goods being returned.

In the end, both parties need to realize that they have to develop a working partnership to derive mutual benefits. Obviously, neither one can live without the other; they need to work together to reduce the number of returns coming back and speed up the processing of those that do come back. Inefficiencies that lengthen the time for processing returns cause harm to both firms.

8.5 Zero returns

A number of firms are experimenting with zero returns programs. In a zero returns program, the manufacturer never again takes possession of a product once it has been sold. The retailer takes the responsibility for the exhibited product in accordance with the manufacturer's stipulations. In return, the retailer receives a payment that is intended to reimburse him for the cost of the returned items and for exhibiting the product. By removing the need to handle the returns, the manufacturer expects to save enough costs to more than offset the increased payments to the retailer.

Under some zero returns programs, the store always receives a credit for a certain percentage of sales, no matter how high the return rate. If the credit is 6%, and the actual returns are only 2%, the retailer is happy, because it still receives a 6% credit. When the opposite happens, the credit is set at 2%, and returns are 6%, the retailer loses. The idea behind the program is that the credit will be set high enough to exceed the average returns experienced by the retailer. However, given the power held by the large retailer chains, it can be difficult for the manufacturer to prevail against the retailer in this situation. Unfortunately, given the lax controls that many firms keep over their returns, the controls over zero returns programs are lacking. Some manufacturers accuse retailers of "double-dipping", taking payment from the manufacturer for destroying the product and then quietly selling the product out the back door to a secondary market firm.

8.6 Reverse logistics strategies

Depending on the life cycle of a manufacturer's products and the value of the products, firms will discover that different combinations of the above strategies will be needed to effectively and efficiently handle their returns. For high-value products with short life-cycles, such as computers, video games and camcorders, a POS system may be a very efficient way for retailers and manufacturers to reduce the costs of fraudulent returns. However, the cost of the POS registration may make it difficult for many items to be managed in this manner. For example, the cost to track an individual low cost item, such as a pair of jeans, would probably prohibit using the POS registration.

Appropriate regulations, innovation-friendly and well designed should meet the following principles:

- Focus on results, not on technology
- Implementation of strict, not lax rules
- Regulations should be applied close to the end user, encouraging upstream solutions
- The staged use of commercial incentives
- Harmonization of regulations or convergence-associated domains
- Development of regulations with other countries at the same time or slightly before them
- The regulator should be more stable and predictable
- Soliciting at the outset of the companies involved in setting standards
- Developing technical expertise in the regulatory bodies
- Reduce time and resources consumed in the regulatory process (Porter & van der Linde, 2008).

Field	Countries with laws REP
Packagings	More than 30 countries (Brazil, Peru, Uruguay, China, South Korea, Taiwan, Japan, Czech Republic, Germany, Netherlands, Sweden, Hungary, Poland and so on)
Electrical and electronic	More than twelve countries (Belgium, Netherlands, Denmark, Sweden, Norway, Portugal, Italy, Switzerland, Germany - voluntary, China, South Korea, Taiwan, Japan, Brazil)
Vehicles	Netherlands, Denmark, Sweden, Germany, France, Japan, Taiwan, Brazil
Ready-made clothes	Sweden, Finland, Brazil, South Korea, Taiwan, Uruguay - Optional
Batteries	More than 15 countries (Austria, Germany, Netherlands, Norway, Brazil, Japan, Taiwan, Uruguay - voluntary measures, and so on)

Table 3. Countries where there are laws on "extended producer responsibility" for some areas (State of the World 2004, Worldwatch Institute)

9. The best-known product recycling programs in Romania

Depending on length, there are several types of distribution channels. Figure 3 shows a complex distribution channel in which there are more than two intermediary links between the producer and the consumer.

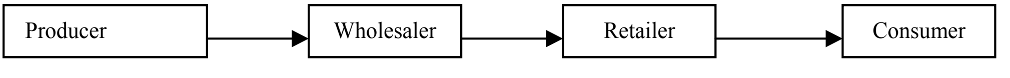

Fig. 3. A distribution channel

Reverse supply can be carried out on the same channel or a different one with one, several or no intermediaries between the customers and the producer. An effective method for collecting waste proved to be the granting of reductions by stores to customers who were bringing in various items (TV sets, refrigerators, phones, glass, PET bottles, and so on), also, the government was involved in such an action, through the program "Rabla" [ii]. One of the challenges that companies collecting recyclable products have encountered, together with the attention to environmental protection and the realization of projects without too high costs, was how to stimulate and encourage customers to bring in the goods that they no longer use. Thus, in Romania, the foundations for ideas on collecting various goods have been set.

At a press conference held in March 2011 at the Auchan hypermarket in Pitesti, the launching of a major ecologic campaign to recover PET bottles, entitled "Recycle and win", was announced. Adriana Gândilă (2011) said that this action, intended to be useful to all customers, was launched by Auchan Romania in collaboration with Greentech and Ropeco Bucharest. Thus, all the inhabitants from Pitesti were invited to bring to the Auchan store all the PETs that they did not need. They would then receive a voucher that could be used for shopping in the hypermarket. At the shop entrance, the device collecting the PETs was located near customer service, together with its instructions for use. Customers needed only to introduce the plastic bottle into a special orifice where it would scan the barcode on the bottle label to identify it. For each container, they would receive a shopping voucher worth 0.60 lei. The PET bottles collected by the machine would be recycled by the Greentech Company from Buzău.

Orange is another big player in Romania introducing a recycling program. This company allows customers with the Buy-Back service, even if they do not belong to the mobile network, to bring in the old telephone when buying a new one, a laptop or any other product available for purchase in the store. In exchange for the old telephone, the customer would receive a coupon with a value between 10 and 190 euros, depending on the terminal. The amount would be granted after analyzing the functionality of the device and could be used in Orange shops. Also, this company brings an online assessment service for the owned mobile telephone. Thus, from home, the client will know the value of his telephone. But if the telephone does not work or if the coupon value is too low, the customer could always bring it in top Orange stores for recycling. The conditions imposed in the regulation were:

- the client could bring in up to five telephones in one calendar year
- Orange has the right to exclude certain telephone models from the list
- the coupon is valid 15 days from the issuance date
- for a single transaction up to three coupons can be used, at least two of which must be issued in the name of the participant.

The Buy-Back Service was launched in Romania (Adriana Dahtide, 2010) in accordance with the initiative of the Orange-France Telecom to offer protection for telephones through the Orange Care program. In Bucharest, on 19 November 2010, the Environ Association, together with the District 1 City Hall and Romprest, started the campaign "Drive away the ghosts of old electronics". Approximately 2325 kg of WEEE were obtained in only three months through this program (Environ, 2007).

[ii] English translation of the program is „The crock", and encourage the population to get rid of the old car, against value coupons to be used for purchase of a new car.

Environ Association guarantees, through its contractual partners, to achieve the highest standards of treatment and environmentally-sound disposal of waste electrical and electronic equipment (WEEE). The processes quality management system, the technical facilities with the most modern recycling installation, are essential attributes of recycling facilities in operation by Remat Holding, Stena DTM and GREEN WEEE.
Since 19 March, another recycling program called "Waste place is not in the house" was started. This currently operates only in Bucharest and the surrounding areas. Any customer may change the old TV for a new one and enjoy a discount up to 15% from large distributors in the market. The NGOs responsible for the collection of waste have launched programs to recycle old appliances. No matter the brand or whether or not they are working, the discount is obtained on the spot. The Romanian Recycling Association has also developed a program through which Romanians can send all electrical and electronic appliances to the recycling centers. Based on a receipt issued, they may receive a discount of up to 25% when buying a TV, refrigerator, washing machine or other appliance.

Recyclable materials	Largest companies
Plastic/glass/paper	Greentech
Electronic and household appliances/batteries	GreenWEEE
Metals	Groups Remat/ Rematholding
Light bulbs	Recolamp
Packaging	Eco-Rom Ambalaje

Table 4. The largest companies who recycle in Romania (Source: author)

Greentech SA is one of the largest plastic recycling companies in the Southeast of Europe and the pioneer of plastic waste recycling in Romania. It is present in every city in this country. It is a private company and was founded in September 2002. Through specific production procedures, Greentech SA is converting the plastic waste in raw materials for different applications. Processing consists of different stages, sorting, crushing, washing with hot water and special cleaning solutions, drying, pelletizing and packing into big-bags (Greentech, 2007).
Eco-Rom Ambalaje was founded in 2003. The founding members are, Argus, Ball Packaging Europe, Chipita Romania, Coca-Cola HBC Romania, Heineken, Mars Romania, Munplast, Pepsi Americas, Romaqua Group Borsec, Tetrapak, Unilever and Titan. Eco-Rom is the market leader of takeovers from economic agents of the obligation for recycling and selling packaging waste. The model is inspired by the European Union, where, on the basic products packaging, is printed a green dot — a symbol of the company dealing with recycling. In Romania, Eco-Rom makes certain that the companies they represent meet their collection and recycling obligations (Ecorom Ambalaje, 2003). Monthly, it receives from each company the amount of money for the quantity of waste that is put on the market. The proceeds are further invested in the collection system, transport and the recycling of packaging waste.
The mission of REMATHOLDING is to take over and efficiently process the scrap to protect the environment. For its collaborators, this company transports a wide range of scrap

(ferrous, non-ferrous, board and paper, hazardous waste, and so on), with a modern fleet (Rematholding, 2003). The EMS (Environmental Management System) is an approach, a tool, a set of procedures, a planned and organized way of doing things to manage an organization's interaction with the environment (Ionescu, Andreea, the SEPIC project). An EMS is like any other planning and implementing management system for continuous improvement. The same basic steps apply to enterprise management, production line management, commuting to work management or even economic development management. The EMS goes through the steps of a classical model of planning and implementation built in a spiral of continuous improvement. Using this model, an enterprise systematically examines its own activities, sets environmental objectives and targets a better environmental performance and implements environmental management programs or projects to achieve its goals. The EMS is integrated into the overall enterprise management system.

There are five key steps to ISO 14001 EMS implementation (ISO 14001, 2009):

1. Environmental Policy
2. Planning
3. Implementation and Operation
4. Checking and Corrective Action
5. Management Review.

After discussing the research results with experts and manufacturers, some important suggestions were concluded, among the most important were:

- Promote Ecodesign: Ecodesign is an activity that integrates the environmental aspects into product designs and developments. The integrated activities lead to continual improvements in the environmental performance of the entire product through technological innovations. Developing environmentally-friendly products causes a change in the product design, using two principles, (1) a design to extend the lifetime of product; it can be improved, repaired and re-used in products such as modular design and, (2) a design for recycling/design for disassembly after the end-of-life products, so that more can be recovered.
- Control hazardous substances, complying with RoHS and other regulations
- Set rules for disposing of electronics waste and consider more investments in recycling plants
- Propagate GSCM knowledge and encourage the use of environmentally-friendly goods
- Set a directly-responsible unit to take charge of only the electronics waste, which will increase the reverse logistics efficiency
- Promote the refurbishing and recycling through campaigns/activities to raise the reuse/recycle awareness in electronics consumption
- Expand product lifespan by designing for disassembly or upgrading computer specifications instead of buying new ones or using computer rental services
- Set a database unit to collect and record information about the production, import/export data and waste management (do traceability)
- Encourage team building and train skilled laborers for reverse logistics management
- Raise the applications in Extended Producer Responsibility (EPR). EPR is an environmental protection strategy based on the "polluter pays" principle, by making the manufacturer of the product responsible for the entire life-cycle of the product and the packaging they produce

- Promote Product Service System (PSS): services and product-service combinations are recognized as a potentially powerful concept for sustainable developments. A product-service system (PSS) is a new trend that has the potential to minimize the environmental impacts of both the production and consumption. Thus, more traditional material-intensive ways of product usage are replaced by the possibility for fulfilling the consumers' needs through the provision of more de-materialized services.

9.1 The limitation of chapter's research

The number of sample companies is too small and the data collected are too little. However, it reflects the predicament of the current Romanian household appliances industries, because the manufacturers are criticized for the lack of a special recycling department and also face the risks of wasted financial resources. Also, companies can cooperate with each other to set up one common recycling center for pooling all of their end-of-life products and sharing the experiences on reverse logistic product design. Future research should be focusing on how to stimulate and encourage consumers to take back their end-of-life products rather than leave them in the corner.

9.2 Further study

Further study needs to concentrate on the practical possibility for implementing a legislation method, for example, WEEE Directives and RoHS Directives in Romania, and what will be the reflections.

10. Conclusion

While much of the world does not yet care about the reverse flow of products, many firms have begun to realize that reverse logistics is an important and often strategic part of their business mission. There is much money being made and saved by bright managers who are focused on improving the reverse logistics processes in their company. It is clear that, while sometimes it derisively referred to as junk, much value can be reclaimed cost-effectively. While the efficient handling and disposition of returned products is unlikely to be the primary reason upon which a firm competes, it can make a competitive difference.

In Romania, such programs are beginning to expand. It also important to note that Romanian consumers realize the importance of having such programs and of cooperating with the authorities and companies that collect recyclable materials. However, besides its own interest in protecting the environment, the consumer wants to have an immediate benefit (preferably a financial one). Auchan and Orange were the first stores in Romania to have launched such projects, but the Government was the promoter of this idea, through the "jalopy" for cars.

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18

Addressing Sustainability Issues Through Enhanced Supply-Chain Management

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1. Introduction

A search on Google for 'sustainable Supply-Chain Management' (SCM) gives 15 000 000 results. 'Green supply-chain management' has even more. Both topics are addressed in numerous international and national publications. Already in 2001 the Sigma Report from the UK examined the fundamentals of sustainable supply-chain management and the challenges for its further expansion[1]. The UN secretariat explored the issues further in its report on "Industrial Development for the 21st century"[2]. A report by the World Bank discussed the situation of suppliers in developing countries[3]. The UN Global Compact[4] has prepared a 'tool kit' for corporations to facilitate the application of sustainable SCM. Many publications of the World Business Council for Sustainable Development stress the importance of sustainable supply chains in developing forward-looking corporate strategies. Business journals regularly feature articles on SCM and its relationship to corporate social responsibility (CSR).

After a decade of promotion and producing motivational material on sustainable supply chain management, it is now opportune to review the state of its application. And as the sustainability agenda is not standing still we should also discuss how supply chain management links to new thinking behind the concepts of value-chains, life-cycle management, sustainable consumption, and corporate social responsibility. We outline some factors that would assist SCM in contributing to the sustainability agenda. In particular a more holistic framework for sustainable SCM will be needed in future, in the same way that environmental management systems arose to overcome the earlier fragmented approach to solving pollution problems.

Why should SCM consider issues of sustainability? Quite simply because many of the challenges faced by companies have their genesis in the operating practices of sub-contractors and suppliers, whether this relates to chemical content, labour practices, or impact on communities and habitats. And the political agenda has moved on; it is no longer accepted that we blame someone upstream for deficiencies in the products we put on the market, nor for the environmental impacts may they have caused there. By building

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[1] http://www.projectsigma.co.uk/RnDStreams/RD_supply_chain_strategy.pdf
[2] http://www.un.org/esa/sustdev/publications/industrial_development/full_report.pdf
[3] http://siteresources.worldbank.org/INTPSD/Resources/CSR/Strengthening_Implementatio.pdf
[4] http://www.unglobalcompact.org/Issues/supply_chain/guidance_material.html.

sustainability criteria into its purchasing practices a company is taking a preventive approach that translates into lower liability risks and greater operating efficiency, and increasingly also into innovative product development.

Many companies have already oriented their future strategic approach around the sustainability agenda. A recent article in the Harvard Business Review[5] included it as one of the 'mega trends' that are here to stay. Supply-chain management exerts its influence over various parts of the life cycle of materials and products. It can thus be a powerful lever to enhance sustainability performance across all services, products and processes in which a company directly or indirectly engages.

For SCM to do this however it has to expand its reach as well as incorporating additional performance parameters. 'Supply-chain' traditionally refers to the sources of raw materials and components coming into the production plant. The more recent and broader concept of 'value chain' includes all points and activities directly related to a company's products, from the extraction of raw materials through to processing, manufacturing, distribution, and sale. Importantly, it includes the consumption phase (of products, materials, services…), and the eventual recovery, recycling and disposal at the end of the product life. Value chain is also a wider notion than the conventional concept of 'life cycle' which is usually employed to communicate to clients and other stakeholders the environmental footprint of a single product. Much discussion on product life-cycles has a technical or political connotation of materials and energy flows, and is not always linked with options of corporate decision-making. The value-chain framework leads to a reconsideration of how supply-chain management can contribute more strongly to the sustainability initiatives being pursued within the company. Fig. 1 below shows the relationship between some of the key concepts.

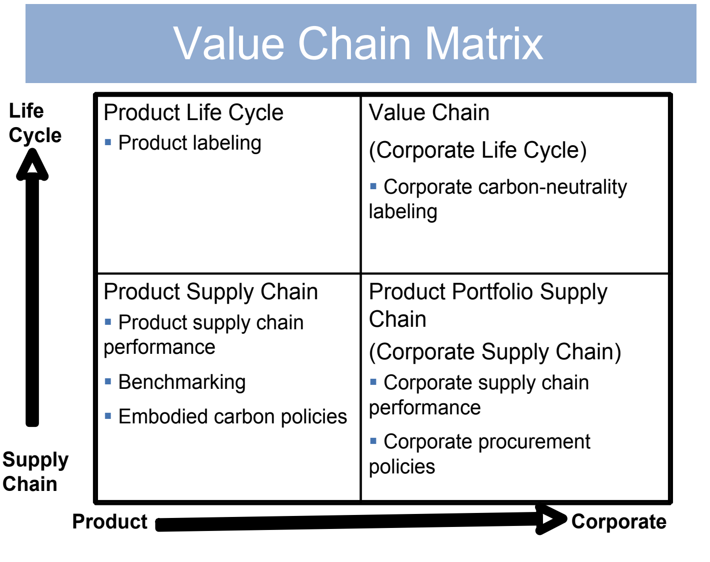

Fig. 1. Value Chain Matrix

In promoting a greening of the supply chain, there remains in some minds the question 'why do it'? We will see that by addressing sustainability issues via supply chain

[5] http://hbr.org/2010/05/the-sustainability-imperative/ar/pr

management it becomes easier for the company to implement its corporate sustainability programme, to reduce potential environmental and social liabilities, and to facilitate future product development and marketing. In short, environmental and social compliance is easier and cheaper where the supply-chain is more closely linked to corporate sustainability policy. There is of course a cost in doing this – it leads to more complex SCM, requires additional training of company and suppliers' staff, more extensive monitoring and tracking, and more time spent in developing closer relationships with suppliers and clients. The experience of most big companies is that the benefits outweigh the costs.

2. Background to sustainability issues

2.1 What is meant by sustainability?

In 1987 the Brundtland Report[6] defined sustainable development as a form of societal progress that satisfies current aspirations while simultaneously protecting the needs of future generations. While our future quality of life depends on an adequate protection of environment and natural resources, sustainable development also considers in equal measure social and economic criteria. Putting this simple concept into practice has occupied the governmental and business communities for over two decades, including negotiations at major international meetings of heads of state[7]. At these venues key partners – including the business sector - were encouraged to reformulate their activities along 'sustainable' lines.

Despite regular references to 'win-win' strategies, optimising simultaneously our environment, social and economic progress requires some compromises, increasingly so as we deal with local issues. Along the way the meaning of 'sustainability' has been defined in a host of different and sometimes incompatible ways, sometimes to a point where it has almost lost its original meaning. In this chapter we will be referring to the key issues identified by various leadership organizations at national and international levels and as included in major global initiatives, agreements and conventions. Thus the United Nations Environment Programme (UNEP) has defined key sustainability challenges concerned with an environmental point of view (Fig. 2). The complete sustainability agenda also includes social and human rights issues. In its outreach to the business sector, the UN Global Compact[8] has defined nine major issues in four categories (human rights, labour rights, environment, anti-corruption) on which it invites a business response from global and national companies.

For industry, preoccupied with costs, profitability and workplace issues the sustainability agenda may seem far removed from immediate concerns. In part this is due to the language used in international fora. A closer look shows that many issues – but hiding under other names – are already serious concerns for managers. Many companies face land-use conflicts over plant location and resource extraction in environments of high conservationism value. Polluted water must be cleaned before it can be used in manufacturing processes (and of course discharged after use). Occupational safety and health requires serious attention everywhere. Companies have been known to go out of business due to chemical contamination they were unable to control. Importantly, environmental management has understood that the company is no longer an isolated entity – actions of upstream suppliers

[6] http://en.wikipedia.org/wiki/Our_Common_Future
[7] http://en.wikipedia.org/wiki/Earth_Summit and http://www.un.org/jsummit/
[8] www.unglobalcompact.org

can also affect regulatory compliance, pollution liability and reputation damage to the company.

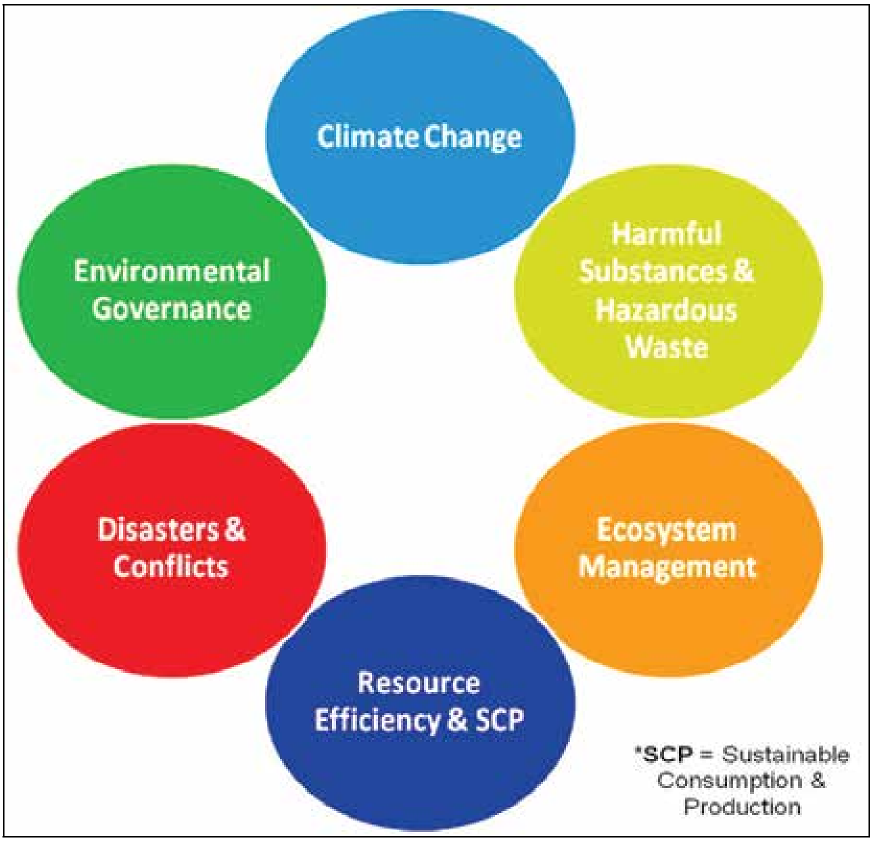

Fig. 2. UNEP's midterm strategic priorities

Addressing impacts after they have been allowed to occur is expensive compared with avoiding them from the outset. Experience has shown that 'upstream, preventive' action is cheaper (and more effective) than crisis control and remediation. Sustainability programmes now almost always embrace the use of management approaches such as cleaner production, pollution prevention, eco-efficiency, green productivity, life cycle management and so on. These approaches all depend on two common factors: (i) preventive action to avoid wastes, pollution and other impacts from being generated in the first place, and (ii) a focus on the entire value chain since many interventions need to occur well before the manufacturing steps (eg in product design, raw material selection, transport, packaging etc). This latter aspect extends to the consumption-side issues of efficiency in use, recycling and of end-of-life disposal.

2.2 What has been the response to the sustainability agenda?

There is an increasing trend in companies to adopt sustainability policies, and to integrate wider social factors into business strategies. "Shared values" was the term used in a recent publication (Porter, 2011). For instance the Lafarge cement company[9] says "…..we have identified our most significant sustainability issues. Addressing these issues is essential for maintaining our legitimacy to operate. In areas such as emissions control, industrial ecology and recycling, sustainability also helps drive efficiency and competitiveness." When groups of companies are faced with the same problem(s) there have also been attempts to develop sector-wide sustainability codes and principles.

While governments[10] are still grappling with the complexity of transforming preventive, up-stream approaches into regulations (Gunningham et al., 2004), industry - often in partnership with other organisations - has moved ahead to develop and implement management systems and tools and sometimes redefined its product lines. It has found that in the same way that 'add-on' pollution controls are inefficient, so is add-on sustainability management. The best results occur when the entire company and all its procedures embrace the sustainability objectives as set by corporate policy. The mobilisation of the company's production and marketing sections to this end has not always been easy, especially in bigger corporations, but there are enough examples to show how it works. Since both the 'upstream' and the 'value-chain' elements are invoked in such sustainability management it is not difficult to see why further development of traditional supply-chain management is one of the key elements in implementation (Füssler et al., 2004).

Ensuring that all parts of a company pull together in a co-ordinated fashion usually requires a formal management system, commonly of the type ISO 14000[11], most recently accompanied also by ISO 26000 on Corporate Social Responsibility. The (sustainability) objectives and targets that underpin these management systems are either separately enunciated or else encapsulated in CSR statements. Such self-adopted standards may also be influenced by various voluntary industry codes that groups of companies have prepared. While few governments make corporate management systems mandatory, financing institutions and investment bodies increasingly require companies to have in place visible systems for managing sustainability issues. Even between industries the mandating of the use of such systems is becoming common. Large companies often require suppliers and contractors to have certified environmental and other management systems in place at the same level as the parent company.

At the operational level companies (and some governments) use a range of environmental instruments and tools to give effect to their standards. In particular, there is increasing use of assessment procedures such as environment impact assessment, life cycle assessment, chemicals risk assessment, social impact assessment, etc. all of which help an organization to look into the future and predict what sustainability issues and impacts may be attached to a product or process. This assists not only in achieving 'cleaner operations' but also the planning for more sustainable products, services and operations. For example at the level of product conception, the use of Product-Service Systems (PSS), eco-design and eco-labelling is becoming increasingly common. At the manufacturing stage extensive monitoring of supply chains and operations ensures that sustainability principles are efficiently (and

[9] http://www.lafargenorthamerica.com/Lafarge_sustainable_development-Sustainable_report_2009.pdf
[10] http://www.oecd.org/dataoecd/18/39/33947759.pdf
[11] http://www.iso.org/

effectively) applied. Most major companies put in place pollution prevention programmes, energy efficiency, water saving, as well as work-place and public safety initiatives.

Companies may also practise various forms of green purchasing for their raw materials and operational supplies, or engage in types of 'offset' activities by purchasing carbon or other environmental credits. Major distribution chains such as Ikea, Walmart, Tesco and others now have stringent requirements on certain substances that must not be included in products, e.g. chlorine-free for Ikea, low embedded energy for Walmart. Others, especially food retailers (e.g. Tesco in the UK and Monoprix in France), have put emphasis also on ethical and/or locally produced food, as do many individual product brands, of which Max Haavelar (see for more details below) is perhaps the best known. Most major retailers now require that no child or prison labour be used in the supply-chain of the products they offer.

Some go further, for example, in 2000 Carrefour worked with the Fédération Internationale des Droits de l'Homme, a group of more than 100 human rights organizations from around the world, to establish INFAS, a monitoring agency to help Carrefour have a code of conduct for its suppliers. The purpose of the code was to commit the company's suppliers to recognize and respect international standards regarding working conditions set out in various conventions of the International Labour Organisation (ILO) with regard to the abolition of child labour and forced labour, freedom of association and collective bargaining, etc. According to CSR Europe[12] the basic goal was to contribute to the gradual and total elimination of child labour while respecting cultural diversity.

A number of green supply concepts are also employed by governments, either in their own activities or by way of a statutory requirement on operators. Companies are constrained by increasingly tight environmental and safety standards to reduce the level of environmental impact of operations but of their products. Authorities are also involved in various forms of supply-chain management such as green government purchasing, setting targets for recycled material content, and promoting ecologically based products such as organic food. An interesting example is the US government requirement that electronic products must now not only be free of ozone depleting substances (ODS) but that even the manufacture of the products did not involve the use of ODS as for example as solvents. Some countries now ban the use of certain toxic substances such as cadmium or persistent organic pollutants (so-called POPs) in consumer and industrial products, placing the onus on manufacturers to ensure that their suppliers do not incorporate these chemicals.

3. Supply-chain management and the value chain

3.1 Supply-chain management as a management activity

The value-chain spans the entire upstream-downstream progression from raw materials through manufacturing to the final product, including its use and eventual recovery or disposal.

Traditional supply chain management has an important place in this progression. For convenience we can consider the following five basic components of SCM[13]:

1. Plan — Companies need a strategy for managing all the resources needed for their product or service. A big piece of SCM planning is developing metrics to monitor the various aspects of the supply chain.

[12] www.csreurope.org

[13] http://www.cio.com/article/40940/Supply_Chain_Management_Definition_and_Solution

2. Source — Companies must choose suppliers and create metrics for monitoring and improving also the relationships and managing their goods and services inventory.
3. Make — Companies need to schedule the activities necessary for production, testing, packaging and preparation for delivery. This is the most metric-intensive portion of the supply chain—one where companies are able to measure quality levels, production output and worker productivity.
4. Deliver — This is the logistics, to coordinate the receipt of orders, storage, transport and delivery
5. Return — This can be a problematic part of the supply chain for many companies. Planners have to create a responsive network for return of defective and excess products and increasingly, end-of-life products.

In the context of a corporate sustainability objective, 'managing all the resources needed' takes on a new meaning. Suddenly additional criteria become relevant in the choice of materials and suppliers. But it is important to not regard sustainability merely as a constraint or some form of restrictive operating framework for companies. Careful choice of incoming raw materials also improves efficiency, avoids pollution problems and cuts manufacturing costs, as well as reducing subsequent product liability risks. Many sustainability issues give rise to new business opportunities when properly managed, as for example the increased market for organic food, higher efficiency appliances, newer materials and energy technologies. Incorporation of social and environmental issues also makes the company less vulnerable in an uncertain and fast-changing commercial world. Pro-active supply-chain management can help to identify and implement these opportunities in addition to its traditional role of addressing cost and quality.

What is the impact of responsible sourcing, environmental sustainability and the "green" movement on the supply chain? If the technological side of supply chain management was not hard enough, the new corporate social responsibility movement inside 21st century organizations adds another layer of complexity. Broadly defined, CSR initiatives for companies include such strategies as being able to show environmental sustainability (eg. reducing the carbon footprint), responsible sourcing from a wide range of global suppliers, and how "green" an organization is. So how does that affect supply chain management? In order to prove that a company has lowed its carbon emissions, is not dumping hazardous materials into rivers and doesn't buy its materials from suppliers that employ underage workers, company leaders need to be able to gain insight into and track the actions of their suppliers, and their suppliers and their suppliers—all the way down the chain into some good and not-so-good parts of the global economy. This ability also becomes critical when tainted goods need to be identified and found quickly in a supply chain, before the goods spread throughout a country's population[14].

3.2 Green supply-chain management

In the two decades following the Brundtland Report, environmental and social parameters have still often been overlooked in SCM in many industry sectors despite the increasing prominence of corporate social responsibility programmes.

In an attempt to redress this situation a number of initiatives in what can be loosely called "green supply chain management" have sprung up in recent years. The driving force comes

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[14]http://www.cio.com/article/40940/Supply_Chain_Management_Definition_and_Solutions?page=5#scm_green

from two different directions. The first is from the environmental movement (including government ministries) as it looks for new instruments to help implement sustainability policies in public life. This constituency stresses the environmental outcomes rather than the business benefits, but the end-result is still a business issue. For example, government legislation on recycled content of products such as paper is deemed to be beneficial for the environment and changes market conditions in favour of companies that can modify their processes to incorporate paper scrap. Governments and environmental groups promote 'green purchasing' as a way of moving the environmental agenda forward, with some successes, but also some limits[15].

The second and possibly now more major force is from business itself. Many companies have found a commercial reason to green their value chains, exposed as they are to regulatory and consumer pressure in environmentally aware societies. This applies especially to retail and consumer distribution chains. Major retailers such as those mentioned above Walmart, Carrefour, Tesco, Ikea, Monoprix and also others are offering customers a choice of 'green' products, and are increasingly applying sustainability criteria to their entire product range. The outcome for their suppliers is a modification not only of the composition of the components of their products (e.g. free of toxic chemicals), but perhaps also to change the type of product completely. This latter factor may well lead to the selection of an entirely different supplier who can better meet both criteria.

According to the New York Times[16], Walmart is now examining the environmental footprint of the products it distributes. While there is a special focus on energy efficiency, other sustainability factors such as water are also considered. The initiative is not directly reflected in the price of the goods, rather Walmart is aiming to gain sustainability respectability with its broad customer base. As it has the purchasing power, it is establishing a de-facto industry standard for others to follow. The company has a sophisticated assessment and identification scheme that informs its purchasing department about selecting appropriate products and suppliers.

IKEA[17] markets low-cost home furnishing products that try to impact on the environment as little as possible and are produced in a socially responsible way. IKEA's Code of Conduct outlines minimum demands on its 1,600 suppliers in connection with social, environmental and work-related conditions. The use of life-cycle thinking ensures that the company is abreast of development trends and at the same time contributes to a sustainable development for IKEA itself and for its suppliers. Supply chain management factors include resource use, sustainable forestry practices and training for employees.

Related to the above is the increasing trend to form consumer groups around green purchasing, green procurement, equitable commerce etc. These initiatives[18] are often not at the same level of sophistication as corporate SCM, but the objectives are similar – the inclusion of sustainability principles in the provision of goods and services. Their reach can be quite large. 'Equitable producer' systems have grown up as a result of these purchasing initiatives. Whatever the configuration of these systems, the conscientious end-user is exerting an influence all the way up the supply-chain to the primary producer via a variety of intermediaries.

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[15] http://www.cio.com/article/638219/Retailers_Going_Green_But_Customers_Remain_Apathetic
[16] http://www.nytimes.com/2010/02/26/business/energy-environment/26walmart.html
[17] http://www.lca-center.dk/cms/site.asp?p=4683
[18] http://www.igpn.org/ http://www.fairtrade.org.uk

Max Havelaar[19] coffee intends to guarantee the growers a reasonable share of the profits of end-of-point sale. Criteria are well established, and producers are regularly checked for compliance. While the product does not make claims about other sustainability criteria such as land-use, pesticide use or other environmental damage arising from coffee production, growers are 'encouraged' to take these factors into account. Thus the ultimate purchasers of the coffee can consider themselves as practising a form of green supply-chain management that can actually be better described as "sustainable (or equitable) procurement".

Many of these green purchasing arrangements consider a limited set of issues (often only a single issue). No doubt this simplicity is partly responsible for their success as it is easy to understand. But it also means that other equally important issues may go unaddressed. The major distribution chains are gradually expanding their vision by increasing the number of criteria, nevertheless even in such a highly organised sector the limited extent of the sustainable elements is still evident. For Max Havelaar coffee the sustainable supply-chain focus is on the growers rather than on the subsequent processing, distribution and consumption stages, and the number of criteria taken into account is still limited. Organically grown food, similarly, may subsequently be processed or packaged in environmentally unfriendly ways without affecting its label. The distillation of public sustainability sentiment into a number of popular surrogate issues, each with a simple label like organic food, fair trade, chlorine-free, sustainably harvested timber etc thus satisfies certain market requirements even if it does not always accord with a rigorous sustainability management approach.

Intimately linked to green purchasing is the issue of eco-labelling[20], or sustainability labelling. A number of such schemes are in use around the world, the best known probably being the Blue Angel[21] scheme in Germany. France has recently launched its programme "Affichage environnemental" to allow consumers to learn more about the life-cycle impacts of the products they buy[22]. Independent or governmental frameworks for labelling schemes are regarded as more reliable than allowing individual producers to prepare their own labels without reference to standardised criteria. Their utility of eco-labels depends very much on the selection of criteria, and the way these are assessed. Despite the frequent wish for it, it is generally considered as unrealistic to develop a single ranking number for products when multiple criteria are involved.

Green supply-chains are not limited to consumer goods. They also apply to heavy industry sectors such as construction, chemicals, oil and mining. Many corporations in these industries are sensitive to pressure from shareholders and institutional investors and thus have well-defined sustainability policies. These companies increasingly apply their criteria along the supply-chain to their raw materials suppliers in whatever country of origin. It can be noted that government and privately owned companies are somewhat less influenced by such a movement and provide fewer examples of green SCM than do listed public companies.

For instance the Indian subsidiary of the major cement company Lafarge undertakes sustainability audits of its regional gypsum supplier in Bhutan to ensure that it has a level of sustainability performance acceptable to the parent company in Europe. Labour and safety

[19] www.maxhavelaar.org
[20] http://www.unep.fr/scp/ecolabelling/csd18.htm
[21] http://en.wikipedia.org/wiki/Blue_Angel_(certification)
[22] http://www.developpement-durable.gouv.fr/Consommation-durable,19201.html.

factors were given particular emphasis in addition to the checking of regulatory compliance with environmental standards. From Lafarge's 2009 sustainability report[23]: "In 2009 our global purchases totalled €8.15 billion. We are engaged in a process to ensure that our external sourcing of goods and services properly reflects our sustainability principles. The significant role played by local suppliers in Lafarge's operations enables the Group to have a positive impact on the economies of countries where we operate."

A special example of green SCM occurs where groups of companies or institutions collaborate to develop a common sustainability code. Many times such a Code can only be implemented if the entire supply-chain is brought into concordance. Such collaboration has occurred especially in the controversial resource sectors of forest products, fisheries, and mining as some of the examples below illustrate.

Example of natural resource management: fish and forests. In order to reduce the deleterious impact on natural resources, a number of initiatives have been launched to avoid (or to prefer) products sourced according to bad/good practices respectively. One of the best known is the Forest Stewardship Council[24], a multi-stakeholder initiative that seeks to ensure that rainforest timber is sustainably managed, harvested and sold. Technical guidelines describe 'sustainable' practices. Operators and suppliers are independently audited. End-distributors agree to only source their timber from such operators. Annual reports of compliance are available, and a multi-stakeholder Council oversees the process. The process is designed to guarantee a high (ethical) value product that attracts a significant clientele, and through consumer pressure to encourage the entire industry to move in this direction. The supply-chain management by the end-distributors does most of the work to ensure the procedures are followed. Independent auditing guarantees that the outcome is credible. Similar arrangements exist for marine fisheries through the Marine Stewardship Council[25] and a number of other collaborative fora with similar aims.[26]

The FSC and MSC examples involve short supply-chains, and are based on a common agreement rather than a traditional SCM approach of formal tendering. Of course the FSC will also involve contracts eventually, but the initial agreement was the result of a conference process rather than contract negotiation. Neither FSC nor MSC extend downstream to the consumer to try to influence how the product is used. The next example shows how it is possible to take this extra step.

Example of chemicals management: cyanide in gold mining. One of the most sophisticated value-chain management instruments is the International Cyanide Management Code.[27] This was developed to help gold producers avoid the stigma of 'dirty gold' ie gold mined and produced in ways that contaminates the environment with this toxic chemical. Rather than ban this chemical outright as various pressure groups had advocated, the industry decided to demonstrate that stringent supply-chain management with all appropriate safeguards can avoid the contamination and human risks that were sometimes seen in the past. The cyanide code requires companies to apply strict rules, both technical and procedural, for handling cyanide. A particular feature is its value-chain reach: even the

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[23] http://www.lafargenorthamerica.com/Lafarge_sustainable_development-Sustainable_report_2009.pdf

[24] www.fsc.org

[25] www.msc.org

[26] www.sustainablefish.org

[27] www.cyanidecode.org

upstream chemical manufacturers, suppliers and transporters must comply with the Code requirements before the end-user mining company can purchase the substance. The Cyanide Code is one of the most rigorous examples of life-cycle management in the resource industry. It incorporates pollution, safety and health criteria. It was not designed to cover energy or other social issues so its "sustainability" reach is still only partial. The code concept has now also been used in other related sectors, such as by diamond (the so-called Kimberley process[28])and jewellery suppliers[29]. In each case the entire supply-chain is subject to the sustainability requirements of the end-user – pollution, risks, social conditions etc. The selection of sustainability criteria varies greatly, usually incorporating a strong emphasis on social issues as well as pollution-type factors; however land-use and conservation issues are less extensively incorporated.

3.2 Some lessons learned from the supply-chain management examples provided

The examples above show how green SCM can be used to work towards sustainability objectives. But they also illustrate some of the limitations in the way it is presently used.

A common limitation is the restricted number of sustainability elements taken into consideration. Energy content is a common 'green' factor (e.g. Walmart), alongside also chemical content (e.g. IKEA). Certain social features such as possible child or prison labour are carefully scrutinised by popular brands of clothing or sports items (e.g. Nike). Big mining companies are now careful about workplace safety among their sub-contractors and suppliers. Biodiversity is becoming a more common factor among resource companies generally. While single-issue programmes are still common among the smaller players the larger companies are gradually moving more confidently into multiple-issues. Most are focussing on energy, greenhouse gases, water, and waste as core elements with labour issues also mentioned separately. All the same the number of SCM initiatives that prominently address the entire set of sustainability issues as recommended by global bodies such as the UN, business councils and independent institutes is still small. A contributor to this sustainability myopia is likely to be the perceived relative importance of high-profile issues to which a company has subscribed, whether a labour convention, the cyanide code or a conservation objective etc, and which leads to other issues to take second place in the action agenda. For some it can also be surmised that the 'too hard' factor is at work, and that companies prefer to take a gradual approach, gaining experience and confidence in the process.

As an example we can look at Unilever which has selected greenhouse gases, water and solid waste as the key factors to address, while also aiming at "sustainable agriculture" for its principal source of supply. As well as adopting multiple criteria (four), Unilever has acknowledged the importance of the end-consumer in reducing the impact of its products across the entire value-chain as the box below demonstrates.

Unilever's sustainability strategy addresses environmental impacts across the value chain[30].

"Our commitment to reduced environmental impact extends right across our value chain – ie, from the sourcing of raw materials through our own production and distribution to consumer use and eventual disposal of residual packaging. Consumer use accounts for around 70% of our greenhouse gas footprint. Engaging consumers …. will be key to

[28] www.kimberleyprocess.com

[29] www.responsiblejewellery.com

[30] http://www.unilever.com/sustainability/strategy/vision/index.aspx

achieving our vision. Metrics for our four priority environmental impact areas across the value chain include greenhouse gas (GHG) emissions, water, waste, and sustainable sourcing. These metrics are designed to measure the impacts of our products when used by consumers, such as grams of greenhouse gas per single usage occasion. During 2009 around 1 500 products were assessed to allow us to understand their water, waste and GHG impacts in 14 of our largest markets. In 2009 we also started to develop a set of metrics covering social impacts. For those of our brands with social missions, the metrics seek to measure the benefits they bring to society. In 2010, Lifebuoy will be the first brand to pilot the new metrics, helping track the impact of Lifebuoy programmes on hand washing behaviours over a five-year period".

Expanded and more standardised approaches to SCM will no doubt follow further promotional work by the UN Global Compact as well as greater use of instruments such as the Global Reporting Initiative[31] with its transparent checklists although even in GRI any issue that is not included in the checklists is easily overlooked. In the end, a comprehensive approach depends critically on the depth of a company's sustainability policy and objectives. And it is undoubtedly true that some successful green initiatives such as 3M's Pollution Prevention Pays started out with only single-issue objectives eg reduction of pollution. It could even be argued that their limited objectives gave them the initial tight focus that was responsible for their success. 3M's Pollution Prevention Pays (3P) program[32] celebrated its 30th anniversary in 2005. Over the last 34 years, the program has prevented 2.9 billion pounds of pollutants and saved more than 1.2 billion dollars worldwide. The 3P program continues to be a success worldwide because of its design, measurable results and benefits, and integration into business processes and corporate culture.

Another example comes from the drinks industry. SAB Miller[33], an international brewing company with operations in Africa has identified water as a key sustainability factor. Greater water efficiency in drinks manufacture is important in a dry continent, but so is water availability upstream in the supply chain in the growing of the cereal crops that are the basic raw material in beer manufacture. In partnership with WWF and GTZ, the company used the technique of water footprinting within its value chain. The company also focuses on energy efficiency as an important economic factor.

A second and arguably more serious weakness in most initiatives is the short length of the value-chain that is considered in green SCM. Thus the 'suppliers of the suppliers' mostly drop from view; the longer supply chains in the more sophisticated technology sectors are just too complicated for most operators. One exception to this are the companies involved in the Global e-Sustainability Initiative (GESI) where the controversial labour conditions in the primary extraction of precious metals for the electronics industry (coltan) have led to action along more extended supply-chains. GeSI now also has an increasing downstream focus on the use phase of its products as the description below shows. The GeSI initiative is noteworthy for three aspects, (i) it is sector-wide and engages a large number of companies, (ii) it spans nearly the whole of the value chain from mining of resources to consumer use and end-of-life recycling, and (iii) it includes multiple sustainability criteria from labour/social to energy to waste.

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[31] www.globalcompact.org

[32] http://www.mmm.com/sustainability

[33] http://www.sabmiller.com/files/reports/2010_SD_report.pdf

Example on sustainability in the value chain - the Global e-Sustainability Initiative[34] (GeSI), which is an international non-profit association was formed to help Information and Communication Technology (ICT) companies, and the sector as a whole, to become more sustainable. GeSI has linked with the Electronic Industry Code of Conduct (EICC) Implementation Group and other groups to develop a set of tools that meet broad industry needs. These tools include the E-TASC package consisting of a supply chain questionnaire, a risk assessment tool, a common approach to auditing, and a list of web-based resources. Initially the self assessment questionnaire was used only for the first tiers in the supply chain of manufacturing and telecom companies but did not reach to the level of mining the raw materials (where major issues were found). Subsequently GeSI and EICC created an extraction group to provide more information about the sources of the metals. In addition, they joined forces with DigitalEurope and TechAmerica in the creation of an "ICT for Energy Efficiency" (ICT4EE) Forum to address the consumption of energy in the use phase of electronic products (e.g. the battery chargers for mobile devices). Finally, GeSI collaborates with the Solving the E-waste Problem (StEP) Initiative[35] to improve the sustainability performance of the end-of-life of electronic products. For overall sustainability the classical upstream supply chain is thus only a starting point. A full life cycle management approach is needed when striving for global sustainability.

The cyanide code mentioned earlier is perhaps the most complete instrument of all, systematically – and contractually - integrating chemical supplier, transporter, and end-user long the entire value-chain of this material, except for the suppliers of basic chemicals in the initial cyanide manufacture. This is not perhaps a serious criticism since the instrument is quite deliberately focused on cyanide risks and other considerations are beyond the conceptual design boundary of the Code.

Although we are not aware of formal studies to this end, when we read between the lines of various case studies we can infer that many sustainable SCM initiatives are still "add-on" rather than "built-in" i.e. the green supply chain has not been effectively mainstreamed in corporate practice. This is especially so where greening has been externally imposed. Thus the corporate focus on better cyanide management by Code members seems not to have resulted in a significant overhaul of general management practice of other chemicals in these companies. While not necessarily detracting from the effectiveness of the immediate SCM exercise, it represents a missed opportunity for the company, and also for sustainability overall. Where sustainability it is part of a clear business strategy such as in Walmart, the mainstreaming of SCM will be more systematic. Enhanced integration is also more likely where quality issues are critical as for example in the motor industry.

4. Including sustainability factors in supply-chain management

4.1 General considerations

The complexity of the sustainability agenda has led many companies and other organizations to take more systematic approaches to these issues through, for example, use of formal (environmental/ sustainability) management systems and an end-to-end value-chain consideration. These systems co-ordinate the use of appropriate instruments for assessment, ensure a cleaner production approach to manufacturing, put greater emphasis

[34] http://www.gesi.org
[35] www.step-initiative.org

on green design and on social factors, while maintaining appropriate oversight of quality and cost of raw materials and supplies. Monitoring of relevant aspects of corporate operation is the key to achieving and maintaining high performance levels, and ultimately also customer satisfaction and loyalty. SCM is inevitably an integral part of such systems. SCM already considers quality, reliability, resource costs, and increasingly reputational risk (e.g. sourcing products made with child labour). The incorporation of sustainability factors thus adds only a few more parameters to a process that is already established.

We can ask how SCM managers deal with such a complex area in which they may have no formal training. Within large companies considerable guidance and support to SCM managers is available through the various in-house initiatives to link different corporate departments. Detailed advice is also available from manuals, guidelines and handbooks that have been independently published (eg the Global Compact and WBCSD New Zealand publications mentioned in this paper). Here, we will simply mention some of the key steps that will need to be carried out in a systematic effort.

Clearly **identifying the sustainability elements** to be applied is an essential first step. We already mentioned that many companies still rely on a very limited set of elements, perhaps too limited if sustainability pressures continue to increase. Some issues such as pollution and waste, energy efficiency, as well as workplace safety, are now almost universal. Biodiversity, land-use, social justice, among others will be more difficult to deal with. The incorporation of ethical factors will be especially challenging in many companies. For guidance, managers will need to use corporate CSR statements, sustainability reports, and other internal instruments concerning issues SCM should pay regard to. Where such statements and instruments do not yet exist, as in many smaller companies that have no CSR manager, the identifying of relevant sustainability targets in the company would be a necessary first exercise for the SCM manager. Following the identification of issues, and perhaps formulation of quantitative targets, it will be important to undertake consultation with relevant stakeholders, and eventually endorsement by top management.

An important next step is a **description of the supply chains**, the main materials and products, and identifying the main sustainability issues that they embody (independent of the company priority towards such issues). Clear identification of the suppliers – and the 'suppliers of the suppliers' - are important when sensitive issues such as chemicals, pollution or human rights are involved. In some cases the transport aspects are also important e.g. for hazardous chemicals. Social issues such workplace quality and child labours, for example, are site-specific at the supplier's premises and may require further research by the SCM manager. Increasingly the customer dimension of use-pattern and recovery of products are part of the more complete supply-chain descriptions.

How can suppliers be identified and rated/ranked on sustainability factors? Self-assessment performance reports are only credible when independently verified. Short of visiting each supplier (difficult for extended supply-chains) we need a label or certification process. Standardised environmental management systems e.g. ISO 14001 have now become a de-facto way to identify 'good environmental practice' suppliers. SA 26000 does the same for social performance. Nevertheless a number of companies have gone further by putting their own supplier recognition schemes in place, as for example Proctor and Gamble's Supplier Environmental Sustainability Scorecard[36]: Thus: "On May 12 2010, the Procter & Gamble

[36] http://www.pginvestor.com/phoenix.zhtml?c=104574&p=irol-newsArticle&ID=1425862

Company announced the launch of the Supplier Environmental Sustainability Scorecard and rating process to measure and improve the environmental performance of its key suppliers. The new scorecard will assess P&G suppliers' environmental footprint and encourage continued improvement by measuring energy use, water use, waste disposal and greenhouse gas emissions on a year-to-year basis. "We worked closely with a global team of P&G personnel, suppliers and supply chain experts to determine the most effective way to measure the environmental performance of our diverse global supplier base," said Rick Hughes, P&G global purchasing officer. "Our suppliers wanted a tool that was flexible yet grounded in existing measurement standards and, by working together, we developed a framework that will help drive real improvement across all industries."

Following the identification of priorities (an internal exercise within the company), a number of different possibilities for action appear. In most cases there are adequate possibilities for taking action on sustainability. It may be possible to switch to suppliers who have a lower environmental or social footprint. Alternately, joint work with existing suppliers may improve their sustainability performance. Specifying in contractual documents the suppliers' desired environmental and social performance is the most common way of greening supply chains. In large companies contract management is already a sophisticated, well-managed exercise and can easily incorporate the additional criteria.

But there are also in-house options for optimising sustainability such as redesign of the product or of revamping the manufacturing processes to allow the use of alternative raw materials that have better sustainability credentials. These are the so-called eco-design options. There may also be more holistic options such as Product-Service Systems (PSS)[37] that involve a more fundamental rethink to the entire business model. Closing the materials loop by recovering and recycling end-of-life products back into the manufacturing chain is an example of this as shown by the Interface company that leases, recovers and recycles the carpets it makes.

Incorporation of recycling, and especially recycled materials, as is the case with Interface above, causes major shifts in the way SCM is carried out. For one thing, quality control becomes a more exacting task since many recovered products may be contaminated or contain incompatible components. Assurance of supply is also more difficult since the supply of (recycled) raw materials now depends on the consumption cycle. Finally, collection and storage may present additional complications. Conversely, end-of-life products can be seen as a useful, stable source of raw materials supply. The chemical company Safety-Kleen[38] has based its solvents and oils business on a cycle of 'produce-sell-recover-reprocess-resell' that is sheltered from the fluctuations in supply of virgin materials.

Options such as these go a long way to achieving sustainability goals, but require a whole-of-company approach that the SCM manager can certainly initiate, but which transcend his immediate management responsibilities. Most of the above measures can be implemented using conventional management approaches and tools. But there remain some issues in the sustainability agenda that require more thinking. The most prominent is that of sustainable consumption defined as[39] "the use of services and related products which respond to basic needs and bring a better quality of life while minimising the use of natural resources and

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[37] http://www.unep.fr/scp/design/pdf/pss-brochure-final.pdf

[38] http://www.p2pays.org/ref/02/01572.pdf

[39] http://www.unep.fr/scp/sc/

toxic materials as well as emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardise the needs of future generations."

In view of the fact that business is trying to maximise its volumes and product turn-over, it may seem a contradiction that the subject of a more programmed sustainable consumption should even be part of its objectives. A number of prominent companies have nevertheless been shifting in this direction with revised business plans and operations as they position themselves for future markets and greater international competition (WBCSD et al., 2002). Whether such initiatives can be mainstreamed into entire business sectors rather than remaining a niche for market leaders remains to be seen.

A particular challenge for sustainable companies is how to influence consumers to follow their lead by using their products in a more considered (from sustainability perspective) way. While such influence has long been accepted for reasons of product safety, the application of other criteria has been slow to be incorporated into company advice and guidance. Still, things are gradually changing as the Unilever example illustrates. Unilever in its objectives on greenhouse gas reduction is encouraging the consumers to wash at lower temperatures and at correct dosage in 70% of machine washes by 2020. While 'encourage' may seem a rather loose notion, the objective at least has the merit of being quantified in terms of target and date. In a similar way, chemical suppliers frequently advise the commercial users on the safety and proper use of their products. But it is still considered the role of governments to make this mandatory.

Whatever approaches and actions are taken to green the supply-chain, it will be necessary to monitor the way in which the various objectives are achieved, and at what cost. This is of course in addition to any monitoring for quality, safety and reliability in the manufacturing cycle. Results of such monitoring are now increasingly incorporated into corporate sustainability reports, whether along Global Reporting Initiative guidelines[40] or otherwise.

Taken together, the above procedures clearly require considerable skill and expertise. Insight is needed into the new issues and parameters that managers have to deal with. Some of the assessment tools are quite sophisticated and are also evolving quickly. Consideration of new management options would benefit from exchange of experience with others who have already applied them. To assist the process of information exchange and professional development various practical manuals and guides have been published by business groups and individual companies - see for example the one from the WBCSD New Zealand[41]. Some universities are now offering formal courses. Below is an extract from the subject content of a green supply-chain management syllabus at the University of California, Santa Barbara:

- Industrial ecology, Life cycle thinking
- Life cycle accounting
- Definition of supply chain management (SCM)
- Definition of green supply chain management (GSCM)
- Environmental and economic dimension
- Economic value vs. environmental impact added Environmental cost accounting
- Cost allocation and life cycle costing. Interest rates, cash flow, NPV, IRR, Payback
- Input productivity
- Contracting / Servicing

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[40] www.globalreporting.org

[41] http://www.nzbcsd.org.nz/supplychain/SupplyChain.pdf

- Eco-labeling
- Green procurement
- Cost-sharing, profit-sharing
- Recycled content versus end-of-life recycling
- Reverse Logistics for Green Supply Chain Management
- Pollution prevention

4.2 The role of Life Cycle Assessment and Life Cycle Management

In view of the importance of the evaluation of the supply chain it is useful for SCM managers to become familiar with the Life Cycle Assessment (LCA) tool and its potential. They do not of course need to become LCA experts; but it is important that they can supervise the procedure when carried out by staff or by consultants. It should be noted that LCA has in past focussed chiefly on pollution and energy as these are the easiest parameters to quantify. More recently LCA has also started to develop tools to assess non-quantifiable issues such as land-use, biodiversity, safety, human rights and other social factors. The UNEP/SETAC Life Cycle Initiative[42] provides an international forum for information and exchange of experience on all aspects of LCA development and application, including practical publications.

Life-cycle assessment (LCA) describes the environmental impact during the entire life span of a material or product, according to the boundaries defined to suit the purpose of each particular exercise. LCA studies the embedded raw materials and energy of a product, documents the wastes and other impacts resulting from its manufacture and use. In order to ensure worldwide validity of data and conclusions, assessment procedures have been standardised in the ISO 14040 series. Environmental pressures are often expressed as a 'footprint', quantified in various ways. Carbon footprint refers to impact of greenhouse gas emissions causing climate change. Water footprint is more complex as it may refer to quality as well as quantity. Other footprints are also often proposed. As far as they refer to the product level they are all in line with the ISO 14040 standard series for LCA. Standardisation of calculations of carbon and water footprints is now under development by ISO, but not yet for ecosystem change or eco-toxicity. For this a specific tool called USEtox[43] has been developed by the Life Cycle Initiative referred to above.

Life Cycle Costing (LCC) is an aggregation of all costs that are directly related to a product over its entire life cycle, from resource extraction over the supply chain to use and disposal, and that are directly borne by one "life cycle actor" (producer, consumer, end-of-life actor). Life cycle costing by definition does not consider external effects. Frequently a high share of costs needs to be allocated, but smarter cost models help circumvent this to some extent. Definition of cost categories is difficult especially along supply chains (Ciroth, 2008). LCC can be used to assist management in the decision-making process. The application of life cycle costing in the tendering procedure may help to procure a product with a better environmental performance since, for instance, future energy cost saving due to investments into energy efficiency measures will be highlighted. Such scrutiny will reveal costs of resource use and disposal that may not otherwise have received proper attention. Both LCA and LCC bring important information into SCM, and especially into green SCM.

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[42] http://lcinitiative.unep.fr/

[43] www.usetox.org

Based on the above information, **Life-cycle Management (LCM)** takes a systems view to maximise the sustainability performance of the value-chain as a whole rather than optimising each link in this chain separately as is often done at present. The use of LCM results in a more optimum overall outcome and is thus a strategic management approach. Even where the entire value-chain is not dealt with in its entirety, it facilitates the identification of areas of high importance along the chain. The LCA/LCM combination can pinpoint the stages that are especially important for systems optimisation (or for optimisation of key individual parameters e.g. energy) and then apply appropriate management intervention as necessary. It is important to note that LCM uses standard corporate and regulatory management instruments and approaches to achieve an agreed outcome while LCA is chiefly concerned with data gathering and analysis. Because LCM aims to achieve a systems optimisation rather than an improvement in only the end-point of the chain, SCM can thus be considered as a sub-set of LCM. This notion is reinforced by the traditional role of SCM is improving the upstream supply chain of the company, leaving the downstream user interface to be dealt with by other divisions in the company. LCM addresses both the upstream and downstream stages as parts of the overall value-chain. LCM involves all levels of the organization (Fig. 3).

Fig. 3. LCM involves all levels of the organisation (UNEP, 2007)

A simple example will suffice to illustrate the above. In the life-chain of an automobile, the use phase accounts for about 80% of the energy consumed over the life of the product. While efforts to reduce the energy used in the manufacture of the product (i.e. the car) are certainly desirable, it is the design, choice of materials, driving habits of the owner etc that strongly influence fuel consumption during use, and this is where most of the energy over the life of the car will be consumed. (A full systems approach with broader boundaries may even propose alternatives to the auto in the first place.) LCA can identify the stages with the most impact. LCM can then propose interventions that would achieve the best overall reduction in energy consumption over the life of the vehicle at a defined cost as identified by LCC. It can link with each member in the value chain to orient these partners to better achieve co-ordinated sustainability objectives at their level, and ultimately along the entire value-chain. For example, more efficient metals production (mining, smelting) produces less pollution and also reduces the embedded energy of the product. Better design and lighter materials in frames, panels and components will allow users to drive more frugally, as would industry-sponsored driver education facilities. Authorities can help traffic to flow more smoothly. Recovery at end-of-life returns metals to society, and so on. Such considerations are not unique to the automotive sector. Similar thinking applies in the building industry, where much of the resource consumption and environmental impact calculated over the life cycle actually occurs in the use phase rather than in construction.

Even if some stages are more significant than others, all parts of the value chain can contribute to the optimisation of the entire system. It is the function of LCM to put in place the management objectives, systems and arrangements that allow the various partners along the value-chain to cooperate in achieving this systems optimisation that they cannot achieve by acting on their own. Seuring & Goldbach (2002) identify two options, the co-operative and the coercive models. In reality a mixture of the two would be employed, with the co-operative model generally getting better results in longer value chains.

4.3 Relationship between Life Cycle Management and supply-chain management

It is useful to now consider how LCM can achieve the above optimisation within the context of supply-chain management. It is easy to see how SCM could contribute to lowering some of the 20% of embedded energy in the motor car through judicious choice of energy-efficient suppliers. In terms of the use of lighter materials in vehicles, this has not been the primary role of SCM but rather that of the product designers. Nor have we seen widespread use of SCM in influencing the end-user (although SCM could assist in facilitating end-of-life recycling for example by for example specifying the use of recycled materials in the raw materials). While SCM is gradually reaching down also to the downstream side of production to build a stronger loyalty of the end-consumer to the manufacturer and supplier, LCM is actually better adapted to take on such a systems-wide function. Through this example we see SCM as one of the important instruments in the implementation of LCM, based on the identification of important value-chain steps by LCA. If the exercise were simply the greening of the supply chain, then the LCA/SCM combination would be enough.

Overall, the growing experience with LCM will soon make it an important framework for achieving complex sustainability targets. Both SCM and LCA/LCM have vibrant networks that SCM managers can use to enhance their practice of sustainable SCM.

5. Discussion and synthesis

The increasing prominence of the sustainability agenda has resulted in major changes in decision-making in business and government. Environmental and social factors can be expected to become ever more important considerations in the foreseeable future. The visibility many companies now give to corporate social responsibility is already a reflection of this ‘mega trend’ that has major implications on corporate practices, including supply-chain management. Companies are moving quickly to ensure that both their operations and their products are compatible with sustainability principles.

In the supply of sustainable goods and services, 'the world behind the product' is taking on increasing significance. It is now important to understand, and to better manage, the totality of the embedded environmental and social footprints of the products and services we consume. 'Green' or 'sustainable' supply-chain management is thus on the increase. Many large companies already have sophisticated internal procedures to bring suppliers into line with corporate policies on environment, social and ethical issues. In some cases groups of companies, in for example the electronics and resource industries, have joined up to produce global guidelines that define performance of their members' supply chains on selected issues such as water, wastes or labour conditions. We also see more and more independent 'sustainable purchasing' arrangements applying a variety of sustainability criteria, individually or in combination.

Encouraging though these developments are, many of the present initiatives suffer from certain structural deficiencies such as a limited number of sustainability criteria and short length of the supply chains. As a result the global sustainability objectives are often only partly achieved, leaving serious issues in both geographical and thematic locations unaddressed. Incomplete integration and fragmentation of effort is also a common factor. All these problems will not be easy to overcome as they arise from the inherent complexity of managing large networks of relatively independent partners. Fortunately there are also some examples that can serve as inspiration and encouragement.

The picture of a supply-chain is now evolving away from a 'materials life cycle' towards a more holistic concept of 'value chain' where the traditional upstream stages of raw materials and manufacturing are joined also by the downstream elements of product, use, consumption, and end-of-life issues. There are many additional partners involved here and the linear chain concept is gradually transforming itself into a notion of a network, where multiple nodes of suppliers and consumers all warrant attention. Within this concept a wider life cycle management approach is becoming more prominent, dealing in an integrated way with the downstream aspects of the product as well as the upstream management elements of traditional supply chains. LCM uses standard business management instruments to identify, prioritise and act on key sustainability impacts along the value chain in such a way that the sustainability of the total value chain is optimised rather than just each stage individually. LCM relies heavily on the results of expanded techniques of LCA, however it is a management rather than a scientific exercise. Given the range and extent of most value-chains, the use of various techniques of consultation, negotiation and collaboration is a major part of the LCM challenge.

From the corporation's viewpoint, moving to sustainable value-chain management and LCM makes business sense. Systematic value-chain management can better identify appropriate opportunities for adjustments to the entire life-chain of materials and products, including consumer use and end-of-life aspects. Optimising the social and environmental factors inherent in the entire the value-chain has intrinsic advantages for cost and quality management in the company. But in particular it can greatly assist the company in its longer-term product development and marketing strategies.

While the potential benefits are clear, there are also challenges. An expansion of supply-chain considerations into the downstream product cycle brings new partners (both from inside and outside the company) into the picture, as well as additional sustainability objectives, for example product use efficiency, recycling and end-of-life disposal (or reconversion) of the product. While assessment tools are available for evaluating the options, the design, marketing and service departments within most companies have traditionally not pre-occupied themselves with such considerations. Expanding the value-chain partners beyond the first tier (ie immediate suppliers or clients) will remain a challenge for rigorous companies since the number and complexity of partners increases rapidly. A variety of techniques is available for profiling the various supply chain partners against sustainability criteria, however the lack of co-ordination often causes problems where the suppliers have demands from different customers. It is especially in this respect that greater use of new international standards (including verification systems) will be required. It will also require new methods of communication and negotiation with value-chain partners many of whom will be in remote places, operating in other cultures and languages, and unaware of the nature of the end-products.

Accordingly, at the global level the practice of sustainable value-chain management would benefit from a clearer framework that helps to avoid fragmentation and inconsistencies (and eventually discouragement) at the point of the suppliers and clients. It is important that the suppliers of the suppliers also be linked into the sustainability initiatives, despite the difficulties this may involve. A variety of 'tool boxes' for sustainability management is already available for the practitioners. What is still needed is a set of broader agreements on objectives, boundaries and techniques, to standardise the practices, and give a common reference point to the many partners and players involved. Again, in view of the pattern of global trade now, such agreements should ideally be at international level. At the same time the hierarchical relationships between supply chain management and other management streams such as environmental management systems, CSR, eco-design etc could be further clarified. At present, ISO has not developed any specific standard or guideline on sustainable supply chain management, let alone on value-chain management or on life cycle management. Experience with a number of sector-wide supply chain frameworks that have been established in certain industries could nevertheless provide some useful references on the above.

6. Conclusion and perspectives

In the evolution to new models of supply chain management it is important not to loose sight of the fundamentals. Correct identification of the sustainability issues – both present and those likely to be important in the future – is vital to focus the exercise and deal with the issues most relevant to the company. This identification is not always straightforward for global companies operating in different countries and cultures, or where products will be sold in global markets.

The management of 'green' issues in SCM can be usefully built on experience with traditional corporate practices and techniques by expanding the parameters and adding new knowledge from various assessment tools such as LCA. It is also important to recall that sustainable supply chain management is a further development of, and hence an integral part of, traditional SCM, not an independent additional action to be undertaken in parallel. And close integration of SCM with CSR remains an important ingredient for success.

Taken together the above presents a considerable challenge to SCM managers in all companies and organizations. The moving targets of sustainability, techniques and even regulations require regular updates and exchange of information. While various manuals and conferences are now available to promote such exchange, further emphasis on professional development training would help smooth the path to a more sustainable future.

Time moves on, sustainability issues evolve and ideas about how to deal with them mature. Both the external and internal business environments can change rapidly. Supply-chain management has traditionally been one of the threads that bind corporate units together. The adoption of a broader view of value chains and of how to manage them leads to a changing business landscape. In this context, corporate social responsibility and product stewardship constantly redefine the concept of sustainable supply-chain management. Dealing with this change will require adaptability and new working methods, but the basic objectives of managing a supply chain for a sustainable future will remain intact.

7. Acknowledgement

Fritz Balkau is an independent advisor, focusing particularly on strategic guidance to assist the transition to future sustainable societies. Until 2005 he was Head of UNEP's Production and Consumption Branch, in Paris, France. Guido Sonnemann is UNEP's Programme Officer for Sustainable Innovation and Coordinator of the Secretariat for the Life Cycle Initiative and science focal point for the Resource Efficiency/ SCP subprogramme.

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19

Supply Management Governance Role in Supply Chain Risk Management and Sustainability

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1. Introduction

Supply chains face increased pressure from stakeholders to incorporate a plethora of corporate responsibility and sustainability aspects in their constituents' business practices. Legal and extra-legal demands are dynamically changing; almost no industry, supply chain, organization, and an organizational function are unaffected. Owing to the outsourcing wave of the last decade (Reuter et al., 2010), in particular purchasing and supply management (PSM) plays an ever more important role in assuring sustainable supply chains in the marketplace.

In order to manage supply chain risks, supply management must ensure that their local and international practices and relationships comply with their stakeholders' expected codes of conduct and that environmental and social misconducts do not occur, while maintaining profitability. The proposed framework (Figure 1) highlights the "dynamic nature" of requisite supply management capabilities and governance mechanisms. This is mainly due to the need to creating a strategic fit between supply chains and the continually changing supply chain risks. This strategic fit denotes "supply chain resilience;" defined as "the capacity for a supply chain to survive, adapt, and grow in the face of turbulent change" (Pettit et al., 2010). Resilient supply chains are proposed to require certain forms of supply management governance, i.e., structures and processes intended to coordinate and integrate various dimensions of supply management. Governance represents the structures and processes by which supply chain constituents share power, also shapes individual and collective actions (Young, 1992).

Despite interest, there is clear dearth of research on the nature of supply management's role in sustainability. It would be of great insight to the supply management field to explore "*What are the supply management capabilities and governance mechanisms used to sustain a supply chain?*" This conceptual study contributes to prior research in the fields of SM and supply chain sustainability by extending insights of the resilience and capabilities view to analyze how SM governance integrates sustainability aspects in its supply chain practices.

This conceptual study responds to the need for well coordinated efforts that draw on established theories concerning supply chain's sustainability. Building a supply chain sustainability theory offers not just scholarly but also practical value (Ketchen and Hult, 2011).

This study aims at generating and presenting the sustainable supply chain theory by introducing the concept of ecological resilience. The proposed framework is grounded in the resilience perspective, which is increasingly applied to the study of the dynamics of social–ecological systems (Folke, 2006). This perspective offers an integrative view that permits understanding, managing, and governing complex linked systems of people and institutions. Introducing ecological resilience implies a developmental process that involves grafting this new concept onto the existing structure of sustainable supply chain theory in a way that shifts attention to new opportunities without overtly challenging entrenched positions (Skilton, 2011). With introducing this new concept to a recently heavily researched theory, along with pertinent new proposed relationships and the realignment of existing ones, a more parsimonious logical structure of sustainable supply chain theory is sought. The main goal is to excite these essentially aesthetic sensibilities other scholars about the proposed framework and its falsification, and thereby extend the life of the proposed theory.

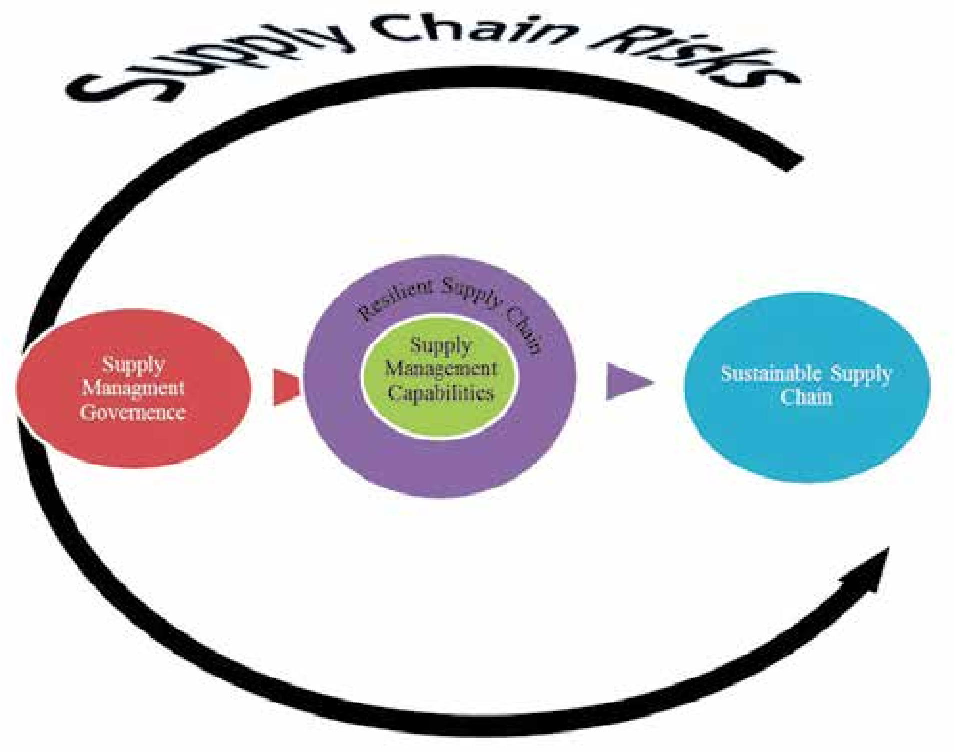

Fig. 1. Framework of Supply Management Governance, Supply Chain Risks, and Sustainability

On the one hand, over the last decade, the bulk of research that uses resilience has linked it to ecology. Unlike the supply chain phenomenon, where social-ecological systems cannot be tightly controlled and independently manipulated, most of the work in building the resilience theory is based on controlled experiments and classical scientific approaches conducted under highly reduced and controlled conditions. This study seeks to extend the resilience theory to supply chain; a context that parallels the natural ecosystems that the ecological resilience theory is intended to explain. This in itself will enrich the resilience theory and its applications. On the other hand, the study aims at using a broad interdisciplinary view on "sustainable supply chain" as a phenomenon by adding to the growing body of concepts of this young research strand. To accomplish this goal, it uses an interdisciplinary approach by drawing insights from ecology, economics, marketing, social science, strategy and, supply chain literatures to begin an interdisciplinary assessment of the ideas developed in previous works regarding resilience in interlinked systems of people and ecosystems, with expansions into some areas of supply chain

This study contributes to practice by crystallizing the requisite SM governance and capabilities to supply chain sustainability. These capabilities are path dependent and particularly valuable when supply chains and their constituent members are risk aware and receptive to external stakeholder pressures. Early movers in the field of resilient and sustainable supply chains are expected to reap competitive benefits to a notable extent as a result of resource accumulation and learning processes over time. The following section discusses the literature review and theoretical background of the proposed framework, then proposed relationships are presented and managerial implications are discussed.

2. Theoretical background and literature review

A supply chain is generally conceptualized as a network of companies from suppliers to end-users, which have the intention of integrating supply/demand via coordinated company efforts (Frankel et al., 2008). Supply chains are complex and linked social–ecological systems of people and institutions. The concept of resilience in supply chains combines these previous tenets with studies of supply chain vulnerability, defined by Svensson (2002) as "unexpected deviations from the norm and their negative consequences." Vulnerability can be measured and expressed in numeric terms as "risk", a combination of the likelihood of an event and its potential severity (Craighead et al., 2007; Sheffi 2005). Both these definitions have foundations in traditional risk management techniques and are expanded by other authors (Svensson, 2002; Zsidisin, 2003; Pettit et al., 2010).

The concept of resilience is used extensively in engineering, ecological sciences, and organizational research, all of which provide insight into creating a conceptual framework for supply chain resilience. In the ecological sciences, the standard definition of resilience is "the ability for an ecosystem to rebound from a disturbance while maintaining diversity, integrity, and ecological processes" (Folke, 2006). It may be beneficial for a supply chain not to return to its original "shape" following a disruption, but rather to learn from the disturbance and adapt into a new configuration (Pettit et al., 2010). Network theory views a supply chain as an adaptable living system and a resilient supply chain, therefore, should be efficient, adaptable, and cohesive (Fiksel, 2003). A resilient supply chain enjoys high levels of collaborations required to identify and manage risks where the culture of risk management is a necessity.

2.1 Supply chain risks

The escalating interest in sustainable supply chains is driven by a number of factors. Drawing from the literature on sustainable supply chains management (SCM) and green SCM, the drivers are classified into (Mann et al., 2010): (1) external to business, i.e., legislation and environmental drivers and (2) internal to the business, i.e., financial' drivers, internal business process drivers and the drivers related to the customer. These drivers represent sources of risks to a supply chain that have the potential to degrade a supply chain's operating condition and, thereby, it's economic, environmental and/or social performance outcomes. When the conditions of an ecosystem, a supply chain in this case, degrade to the extent to which it experiences attritions of its constituent members (i.e. individual firms), it transforms into an inferior and different regime.

On the one hand, this degradation may be drastic and sudden due to the very nature of supply chain phenomenon that causes vulnerabilities and risks. Uncertainties and nonlinearities in a supply chain often arise from both complex internal feedbacks and from interactions with structures and processes operating at other scales (Gunderson and Holling, 2002). Individual firms' expert knowledge is, therefore, incomplete and biased within a supply chain domain. Petit et al. (2010) referred to a recent example that demonstrates the importance of sudden instantaneous disruptions to the automotive manufacturing supply chain: "In 2007, a magnitude 6.8 earthquake in central Japan severely damaged the facilities of Riken Corp., a supplier of automobile components including specialized piston rings. Riken had located all of its plants in a single area of Japan to increase efficiency, making the entire production capacity vulnerable to a catastrophic incident. Earthquake damage to Riken facilities and its utilities completely shut down production for one week, and required another week of repairs to return to full output. As a result of carrying limited inventories, Toyota, one of Riken's many customers, was highly vulnerable to production and transportation disruptions. Toyota's sourcing strategy emphasized close relationships with a limited number of suppliers, but in this case Toyota was forced to shut down all 12 of its domestic assembly plants, delaying production of approximately 55,000 vehicles."

On the other hand, supply chain degradation might very well occur over a period of time that spans several business generations due to market imperfections (i.e., inefficient firms, externalities, flawed pricing mechanisms and information asymmetries) that contribute to environmental degradation and disruptions of supply chains wellbeing (Cohen and Winn, 2007). Ford, another auto maker, reported that the nature of their supply chain is that the big auto parts makers, or Tier 1 companies, rely on hundreds of lower-tier companies. For example, steel from a Tier 4 supplier is sent to a Tier 3-forging company that cuts it into pieces that are sent to a Tier 2 supplier that machines them into gears. The gears are sold to the Tier 1 transmission maker who supplies the finished gearbox to an automaker. Failure at any of these levels can stop an assembly line. The intertwined relationships rely on the final customer, the automaker, being financially stable and able to pay the bills. This is a scenario where social reputation risks and economic risks were intertwined over an extended period of time. The attrition rate in the supply chain has been 5 percent to 10 percent with about 40 major bankruptcies in 2008, many of them progressing rapidly from Chapter 11 to liquidation, said Dave Andrea, OESA's vice president of industry analysis and economics. With attrition, there are too many suppliers, and failure to shrink the supply base in an orderly fashion means it will occur in a more painful way, said Tony Brown, Ford group vice president of global purchasing.

A literature review of the topic in prominent SCM journals reflects the magnification of the role that supply management has been playing in risk management over the past decade. Supply chain management encompasses the planning and management of all activities involved in sourcing and procurement, conversion, and all logistics management activities. Importantly, it also includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. In essence, supply chain management integrates supply and demand management within and across companies" (Frankel et al., 2008). The outcomes of risk management varied in literature from resource efficiency, economic and social responsibility. Notably, more recently these outcomes became more encompassing and drove attention to "supply chain sustainability."

Most of the recent discussions of sustainability are driven by the basic notion that a supply chain's performance should be measured not just by profits, but also by the impact of the chain on ecological and social systems (Pagell and Wu, 2009). Supply management literature describes and measures supply chain inclusive wealth (wellbeing) in this sense on the basis of three components (triple bottom line): the natural environment, society, and economic performance; triple bottom line performance (Carter and Rogers, 2008).

The concept of "sustainability" has recently received noticeable attention from supply management researchers and practitioners (e.g., Krause et al., 2009; Pagell and Wu, 2009; Petit et al., 2010 and Pullman et al., 2009). Calls have been proposed that sustainability and its components represent an addition to the traditional set of competitive priorities for supply management. Kruase et al. (2009) proposed that, in addition to quality, cost, delivery, flexibility and innovation, sustainability must be addressed by each company as a competitive priority that should be manifested, in part, through the supply management practices, such as supplier selection and retention decisions. Nevertheless, supply management students and researchers seem to emphasize the minimization of cost and risk (Krause at al., 2009). This dual emphasis may be suboptimal when sustainability is an important competitive priority. There is lack of clarity when it comes to the role of supply management in capturing that duality; profitability while sustainable.

Guinepero and Eltantawy (2004) posited supplier management processes and relationships are the most susceptible link in a supply chain. An overview of supply management sustainability literature reveals, however, supply management research rarely addresses multidimensionality of its own susceptibility; economic, environmental, and social risks. Supply management governance mechanisms geared to capture economic goals may often times came at odds with social and/or environmental risk management goals and vice versa. The goal at this point is to instill the mechanisms that would minimize and allow tradeoffs when needed in ordered to sustain supply chain.

2.2 Supply chain sustainability: Tradeoffs

Consideration to the concept of sustainability is increasingly found in the management literature. An increase in publishing frequency of about 3/1000 to 15/1000 articles, over the period under consideration. (Linton et al, 2007). Sustainability, in essence, entails the maintenance of the productive base of an economy (i.e., supply chain) relative to its population (i.e., individual firms). Supply chain sustainability is a dynamic state influenced by two dichotomies: the supply chain versus the determinants of individual firm wellbeing, and current versus sustainable wellbeing (Cash, 2006). Accordingly, sustainability involves both a cross-sectional dimension and a temporal dimension. A supply chain enjoys sustainability if and only if: (1) relative to its firms, its inclusive wealth (economic, environmental, and social) does not decline (cross-sectional dimension), and (2), the supply chain could sustain its wellbeing (economic, environmental, and social) across business generations (temporal dimension).

Supply management literature largely defines sustainability as the tripartite pursuit of economic, environmental, and social performance, which is also referred to as the triple bottom line of the organization (e.g., Kleindorfer et al., 2005; Carter and Rogers, 2008; Reuter et al., 2010). In essence; "*to be truly sustainable a supply chain would at worst do (1)* ***no net harm*** *to* ***natural*** *or* ***social*** *systems while still producing a* ***profit*** *(2) over an* ***extended*** period of ***time***; *a truly sustainable supply chain could, (3)* ***customer willing***, *continue to do business forever* (Pagell and Wu, 2009)." The role of supply management is complex: the three aspects of sustainable supply chains are at odds many cases and tradeoffs are important.

The first aspect of the expected tradeoff (1); ***doing no net harm at a profit***. Doing no harm to the natural or social systems usually comes at the expense of producing profit. Procter & Gamble (P&G), the manufacturer of Pampers disposable diapers, is actively involved with sales-improving socially responsible practices such as infant life-saving health programs and education. However, P&G downplays environmental practices that conflict with their cost objectives (Pullman et al., 2009). Here, the reputational risks minimized were at odds with economic goal. In the same study, the authors reported that when analyzing Wal-Mart's recent sustainability report and metrics, they admit that their environmental sustainability efforts, e.g., environmental goals of 100 percent renewable energy, zero waste and products that sustain natural resources and the environment, are in alignment with cost savings for the firm, suppliers and customers. However, their social sustainability indicators are lacking, implying that those particular practices are not in alignment with cost savings.

The second set of tradeoffs (2); to do no harm at profit for ***an extended period of time***. This may be untenable, unworkable and beyond reach in many cases. This is where there is a tradeoff between long-term vs. short term economic sustainability. Supply management students and researchers seem to emphasize the maximization of profit and minimization of cost and risk - this dual emphasis may be suboptimal when sustainability is an important competitive priority (Krause at al., 2009). Lean supply chains research and practice were driven by profit maximization and cost minimization goals. On the one hand, lean production may be conducive to environmental responsibility because it propagates the attainment of productivity goals using minimal inventory. The term is usually associated with the 1970s "just-in-time (JIT)" tactics of Toyota's assembly plants. In the 1990s, the term "lean" replaced JIT to emphasize the true objective of the philosophy: the elimination of waste throughout the supply chain (Jeffers, 2010). On the other hand, lean practices leave firms and supply chains vulnerable to risks and disruptions. In this case, the pursued economic sustainability; via lean practices, may impair other sustainability aspects and in some case mere survival goal when sudden interruptions to the supply chain take place. The 8.9 magnitude quake and ensuing tsunami of 2011 in Japan destroyed infrastructure and knocked out factories supplying everything from high-tech components to steel. Plant closures and production outages among Japan's high-tech companies were among the biggest threats to the global supply chain as an estimated fifth of all global technology products are made in Japan. Lean supply chains such as Toyota Corp's and Sony Corp's had to suspend production.

The third aspect of the expected tradeoffs in a sustainable supply chain (3); to do no net harm at a profit for an extended period of time, ***customer willing***. This is a moving target. Customers define the success requisites for any supply chain. Today, shorted product life cycles and faster shifts in customers' tastes and preferences occur due to numerous factors including technological advances, innovation and innovation diffusion rates, and/or domestic and international competition, which usually lead to overcapacity which in turn switches the competition to price cutting and profit erosion. For example, after decades of dominance in the automobile industry, the large family-sedan appears to be well into the decline stage and only a few large cars, such as Ford's Crown Victoria, are being manufactured today. Far removed from the days of Ford's one-size-fits-all automobile, their supply chain today envisions cars being made to match an actual customer's taste and budget—and in less than a week. On the sales side, the degree to which sustainability, i.e., doing no harm to the social and natural systems, may alter customer preference negatively or positively depending on the type of benefit consumers most value for the product category in question. For example, in a recent study, Luchs and colleagues (2010) reported that sustainability is not always an asset, even if most consumers care about social and environmental issues. The authors reported that consumers associate higher product ethicality with gentleness-related attributes and lower product ethicality with strength-related attributes. As a consequence of these associations, the positive effect of product sustainability on consumer preferences is reduced when strength-related attributes are valued (an example of this product category would be vehicles), sometimes even resulting in preferences for less sustainable product alternatives (i.e., the "sustainability liability."Conversely, when gentleness-related attributes are valued (an example of this product category would be shampoos), sustainability enhances preference.

Clearly, supply chain sustainability is a complex phenomenon that requires developing a strategic fit between a supply chain and a moving target, i.e., supply chain's ever changing success requisites and dynamic operating environment. There has to be a strategic fit between supply chain's supply management capabilities (represented by the additive combinations of its members' capabilities) and supply chain governance and the changing nature of sustainability.

To that end, "*What capabilities allow a supply chain to effectively tradeoff the aforementioned sustainability dimensions?*" With the complex nature of supply chains and the complexity of the movements of product, services, and information in multiple directions, it would be more parsimonious to focus on one or few of the many supply chain threads. Especially if one is able to point out one of the most impactful threads in terms of supply chain sustainability.

In 2010, the Institute for Supply Management (ISM) estimated that in each supply chain; supply management controls trillions of dollars annually, responsible for and controls 50% to 70% of total costs and resources. The Pareto principle (also known as 80/20 rule) applies here– "in any series of elements to be controlled, a selected small factor in terms of the number of elements almost always accounts for a large factor in terms of effort." Supply management has a hold over a significant portion of a supply chain's resources and, thereby, a hold over its projected sustainability or lack thereof, if the supply management thread severs. The Institute for Supply Management™ (ISM) defines supply management as the identification, acquisition, access, positioning and management of resources and related capabilities the organization needs or potentially needs in the attainment of its strategic objectives. In a given supply chain, supply management determines the capacity to maximizing opportunities and managing risks. Supply management serves to explore business opportunities and implement supply strategies that deliver the most value possible to the organization, its suppliers and customers (ISM, 2010).

Supply management capabilities are a crucial ingredient of every supply chain's sustainability — whether manufacturing or service, large or small. Supply management capabilities allow for improving the bottom-line, capturing interpreting and disseminating relevant supply chain information, increasing efficiency and productivity, supply chain profitability and operational success improving competitive position and customer satisfaction, and building image and social policy.

Despite interest, supply chain sustainability research efforts are, mostly, fragmented explorations and there is clear dearth of research on the nature of requisite supply management capabilities and governance mechanisms. The delineation between supply management capabilities in achieving the traditional competitive priorities vis. a vis. sustainability is not always clear.

These capabilities allow a supply chain to adapt, survive and grow. Resilience, defined as "the capacity for a supply chain to survive, adapt, and grow in the face of turbulent change" (Pettit et al., 2010). What is the nature of supply chain resilience? *What are the requisite supply management capabilities for a supply chain to survive, adapt, and grow?* Another more bearing question is *"What are the supply management governance mechanisms required to develop and maintain these capabilities?"* Governance i.e., structures and processes intended to coordinate and integrate various dimensions of supply management. Governance represents the structures and processes by which societies share power, also shapes individual and collective actions (Young, 1992).

3. Proposed framework

3.1 Supply management capabilities

In a world of turbulent change, resilience is a key competency since even the most carefully designed supply chain is susceptible to unforeseen events. Many supply chain researchers are beginning to understand the value of the concept of ***resilience***, defined as "the capacity for an enterprise to survive, adapt, and grow in the face of turbulent change" (Pettit et al., 2010). Resilience has been reported as a multifaceted construct with two contrasting aspects of stability—essentially one that focuses on maintaining efficiency of the supply chain (engineering resilience) and one that focuses on maintaining existence of the supply chain (ecological resilience). For the purposes of this study, this study will focus mainly on supply chain ecological resilience.

A central concept in my study, therefore, is ***ecological resilience*** which indicates how far the supply chain could be perturbed without shifting to a different regime. Ecological resilience denotes the amount of change a system can undergo and still retain the same controls on structure and function or remain in the same domain of attraction (Walker et al., 2006).

Figure 2 depicts the proposed conceptual model of supply chain ecological resilience; focusing on its supply management antecedents. This study proposes that supply chain ecological resilience is an essential precursor to supply chain sustainability. Strengthening the capacity of a supply chain to ensure ecological resilience is critical to achieving sustainability.

Proposition 1: Supply chain ecological resilience is required to create a sustainable supply chain.

Supply chain ecological resilience is a complex phenomenon that manifests itself in several supply chain members' capabilities. It is proposed that supply chain *ecological resilience* is based on situation awareness, keystone vulnerabilities access, and adaptive capacity (McManus, 2008) of supply chain members. Situation awareness indicates an understanding and perception of its entire operating environment. It is the ability to look forward for opportunities, identify crises and their consequences accurately and also understand the trigger factors for crises. This will allow supply chains to effectively address sustainability-related; economic, environmental, and social, tradeoffs when needed. For examples, awareness of customer's perceptions of a supply chain's value propositions, i.e., strength vs. gentleness in performance attributes provides some guidance for companies in choosing either to include ethical attributes in new products and to promote sustainable products; or if they need to pay special attention to countering the association between sustainability and lower product strength.

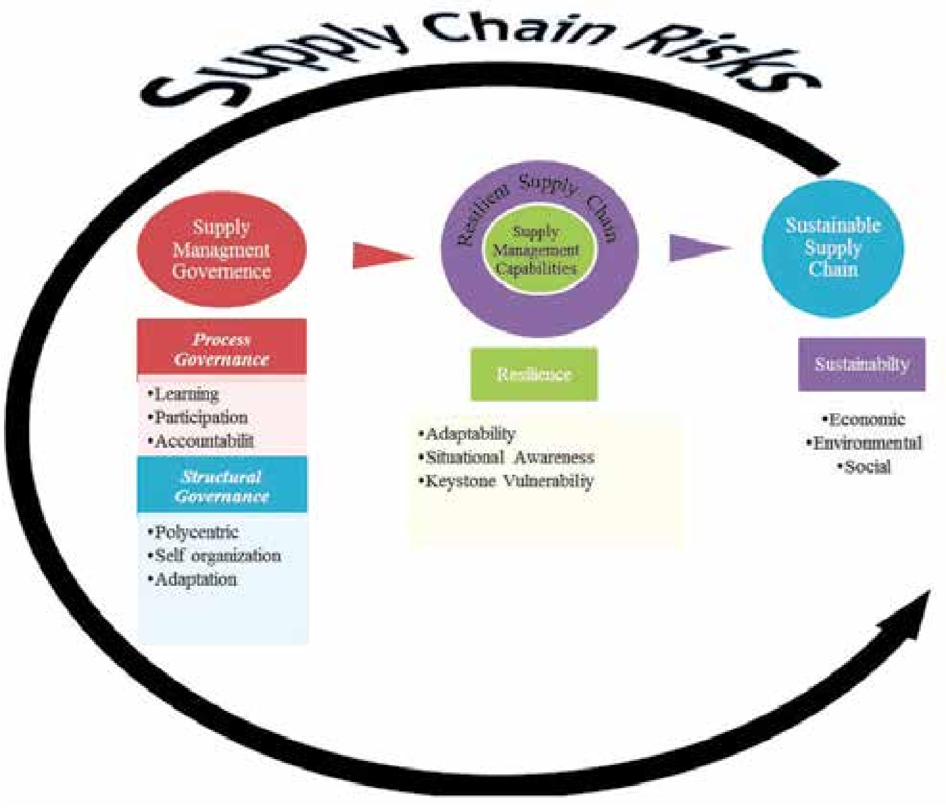

Fig. 2. Proposed Framework of Supply Management Governance Role in Supply Chain Risk Management and Sustainability

Proposition 2a: Supply chain ecological resilience is evidenced by its members' situational awareness of their operating and external environment.

Keystone vulnerabilities define those aspects of a supply chain that have the potential to have significant negative impacts in a crisis situation. This capability addresses the temporal aspect of sustainability and survival goals. The impacts of keystone vulnerabilities may be either catastrophic or insidious. Management of keystone vulnerabilities defines those aspects of an organization, operational and managerial, that have the potential to have significant negative impacts in a crisis situation. It is important for organizations to also have access to the links between supply chain components and the vulnerabilities that may arise from these also. These may include specific tangible organizational components such as: buildings, structures and critical supplies, individual managers, decision makers and subject matter experts. They may also include less tangible components, for example: relationships between key groups internally and externally, communications structures, and perception of the organizational strategic vision.

Proposition 2b: Supply chain ecological resilience is evidenced by its members' access to keystone vulnerabilities.

Adaptive capacity is a measure of the culture and dynamics of an organization that allow it to make decisions in a timely and appropriate manner both in day-to-day business and also in crises. Adaptive capacity is a measure of the culture that allows it to make decisions in a timely and appropriate manner both in day to day business and also in crises. Adaptive capacity considers aspects of a supply chain such as the leadership and decision making structures, the flow of information and knowledge and the degree of creativity and flexibility that the organization promotes or tolerates. Toyota's capacity to overcome the damage of 2011's tsunami in Japan and the speed of such recovery depends on their leadership and decision making structures, the acquisition, dissemination and retention of information and knowledge, and the degree of creativity and flexibility that the organization promotes or tolerates.

Proposition 2c: Supply chain ecological resilience is evidenced by its members' adaptive capacity.

3.2 Supply management governance

In this study, the vehicle to strengthening the capacity of a supply chain to ensure ecological resilience is proposed to be via supply management governance; i.e., structures and processes intended to coordinate and integrate various dimensions of the supply management. Governance represents the structures and processes by which societies share power, also shapes individual and collective actions (Young, 1992). Firms should be deliberate in devising and implementing appropriate supply management governance mechanisms to safeguard against such market imperfections and supply chain uncertainties. Such governance mechanisms make it possible to achieve supply chain ecological resilience, thus enabling the firm to adapt rapidly while retaining coherence even as its supply chain continues to expand. But the question is "which forms of supply management governance are required to achieve supply chain ecological resilience?"

Williamson (2008) points to three styles of supply chain governance that foster sustainability: muscular, benign and credible. Under the muscular approach one of the parties holds the balance of power, and does not hesitate to exercise it. "Muscular buyers not only use their suppliers, but they often 'use up' their suppliers and discard them." The muscular approach to outsourcing of goods and services is "myopic and inefficient." The benign approach is well, too benign because it assumes that cooperation to deal with unforeseen contingencies and achieve mutual gains will always be there. Trust should not necessarily supplant power entirely and indefinitely, Williamson argues, and that is where the credible part comes in. The credible approach to governance is hardheaded (no benign behavior allowed!) but not mean-spirited (as in muscular). In this study, it is proposed that using a credible governance approach in supply management is a precondition to supply chain ecological resilience.

Proposition 3: Deliberate interventions in the form of supply management credible governance determine the extent of supply chain ecological resilience.

Credible supply management governance arises out of the awareness that complex contracts with suppliers and clients are "incomplete and thus pose cooperative adaptation needs" and require the exercise of "feasible foresight." Credible supply management governance maintains supply chain's capacity for renewal in a dynamic environment, provides an ecological buffer that protects the system from the failure as a result of management actions that are taken based upon incomplete understanding, and it allows managers to learn and change.

Credible supply management structural governance includes polycentric mechanisms, supply management self-organization mechanisms and supply management adaptation mechanisms

Supply management polycentric mechanisms are deployable in multilayered institutions and supply chains to improve the fit between knowledge, action, and social-ecological contexts in ways that allow firms and supply chains to respond more adaptively at appropriate levels. Such mechanisms allow access to keystone vulnerabilities and exchange of relevant intelligence among the extended tiers of a supply chain.

Proposition 4a: Managers of sustainable supply chains will employ polycentric mechanisms to improve the fit between knowledge, action, and supply chain contexts in ways that allow firms to respond more adaptively at appropriate levels.

Supply management self-organization mechanisms allow the supply chain to maintain and re-create its identity. Dramatic change has occurred in the last two decades in how supply chains operate. In today's interconnected and information-laden world, supply chain problems increasingly transcend the jurisdictional boundaries of one firm and their specialized functions agencies at all levels. When crises take place self-organizing governance enables the emergence of collaborative institutions in which multiple agencies, and other stakeholders work together to solve problems that affect them. As new vulnerabilities emerge, supply chain they can constituents are expected to self-organize into new networks and sub-networks as required by the situation. Communication and information sharing through technology and access to common data structures enables self-organization mechanisms. The natural evolutionary process for organizations coming together to solve complex problems, i.e., new infrastructure, is based on the relational and structural embeddedness (Bernardes, 2010). The key element in deploying and nurturing this new infrastructure is to design a governance structure where ideas, creativity, and collaboration can thrive. A centralized, top-down governance structure would not have the capacity to adapt quickly to changes in a diverse, technologically dependent entity the supply chain of today.

Proposition 4b: Managers of sustainable supply chains will use self-organization mechanisms that allow the supply chain to maintain and re-create its identity.

Supply management adaptation mechanisms allow the supply chain to get better at pursuing a particular set of management objectives over time and at tackling new objectives when the context changes. With the traditional serialized form of interactions, buyers, suppliers and logistic providers have obstructed views and limited visibility into the activities within the supply chain. Adaptation mechanisms enable full visibility of the supply chain, which allows transforming efforts and strategy to new goals when needed.

Proposition 4c: Managers of sustainable supply chains will use adaptation mechanisms that allow the supply chain to get better at pursuing a particular set of management objectives over time and at tackling new objectives when the context changes.

On the other hand, credible supply management processes governance involves mechanisms that facilitate learning, participation of supply chain constituents, and a sense of accountability.

Learning mechanisms allow for acceptance of the inevitability of change and experimentation. From more influential to less, social mechanisms of governance, hostages and behavioral control should favor knowledge sharing, learning and performance in supply chains. Learning governance mechanisms allow for tacit knowledge generational transfers from senior to junior employees. It allows institutions to train new employees to support the infrastructure of the supply chain, and it allows operational efficiencies to emerge as the learning curve is descended.

Proposition 4d: Managers of sustainable supply chains will employ mechanisms that facilitate learning and acceptance of the inevitability of change and experimentation.

Participation of supply chain constituents is based on mechanism designated to build trust and deliberation among supply chain constituents, which, in turn, leads to the shared understanding needed to mobilize and self-organize. If performance on either dimension of sustainability (economic such as responsiveness or efficiency or environmental, or social) is less than desirable, the supply chain and/or its participant firms must create or alter strategies in order to improve performance. The challenge in and the success of altering strategies stems from the capacity to identifying, collecting, disseminating, and utilizing relevant intelligence into the strategy formation process. This reflects a need for multi-layered inter-organizational sharing of knowledge. Particularly, when supply chain problems involve multiple supply chain participants and their respective knowledge sets, establishing the need for sharing and some form of collective action becomes an imperative aspect of process governance.

Proposition 4e: Managers of sustainable supply chains will foster participation of supply chain constituents to build trust and deliberation among supply chain constituents, which, in turn, leads to the shared understanding needed to mobilize and self-organize.

A sense of accountability governance pursues just distributions of benefits and involuntary risks enhance the adaptive capacity of vulnerable groups and the supply chain as a whole. The importance of accountability in global complex supply chains has never been more evident than today, following the debacles of some large firms and corporate financial scandals. Resilient supply chains, being situationally aware and adaptive, instill accountability governance today to correspond to external regulations as well as pressures from other stakeholders. Accountability is a key element as for supply chain governance, fortifying the latter in such a way that it provides a transparent template for managing keystone vulnerabilities, i.e., governing critical decisions, procedures, and activities. Today's supply chain's environment is a richer yet more complex than ever. Accountability governance deals with a larger number of cross-border stakeholders whose interests are frequently contradictory, facing more difficulties in controlling decision-makers in globally dispersed yet differentiated supply chains, and encounters greater pressure in the balance between accountability governance and efficiency.

Proposition 4f: Managers of sustainable supply chains will engender a sense of accountability to pursue just distributions of benefits and involuntary risks enhance the adaptive capacity of vulnerable groups and the supply chain as a whole.

4. Conclusions

This study proposes that sustainable supply chains will employ polycentric mechanisms to improve the fit between knowledge, action, and supply chain contexts in ways that allow firms to respond more adaptively at appropriate levels. They are expected to deploy self-organization mechanisms that allow the supply chain to maintain and re-create its identity and adaptation mechanisms that allow the supply chain to get better at pursuing a particular set of management objectives over time and at tackling new objectives when the context changes.

This form of supply management processes governance involves mechanisms that facilitate learning (acceptance of the inevitability of change and experimentation); participation of supply chain constituents (building trust and deliberation among supply chain constituents, which, in turn, leads to the shared understanding needed to mobilize and self-organize); and a sense of accountability (pursue just distributions of benefits and involuntary risks enhance the adaptive capacity of vulnerable groups and the supply chain as a whole).

5. Managerial implications

One of the first reactions supply managers may have in dealing with risk is to grab for greater control (Guinepero and Eltantawy, 2004). This usually leads to increased vulnerabilities to economic risks. Therefore, it is up to the top management and supply managers to instill the governance mechanisms that aid supply chains to adapt and transform in correspondence to vulnerabilities. The proposed framework has great potential for providing management insight into their strengths, weaknesses, and priorities. Firms must first identify their current resources and strengths - what they can do more effectively than their rivals. First, by identifying their external and internal supply chain vulnerabilities. To manage supply chain risks and develop the resilience needed to compete today, supply professionals need to coordinate the relationships in the supply chain and increase the flow of information and communication efforts. Thus, hiring and developing employees is the key to managing risks in supply chain. It is equally important as well that top management allow purchasing the freedom to pursue potentially risky endeavors as long as appropriate plans to manage risks are developed (Giunipero and Eltantawy, 2010).

This study aims at crystallizing the requisite SM governance and capabilities to supply chain sustainability. These capabilities are relevant and valuable when supply chains and their constituent members are risk aware and receptive to external stakeholder pressures. Early movers in the field of resilient and sustainable supply chains are expected to reap competitive benefits to a notable extent as a result of resource accumulation and learning processes over time.

Firms need to identify their highly rated capabilities and a detailed stock of information on their strengths. Deliberate interventions in the form of supply management credible governance determine the extent of supply chain ecological resilience. Managers of sustainable supply chains will employ polycentric mechanisms to improve the fit between knowledge, action, and supply chain contexts in ways that allow firms to respond more adaptively at appropriate levels. They are expected to deploy self-organization mechanisms that allow the supply chain to maintain and re-create its identity and adaptation mechanisms that allow the supply chain to get better at pursuing a particular set of management objectives over time and at tackling new objectives when the context changes.

The framework provides managerial guidance for setting priorities to create a governance mechanisms and strategy for improving supply chain resilience and sustainability. However, resilience is not simply a matter of strengths, but it is the balance between capabilities and vulnerabilities that creates a firm's true competitive advantage (Pettit et al., 2010). Therefore, periodic assessment of the supply management governance and capabilities as well as resilience of the supply chain is necessary.

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Reverse Supply Chain Management - Modeling Through System Dynamics

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1. Introduction

Supply Chain Management (SCM) is one of the disciplines of Operations Management that has developed the most over the last few years. Within Supply Chain Management, Green Supply Chain Management (GSCM) is a relatively young area which has great prospects for the future, due to the increasing deterioration in the environment, the shortage of material resources, the overfilling of rubbish dumps, the increase in pollution levels, the requirements of the legislation and the pressures of consumers ever more aware of the environment. One of the areas of most interest in the study of GSCM is Reverse Logistics.

Many experts have adopted the slogan of "the three Rs" (Reduce, Reuse, Recycle) to promote environmental awareness in the production process. Reprocessing is a combination of "the three R's" in one same activity (Ferrer 2001). Examples of items that can be directly reused without prior repair (except for cleaning and a minimum maintenance) are returnable packaging like bottles, pallets, and containers. In some businesses, customers have the legal right to return products purchased within a specific space of time. In these cases, the money is refunded in whole or in part and the product can be resold if it is of sufficient quality and if there is still demand for it (Mostard, Teunter 2006). Personal computers can be reused by replacing their hard disks, processors, by adding extra memory or a modem for internet, and even screens, keyboards and memories can be sold on to a toy company (Inderfurth, de Kok & Flapper 2001). The packaging returned to companies is generally reused. Pallets and containers can often be restored and returned for reuse (Rogers, Tibben-Lembke 1999). The goal of repair is to restore a product that has failed to make it work properly again with a slight loss of quality. Some examples are household appliances, industrial machinery and electronic equipment. Recycling involves the recovery of material without maintaining the original structure of the product. Examples of recyclable materials are paper, glass and plastics. Reprocessing retains the identity of the original product with the aim of making the product “like new” again by disassembling, upgrading and replacing the appropriate parts. Examples of items that can be reprocessed are airplanes, machine tools and photocopying-machines.

2. Legislative pressure

Many industrialized countries in Europe have strengthened their environmental legislation by laying the responsibility for reverse logistics flows, including used products and waste products, in the hands of the manufacturers (Fleischmann et al. 2000).

There are numerous ways to minimize the environmental costs of production, but the prevention of waste from the products eliminates many environmental costs before they occur. A material recovery system, based on environmentally recoverable products, includes strategies for increasing the lifespan of products consisting in the repair, reprocessing and recycling of products (Jayaraman, Guide & Srivastava 1999). Waste reduction has received increasing attention in industrialized countries in view of the exhaustion of the capacity of landfills and incineration. One of the most widely used measures is that of the obligation to return products after use. In Germany, for example, the packaging law of 1991 requires industries to recover the packaging of the products sold and imposes a minimum percentage of recycling. The electronic equipment law of 1996 establishes similar recycling targets for electronic products. In the Netherlands, the automobile industry is responsible for the recycling of all used cars (Cairncross 1992, in (Fleischmann et al. 1997)). But even where the legislation is not so strict, the expectations of consumers put a lot of pressure on companies to take into account environmental aspects (Vandermerwe and Oliff, 1990 at (Fleischmann et al. 1997)). A "green" image has become an important element of marketing. To comply with this legislation, several German companies developed the Dual System Deutschland ("DSD") in order to meet quotas for the recycling of different types of packaging.

The European Commission presented a set of bills on the collection and recycling of electrical and electronic waste in April 1998. This law sets targets for waste electrical and electronic equipment ("WEEE"), to increase recycling, reduce hazardous substances, and to make the waste safer. The standard includes a wide variety of electronic products such as mobile phones, video games, toys, domestic appliances and office equipment. Norway has announced plans to require manufacturers and importers of electronic equipment (EE) to collect the used products and waste materials. Half a dozen enterprises have undertaken to collect 80% of EE waste in Norway. Following the principle of "the polluter pays", the system will be financed by a tax on new electronic products. In some industries, it is the government that does the collecting, as in the Swedish battery industry. In some cases, installation networks are organized and used by the industry as in the case of the Swedish automobile industry and in other cases, companies must set up their own collection centers.

3. System dynamics: Concept, origins and applications

One of the most widely accepted definitions is the one proposed by Wolstenholme (Wolstenholme 1990, in (Pérez Ríos 1992)):

"System Dynamics is a rigorous method for qualitative description, exploration and analysis of complex systems in terms of their processes, information, organizational boundaries and strategies; which facilitates quantitative simulation, modeling and analysis for the design of the system structure and control".

In the 1950s, Jay Forrester, a systems engineer at MIT, was commissioned by the US company Sprague Electrics to study the extreme oscillations of their sales and establish a means to correct them. From previous experience, Forrester knew the essence of the problem stemmed from the oscillations present in situations that contain inertia effects, or delays and reverse effects, or feedback loops as basic structural characteristics.

In 1961, Forrester published his work "Industrial Dynamics" (Forrester 1961) which marks the beginning of the "System Dynamics" technique as a procedure for the study and simulation of the behavior of social systems. In 1969, the work "Urban Dynamics" was published, explaining how system dynamics modeling is applicable to city systems. "World Dynamics" or "The World of Work" appeared in 1970, a work that served as a basis for Meadows and Meadows to make the first report to the Club of Rome, a work which was published with the name of *Limits to Growth* (published in Spanish by the Fondo de Cultura Económica, México, 1972). The great merit of this book is that it was published a year before the raw materials crisis of 1973, and that it foresaw in part its consequences. This work popularized Systems Dynamics on a worldwide scale.

At present, Systems Dynamics is a widely used technique for modeling and studying the behavior of all types of systems which have the above-mentioned characteristics of delays or feedback loops.

These characteristics are especially pronounced and intense in social systems so that these systems often show unexpected and unpredictable behavior.

System dynamics is applied in a wide range of fields. During its more than 40 years of existence, it has been used to build computer simulation models in almost all of the sciences, such as business administration, urban planning, engineering and in sociological systems where it has found many applications, from more theoretical aspects such as the social dynamics of Pareto and Marx, to issues of the implementation of justice. One area in which several important applications have been developed is that of environmental and ecological systems, focusing on problems of population dynamics and the spread of pollution. Another interesting field of application is that of energy supply systems, where it has been used to define strategies for the use of energy resources. It has also been used for defense issues, simulating logistical problems of the evolution of troops and other similar problems.

The system dynamics perspective is radically different from that of other techniques applied to the modeling of socioeconomic systems, such as econometrics. Econometric techniques, based on a behavioral approach, use empirical data as the basis of statistical calculations in order to determine the meaning and correlation between different factors. The evolution of the model is based on the past performance of the so-called independent variables, and statistics is applied to determine the parameters of the system of equations that relate these to the other so-called dependent variables. These techniques seek to determine the behavior of the system without entering into the knowledge of their internal mechanisms. Thus, many models for investing in the stock market analyze the peaks and valleys in the prices, the boom and bust cycles, etc. and design strategies to minimize the risk of loss, etc. They do not, then, attempt to "know" why a company's market value rises or falls as a function of its new products, new competitors, etc.

In contrast, the basic aim of System Dynamics is to work out the structural causes that provoke the behavior of the system. This involves increasing awareness of the role of each element of the system and seeing how different actions, performed on the parts of the system, intensify or attenuate its implicit behavioral tendencies.

Since its first appearance, there have been numerous applications of system dynamics to corporate policies and strategic issues, though few publications have applied system dynamics to the supply chain and most of these have been applied to the direct supply chain. Forrester (Forrester 1961) includes a supply chain model as an early example of applying the system dynamics methodology. Towill (Towill 1995 in (Vlachos, Georgiadis & Iakovou 2007)) applies system dynamics to the redesign of the supply chain. Minegishi and Thiel (Minegishi and Thiel (2000) in (Vlachos, Georgiadis & Iakovou 2007)) apply system dynamics to improve understanding of the complex behavior of logistics in an integrated food industry. Sanghwa and Manday (Manday Sanghwa and 1996 in (Vlachos, Georgiadis & Iakovou 2007)) investigate the effective control of information in a producer-distributor system by means of automatic feedback control techniques. Sterman (Sterman 2000, (Vlachos, Georgiadis & Iakovou 2007)) presents two case studies where system dynamics models are applied to problems of reverse logistics. In the first, Zamudio-Ramirez (Zamudio-Ramirez 1996, (Vlachos, Georgiadis & Iakovou 2007)) analyses the recovery of parts and the recycling of materials in the automobile industry in the United States in order to offer some impressions on the future of automobile recycling. In the second, Taylor (Taylor 1999, in (Vlachos, Georgiadis & Iakovou 2007)) focuses on the mechanisms of the recycled paper market which often shows instability and inefficiency in terms of flows, prices, etc. Georgiadis and Vlachos (Georgiadis, Vlachos 2004) apply system dynamics to estimate stocks and flows in the reverse supply chain while providing a framework for estimating the annual reprocessing capacity.

4. Description of proposed model

4.1 General description

This part of the chapter describes the development of a dynamic simulation model that facilitates the evaluation of the long-term policies of expansion of collection capacity and reprocessing capacity in a reverse supply chain with just one product. Although the analysis of the model may differ from one product to another, for the purpose of this work which is the development and proposal of the model, the reference product will be as generic as possible in order to facilitate its future implementation in a wide range of real cases. The mathematical formulation of the model is a system of differential equations solved through simulation. There is high-level software available at present that makes the simulation and analysis of these systems more accessible; in this work, the software used was Vensim, The Ventana Simulation Environment. Vensim® PLE for Windows version 5.10e Copyright© 1988-2010 Ventana Systems, Inc.

The system under study comprises the following operations: raw materials supply, production, wholesale and retail distribution, sale, use, collection, inspection, reprocessing, controlled disposal (stock or destroy) and delivery to secondary markets.

The model proponed is based on that proposed by Vlachos and Georgiadis (Georgiadis, Vlachos 2004) for the study of the impact of the effects of regulation and the "green image" on reverse logistics systems with reprocessing and which has been further developed in subsequent works (Vlachos, Georgiadis & Iakovou 2007, Georgiadis, Vlachos & Tagaras 2006).

The contributions made in this work to the last version of Vlachos and Georgiadis' Model are as follows:

The number of links in the direct chain was increased from 2 to 4 to incorporate wholesalers and retailers into the chain. This helps to show more clearly the appearance of the Bullwhip or Forrester effect.

Costs incurred by disinvestment through reductions in the reprocessing capacity or the collection capacity have been considered.

The option of sending the product to secondary markets to recover its value at the end of its lifespan has been introduced.

A line of revenue has been included which represents the recovery of the value of the products when these are sent to secondary markets.

Figures 1 and 2 show respectively the causal diagram and flowchart of the proposed model. Figure 3 shows the flowchart of the cost and revenue model. The description of the variables, ordered alphabetically, is presented in Annex 1. The model equations are set out in Annex 2.

4.2 Explanation of causal diagram

The direct chain begins with the procurement of raw materials (MP) from suppliers. The production ratio (PR) is determined using the stock management structure proposed by Sterman (Sterman 1989). Thus, the of production ratio (PR) is obtained by combining the difference between the expected demands of the distributors (EDO) and the expected reprocessing ratio (RER) with the adjustment provided by the useful inventory (UI), depending on its desired value (UIDE). The production ratio (PR) is limited by the production capacity (PC). The useful inventory (UI) consists of new products through the production ratio (PR), which introduces new products according to their production time (PT) and reprocessed products (REP) through the reprocessing ratio (RPR), which introduces reprocessed products according to their reprocessing time (RPT). Through the useful inventory (UI), the intention is to cover as far as possible the orders from the distributors (OB) through deliveries to the distributors (SD), which, in terms of time, means the delivery time taken to reach the distributors (DST) increasing at this rate the distributors' inventory (DI). The distributors' orders (OB) are made in keeping with the control rule given by Sterman (Sterman 1989). This process is repeated in the same way in the links of the wholesalers and retailers, except that in these cases, rather than linking the useful inventory (UI) with the distributors' inventory (DI), the distributors' inventory (DI) will be linked with that of the wholesalers (MI) and the wholesalers' inventory (MI) will be connected to the retailers' inventory (RI). All unmet orders become backorders which are satisfied after a period of time. The retail inventory (RI) attempts to meet demand (D) through sales (S), just as the backorder (DB) is satisfied after a period of time (DCT). The demand (D) has been represented by the life cycle of the generic product. The sales (S), after their residency period (RT), become used goods (UP) that can be collected for reuse (CP) or disposed of in an uncontrolled manner (UDP and UD).

The reverse chain starts with the collected products (CP), which increase in keeping with the collection ratio (CR), which is limited by the collection capacity (COR), and decrease as the products are accepted for reuse (PARU) or rejected (PRR). The stock of reusable products (REP) is used for reprocessing if the reprocessing capacity (RPC), which limits the reprocessing ratio (RPR), is adequate.

To prevent the uncontrolled accumulation of reusable products (REP), the option of sending the products to controlled disposal (CD) has been proposed, if these are not used after a specified time of maintenance of reusable stock (RSKT). This also means that the products that go to be reprocessed are as recent as possible.

Once the demand (D) of the direct chain for the product falls, provision is made for the liquidation of the inventories of all of the direct supply chain members to send the product directly to the secondary markets (SMPO), thus recovering part of their value.

The collection capacity (COR) is revised at every stage in the simulation time so that it is virtually continuous and the decision to be made is whether to invest or disinvest in the collection capacity (COR) and to what extent. The ratios of expansion (CCIR) or contraction (CCRR) of the collection capacity depend on the discrepancy (CCDI) between the desired collection capacity (CCDE) and the current collection capacity (COR). The desired collection capacity (CCDE) is forecast based on time series of used products (UP). The magnitude of each expansion (CCER) or contraction (CCCR) is proportional to the discrepancy in the collection capacity (CCDI) at a given time and a lower limit has been established to prevent small changes from occurring very frequently.

The discrepancy in the collection capacity (CCDI) is multiplied by a parameter K_{c1} for expansion and K_{c2} for contraction, thus characterizing the two strategies for the planning of the collection capacity (COR). The strategies with high K_{c1} and K_{c2} values are more aggressive than those with lower values; however, in all cases, there is a time lapse (Tc1 and Tc2) between the time the decision is made and that of its effective implementation.

The ratio of the increase in collection capacity (CCIR) and the ratio of the reduction in collection capacity (CCRR) takes into consideration this time delay for the expansion in the collection and reduction capacities, respectively.

The causal diagram for the reprocessing capacity (RPC) is similar, the only difference being that the used products (UP) are replaced by Sales x (1-percent defective products) (Sx(1-FP)), which is used to forecast the desired reprocessing capacity (RCDE). The rest of the variables (Kr1,Kr2, Tr1, Tr2…) fulfil the same function as their equivalents in the collection capacity (Kc1,Kc2, Tc1, Tc2…)

The justification for using different sources of information in determining the collection (COR) and reprocessing (RPC) capacities lies in the fact that the objectives of these two operations are different. The purpose of the collection is twofold:

To supply the reprocessing process

To ensure the controlled disposal of the used products at the end of their useful life.

The aim of reprocessing is to satisfy the major part of the demand (D); thus, the reprocessing capacity (RPC) is of no use at the end of the life cycle of the product. This explains why the desired reprocessing capacity (RCDE) is linked to the sales (S) and the desired collection capacity (CCDE) is linked to the used products (UP).

Figure 1 shows the causal diagram used in the conceptual part of the model. This is a useful diagram for establishing relationships between the different variables. The relationships shown are of two types: the links indicated by a continuous line correspond to material flows and those represented by dashed lines correspond to information flows.

The nature of the links has also been considered, indicating with a "+" sign direct relations, that is those in which there is a direct proportionality, meaning that when one of the variables increases, the one linked to it also increases (+) and vice versa - if the value of the variable decreases the one linked to it (+) also decreases. The complementary case is indicated by a (-) sign, meaning that the relation is proportionally inverse: that is, when one of the variables increases, the one linked to it (-) decreases and vice versa – if the value of the variable decreases, the one linked to it increases.

Since it is generated in the design stage of the model, the causal diagram does not include some of the parameters that will be required later in the modelling phase (Tc1, Tc2, a-CC…). Nor does it indicate the nature of the flow or the level of each variable. All of this information is included when the model is made and the Forrester diagram or flow diagram is generated (fig.2).

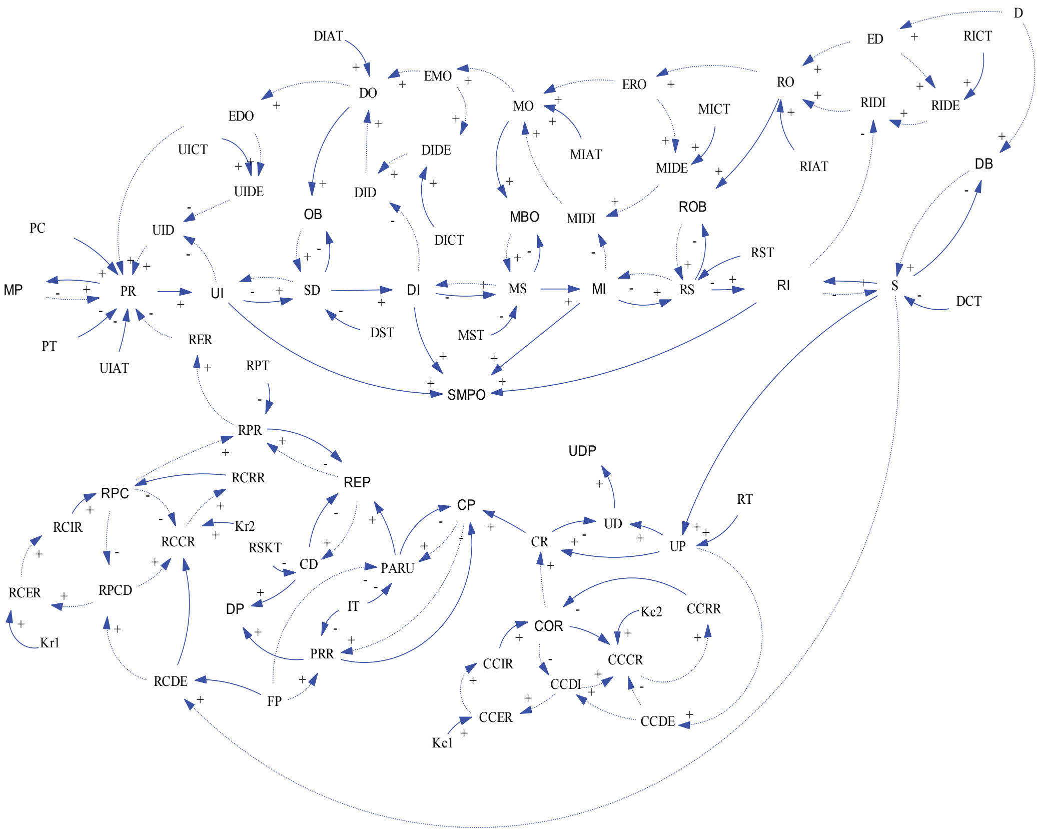

Fig. 1. Causal diagram of the proposed model. (Information on variables in Annex 1 and model ecuations in Annex 2)

Figure 2 shows the flow chart of the model. In this case, the material flows are represented by double-line arrows and the information flows by single line arrows.The chart below now includes all the variables involved in the model and indicates their nature:
The level variables are represented inside rectangles. These variables have an accumulation of material and therefore are linked to material lines.
The flow variables are those that indicate the variation of the level variables and are represented by a hydraulic wrench symbol.
The rest of the elements of the model are variables without accumulation and parameters.
Figure 3 shows the flow chart of the economics part of the model. On the left are shown all the operating costs associated with the model which are: Weekly cost of useful inventory storage (UISWCOST), weekly cost of transport to distributors (DTWCOST), weekly storage cost of distributors (DISWCOST), weekly cost of transport to wholesalers (MTWCOST), weekly cost of wholesalers' inventory storage (MISWCOST), weekly cost of retailers' inventory storage (MSIWCOST), weekly cost of transport to retailers (RTWCOST), weekly cost of transport of sales (STWCOST), weekly cost of reusable product storage (RSPWCOST), weekly production cost (WPCOST), weekly cost of reusable storage (RPWCOST) and weekly cost of collection (CWCOST). On the right are represented the

investment costs of the model: weekly collection capacity cost (CCWCOST) and weekly reprocessing capacity cost (RCWCOST). At the bottom are shown the sales revenue of the model (SI) and the various revenues from inventory liquidation (PLIR, DILI, MILI, ILPIs). The net present value of the entire supply chain (NPVWN) is represented in the centre of the figure.

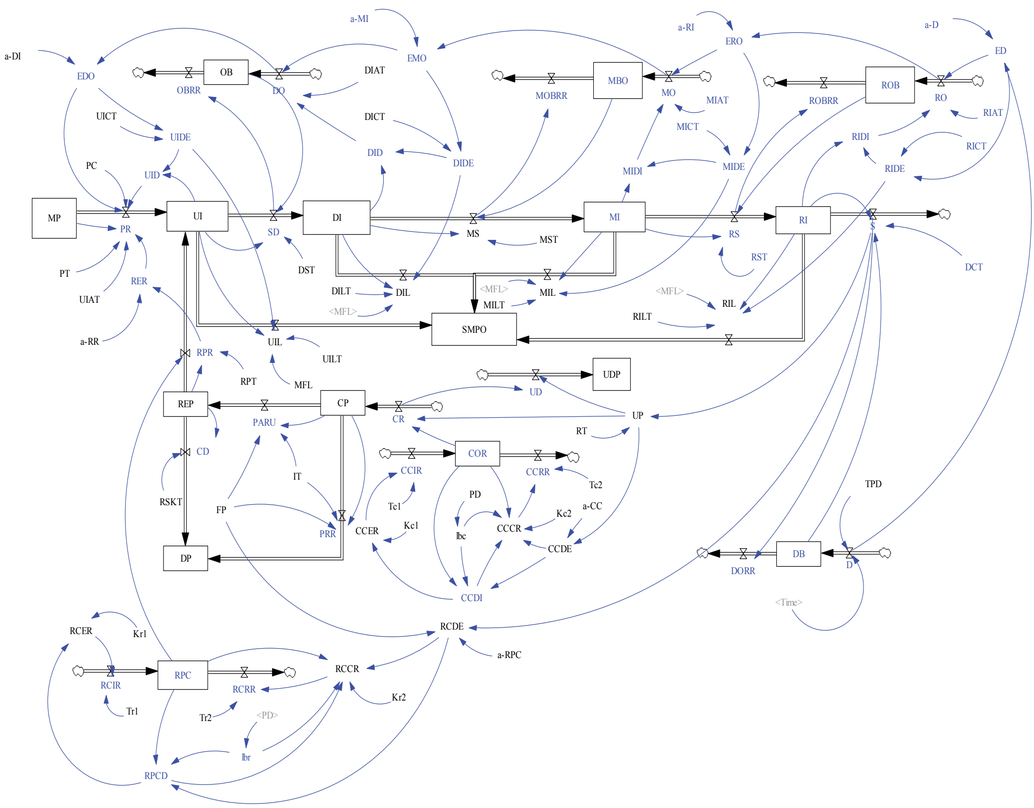

Fig. 2. Flowchart of the proposed model. (Information on variables in Annex 1 and model ecuations in Annex 2)

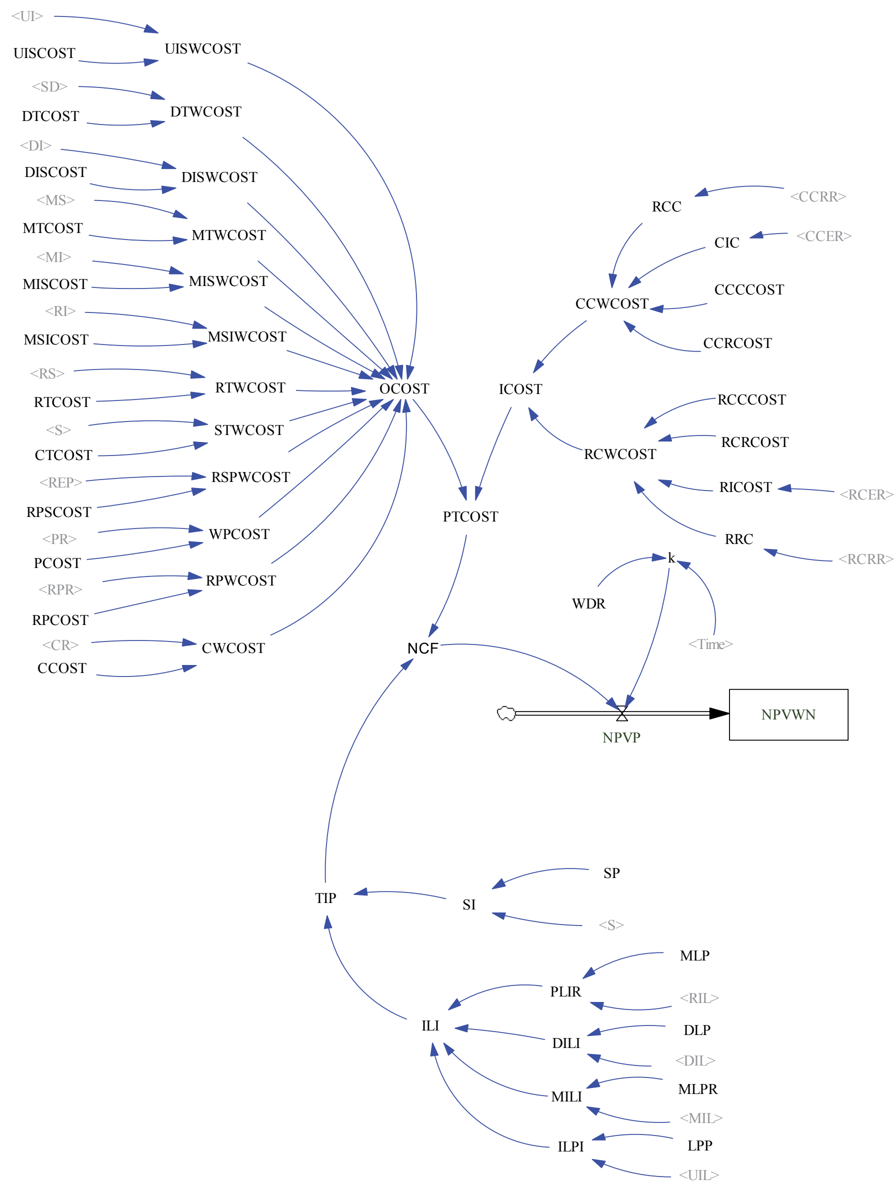

Fig. 3. Flowchart of the proposed costs and revenues model. (Information on variables in Annex 1 and model ecuations in Annex 2)

5. Simulation results

The demand (Fig.4) has been estimated for a product with a life cycle of 250 weeks (approx. 5 years), establishing the demand in the period of maturity at 1,000 units/week.

As the links of the supply chain advance, it can be observed that the inventories expand in order to meet the demands of each of these according to the coverage times set for their safety stocks. (Fig. 5)

As the product life cycle advances, a greater quantity of reprocessed products than new products is manufactured (Fig. 6). It can be seen that there is a delay between the end of the shelf life of the product and the cessation of production activities. This delay leads to an upturn in the supply chain inventories as the material continues to flow even though there is no release to the market.

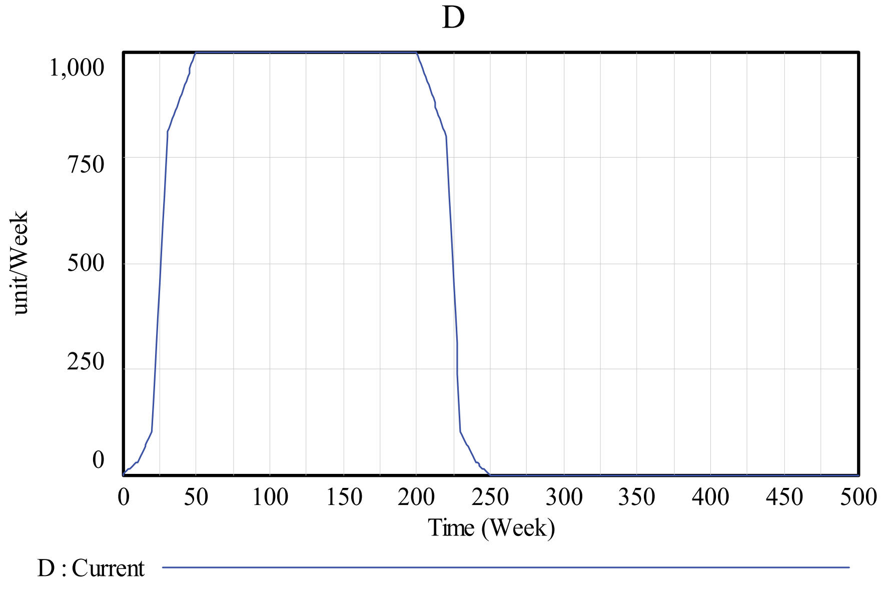

Fig. 4. Demand of simulation

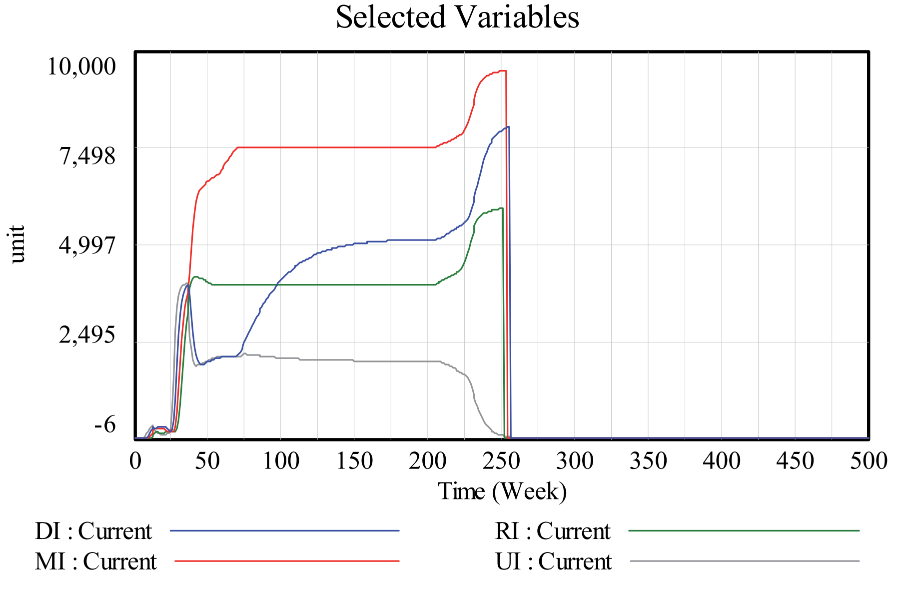

Fig. 5. Evolution of inventories

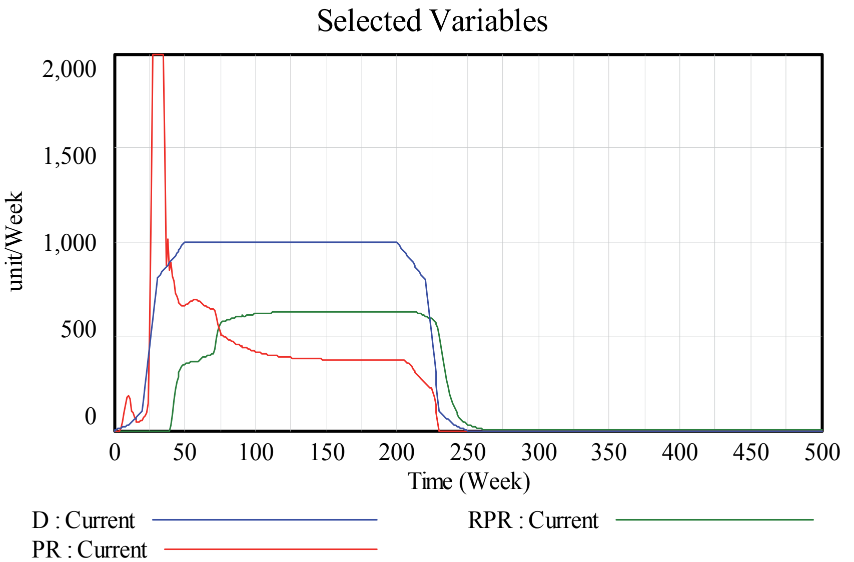

Fig. 6. Demand, production and reprocessing

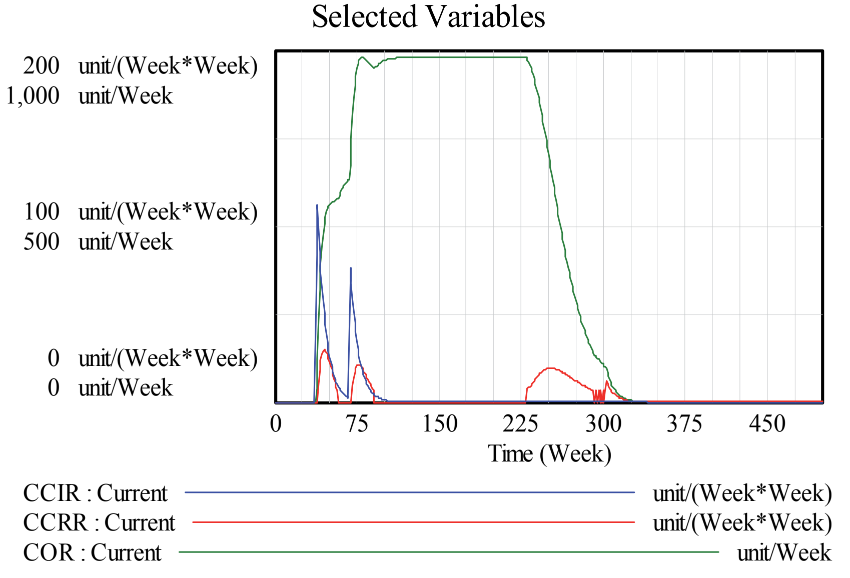

Fig. 7. Collection capacity

The collection capacity (Fig. 7) and the reprocessing capacity (Fig. 8) increase or decrease according to the growth or reduction decisions they receive.

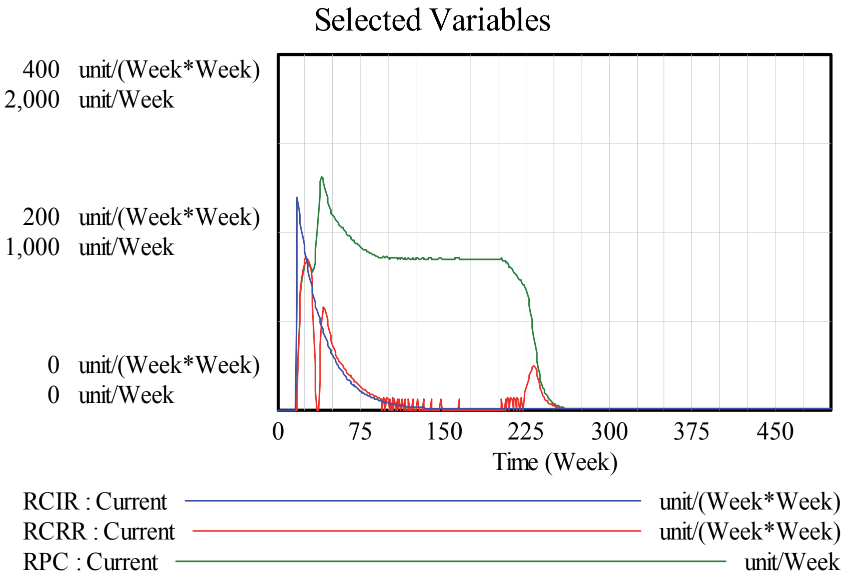

Fig. 8. Reprocessing capacity

For the residence time (Fig. 9), a random sample of values has been estimated according to a normal probability distribution with a minimum of 10 weeks, a maximum of 30 weeks, and an average of 20 weeks with a standard deviation of 2 weeks.

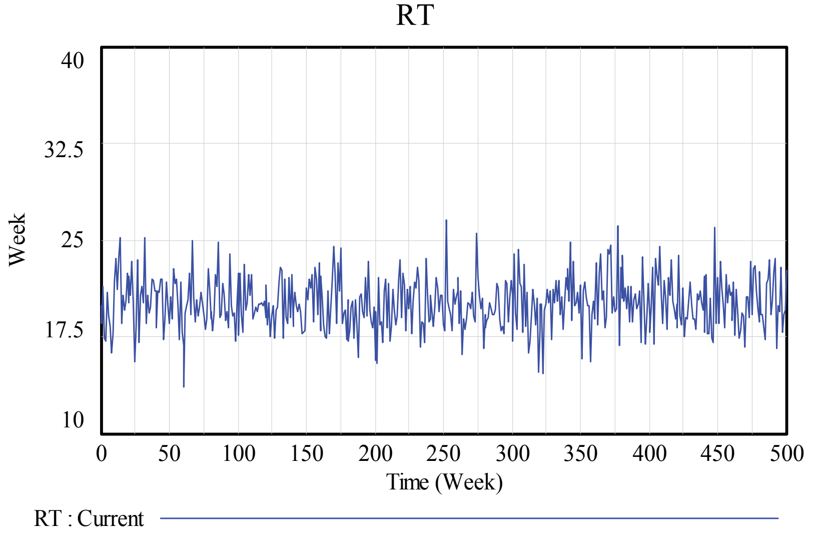

Fig. 9. Residence time

The volume of collected products usually exceeds the number of reusable products until the end of the life of the product, when it increases (Fig. 10).

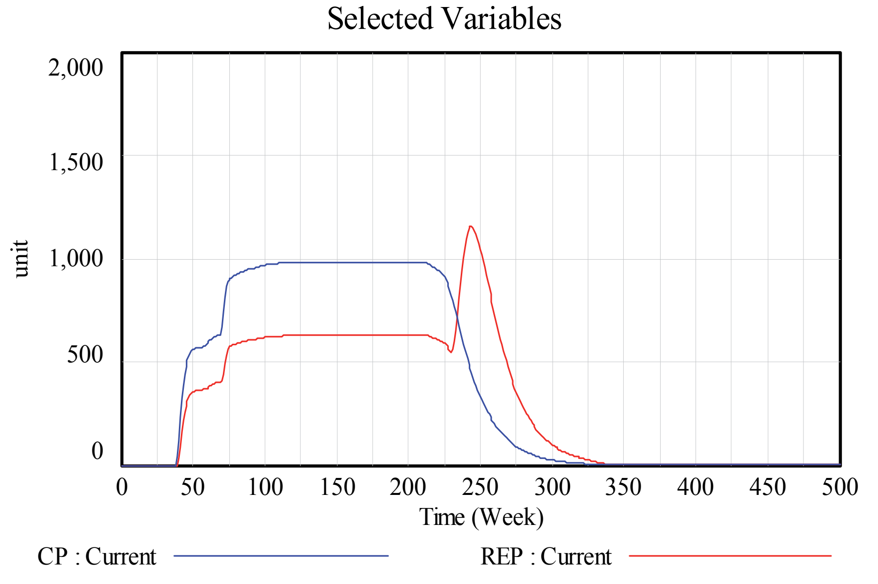

Fig. 10. Collected products and reusable products

The system also tends to ensure that the number of products disposed in an uncontrolled manner stabilizes at values lower than those of the controlled disposal (Fig.11)

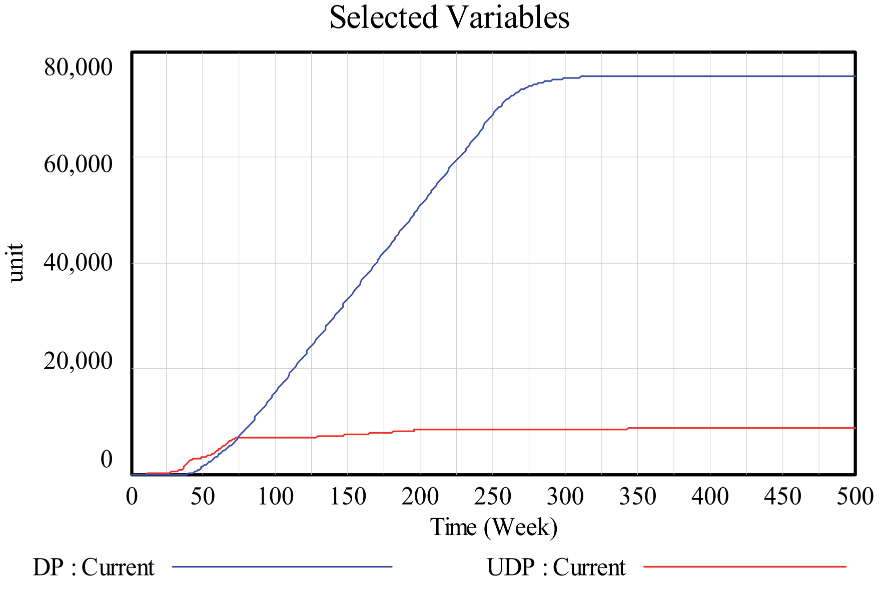

Fig. 11. Controlled and uncontrolled disposed products

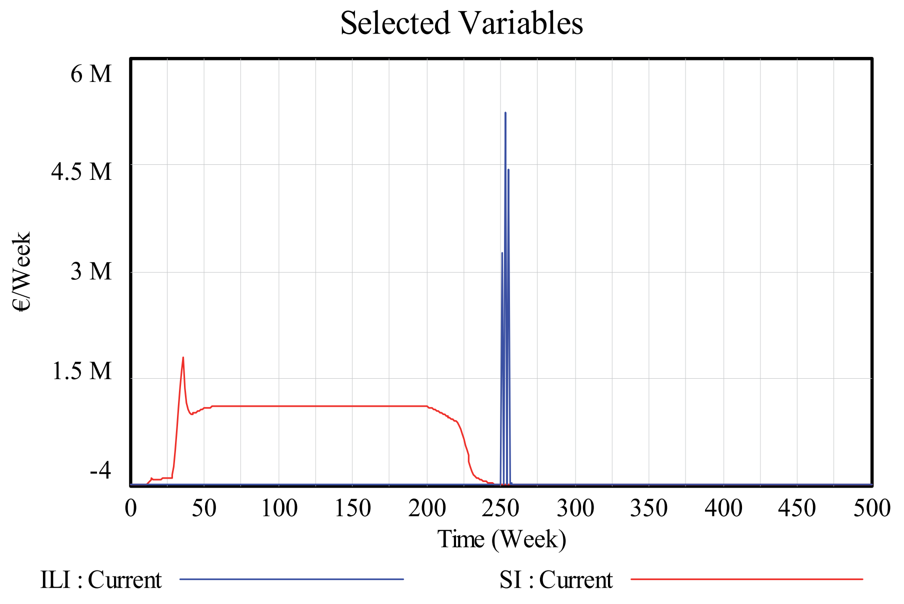

Fig. 12. Revenue

The revenue of the chain (Fig. 12) comes from sales and the final liquidation of the inventories.

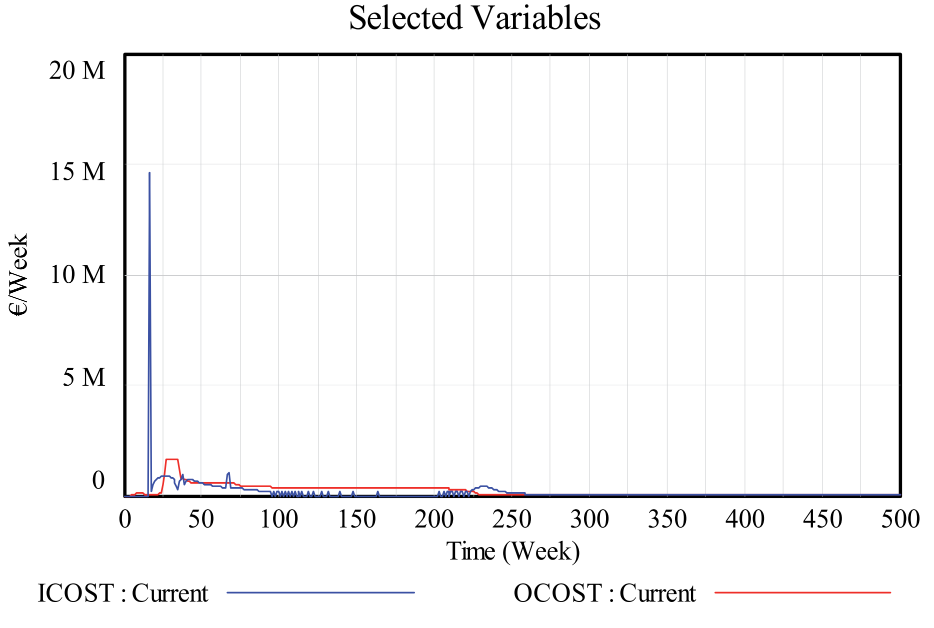

Fig. 13. Costs

The costs of the chain (Fig. 13) can either be operating costs or investment costs. The operating costs essentially correspond to storage, transport and production and reprocessing. The NCV of the whole chain has been estimated (Fig.14), showing that with the parameters set for this model, the investment is recovered after week 165. It can also be noted that there is a recovery of value as a result of the liquidation of inventories.

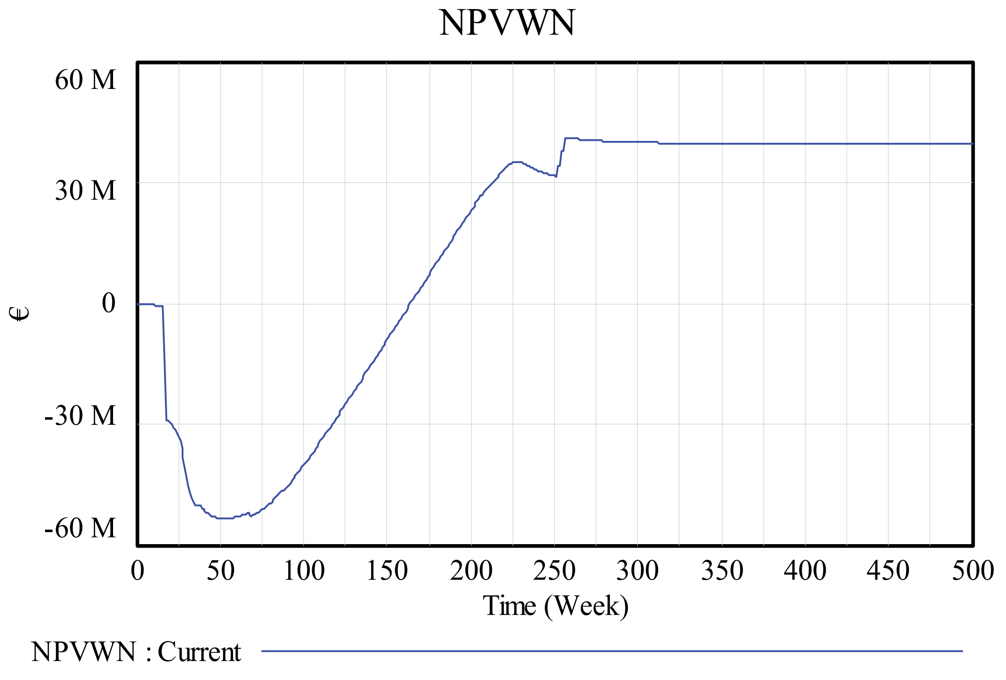

Fig. 14. Cumulative NCV of model

As anticipated at the beginning of this part of the section, the model is highly generic and the answers obtained can vary greatly as a function of the input parameters which are set according to the type of product and its life cycles. However, the parameters of expansion and contraction of the collection and reprocessing capacities (Kc1. KC2, KR1 and KR2) have a great impact on the results and this phenomenon should be analyzed in some future work.

6. Conclusion

The model developed represents quite accurately the behavior of a reverse supply chain for a single product with reprocessing, so that the main proposal of this part of the work is considered to be achieved. Phenomena such as the Bullwhip effect are represented in the model as well as phenomena such as saturation on reaching the peak of the productive capacity, and delays in the system responses resulting from the inertias acquired in the operations.

The assessment of costs and revenues represents the phenomena of investment and disinvestment in a logical way and the cumulative net present value shows that in the case simulated, gains are made and it is therefore viable. It should not be forgotten that this is a

test case, a dummy, so that depending on the type of product that the model is applied to, the economic results can vary significantly.
In short, we consider that modeling with system dynamics is an effective tool for describing reverse logistics systems due to the existence of delays and feedback loops. Moreover, system dynamics is a highly valuable and affordable method for performing simulations since all the variables and parameters are known; it is thus distinct form other simulation techniques that have more of a "black box" nature. Therefore we can conclude that it is a highly useful tool for decision-making.

7. Annex 1. Model variables

VARIABLE OR PARAMETER	SIGNIFICANCE OF VARIABLE OR PARAMETER
a-CC	Parameter of delay in collection capacity
a-D	Parameter delay in demand
a-DI	Parameter of delay in distributors' inventory
a-MI	Parameter of delay in wholesalers' inventory
a-RI	Parameter of delay in retailers' inventory
a-RPC	Parameter of delay in reprocessing
a-RR	Parameter of delay in reprocessing ratio
CCCCOST	Costs of constructions for collection capacity
CCCR	Ratio of contraction of collection capacity
CCDE	Desired collection capacity
CCDI	Discrepancy in collection capacity
CCER	Ratio of expansion of collection capacity
CCIR	Ratio of increase in collection capacity
CCOST	Collection costs
CCRCOST	Costs of reduction in collection capacity
CCRR	Ratio of reduction in collection capacity
CCWCOST	Weekly costs of collection capacity
CD	Controlled disposal
CIC	Coefficient of investment in collection
COR	Collection capacity
CP	Collected products
CR	Collection ratio
CTCOST	Costs of transport to clients
CWCOST	Weekly costs of collection

VARIABLE OR PARAMETER	SIGNIFICANCE OF VARIABLE OR PARAMETER
D	Orders
DB	Backorders
DCT	Time of delivery to clients
DI	Distributors' inventory
DIAT	Time of adjustment of distributors' inventory
DICT	Time of coverage of distributors' inventory
DID	Discrepancy with distributors' inventory
DIDE	Inventory of desired distributors
DIL	Liquidation of distributors' inventory
DILI	Revenue from liquidation of distributors' inventory
DILT	Time of liquidation of distributors' inventory
DISCOST	Cost of storage of distributors' inventory
DISWCOST	Weekly cost of storage of distributors
DLP	Distributors' liquidation price
DO	Distributors' orders
DORR	Ratio of reduction of backorders
DP	Waste products
DST	Time of delivery to distributors
DTCOST	Cost of transport to distributors
DTWCOST	Weekly cost of transport to distributors
ED	Expected demand
EDO	Orders expected from distributors
EMO	Orders expected from wholesalers
ERO	Orders expected from retailers
FP	Percentage of error
ICOST	Investment costs
ILI	Revenue from liquidation of inventories
ILPI	Revenue from liquidation of inventories of the plant
IT	Inspection time
Kc1	Parameter of increase in collection capacity
Kc2	Parameter of reduction in collection capacity
Kr1	Parameter of increase in reprocessing capacity

VARIABLE OR PARAMETER	SIGNIFICANCE OF VARIABLE OR PARAMETER
Kr2	Parameter of reduction in reprocessing capacity
LPP	Liquidation price in plant
MBO	Wholesalers' Backorders
MFL	Minimum for liquidation
MI	Wholesalers' inventory
MIAT	Time of adjustment of wholesalers' inventory
MICT	Time of coverage of wholesalers' inventory
MIDE	Inventory of desired wholesalers
MIDI	Discrepancy with wholesalers' inventory
MIL	Liquidation of wholesalers' inventory
MILI	Revenue from liquidation of wholesalers' inventory
MILT	Time of liquidation of wholesalers' inventory
MISCOST	Storage costs of wholesalers' inventory
MISWCOST	Weekly storage cost of wholesalers' inventory
MLP	Price of liquidation of retailers
MLPR	Price of liquidation of wholesalers
MO	Wholesalers' orders
MOBRR	Ratio of reduction in wholesalers' backorders
MP	Materials for processing
MS	Deliveries to wholesalers
MSICOST	Storage costs of retailers' inventory
MSIWCOST	Weekly storage costs of retailers' inventory
MST	Time of delivery to wholesalers
MTCOST	Cost of transport to wholesalers
MTWCOST	Weekly cost of transport to wholesalers
NCF	Net cash flow
NPVP	Current value of the period
NPVWN	Current net value of the whole network
OB	Backorders
OBRR	Ratio of reduction of backorders
OCOST	Operating costs
PARU	Products accepted for reuse

VARIABLE OR PARAMETER	SIGNIFICANCE OF VARIABLE OR PARAMETER
PC	Production capacity
PCOST	Production costs
PD	Peak demand
PLIR	Revenue from liquidation of retailers' inventories
PR	Production ratio
PRR	Products rejected for reuse
PT	Production Time
PTCOST	Total costs per period
RCC	Coefficient of reduction in collection
RCCCOST	Costs of constructions for reprocessing capacity
RCCR	Ratio of contraction in reprocessing capacity
RCDE	Desired reprocessing capacity
RCER	Ratio of expansion of reprocessing capacity
RCIR	Ratio of increase in reprocessing capacity
RCRCOST	Costs of reduction in reprocessing capacity
RCRR	Ratio of reduction in reprocessing capacity
RCWCOST	Weekly cost of reprocessing capacity
REP	Reusable products
RER	Expected reprocessing ratio
RI	Retailers' inventory
RIAT	Time of adjustment to retailers' inventory
RICOST	Coefficient of investment in reprocessing
RICT	Time of coverage of retailers' inventory
RIDE	Inventory of desired retailers' inventory
RIDI	Discrepancy with retailers' inventory
RIL	Liquidation of retailers' inventory
RILT	Time of liquidation of retailers' inventory
RO	Retailers' orders
ROB	Retailers' backorders
ROBRR	Ratio of reduction of retailers' backorders
RPC	Reprocessing capacity
RPCD	Discrepancy with reprocessing capacity

VARIABLE OR PARAMETER	SIGNIFICANCE OF VARIABLE OR PARAMETER
RPCOST	Reprocessing costs
RPR	Reprocessing ratio
RPSCOST	Cost of storage of reusable products
RPT	Reprocessing time
RRC	Coefficient of reduction in reprocessing
RS	Deliveries to retailers
RSKT	Waiting time for reusable stock
RSPWCOST	Weekly cost of storage of reusable products
RST	Time of delivery to retailers
RT	Time of residence
RTCOST	Cost of transport to retailers
RTWCOST	Weekly cost of transport to retailers
RWCOST	Weekly cost of reprocessing
S	Sales
SD	Deliveries to distributors
SI	Revenue from sales
SMPO	Products sent to secondary markets
SP	Sales price
STWCOST	Weekly cost of sales transport
TIP	Total revenue per period
Tc1	Time of increase in collection capacity
Tc2	Time of reduction in collection capacity
TPD	Total demand pattern
Tr1	Time of increase in reprocessing capacity
Tr2	Time of reduction in reprocessing capacity
UD	Uncontrolled disposal
UDP	Products disposed of uncontrollably
UI	Useful inventory
UIAT	Time of adjustment to useful inventory
UICT	Time of coverage of useful inventory
UID	Discrepancy with useful inventory
UIDE	Desired useful inventory

VARIABLE OR PARAMETER	SIGNIFICANCE OF VARIABLE OR PARAMETER
UIL	Liquidation of useful inventory
UILT	Time of liquidation of useful inventory
UISCOST	Cost of storage of useful inventory
UISWCOST	Weekly cost of storage of useful inventory
UP	Used products
WDR	Weekly discount rate
WPCOST	Weekly production costs

8. Annex 2. Model equations

Below are presented all of the equations that intervene in the model, numbered and ordered alphabetically according to the name of the variables that describe them.

(001) "a-CC"= 12 Units: week Delay Parameter

(002) "a-D"= 2 Units: week Delay Parameter

(003) "a-DI"=2 Units: week Delay Parameter

(004) "a-MI"=2 Units: week Delay Parameter

(005) "a-RI"=2 Units: week Delay Parameter

(006) "a-RPC"=2 Units: week Delay Parameter

(007) "a-RR"=24 Units: week Delay Parameter

(008) CCCCOST=20000 Units: €/units

(009) CCCR=IF THEN ELSE(CCDE>lbc, MAX(-CCDI*Kc2, 0), COR) Units: units/week

(010) CCDE=SMOOTH(UP, "a-CC") Units: units/week

(011) CCDI=IF THEN ELSE(ABS(CCDE-COR)>lbc, CCDE-COR, 0) Units: units/week

(012) CCER=MAX(Kc1*CCDI, 0) Units: units/week

(013) CCIR=SMOOTH(CCER, Tc1) Units: (units/week)/week

(014) CCOST=5 Units: €/units

(015) CCRCOST= 5000 Units: €/units

(016) CCRR=CCCR/Tc2 Units: units/(week*week)

(017) CCWCOST= CIC*CCCCOST+RCC*CCRCOST Units: €/week

(018) CD=REP/RSKT Units: units/week

(019) CIC=CCER^0.6 Units: units/week

(020) COR= INTEG (CCIR-CCRR,0) Units: units/week

(021) CP= INTEG (CR-PARU-PRR,0) Units: units

(022) CR=MIN(COR, UP) Units: units/week

(023) CTCOST=1 Units: €/units

(024) CWCOST=CR*CCOST Units: €/week

(025) D=TPD(Time) Units: units/week

(026) DB= INTEG (D-DORR,0) Units: units

(027) DCT= 2 Units: week

(028) DI= INTEG (SD-MS-DIL,0) Units: units

(029) DIAT= 1 Units: week

(030) DICT= 2 Units: week

(031) DID= MAX(DIDE-DI, 0) Units: units

(032) DIDE=EMO*DICT Units: units

(033) DIL=IF THEN ELSE(DIDE<MFL, DI/DILT, 0) Units: units/week

(034) DILI=DLP*DIL Units: €/week

(035) DILT=1 Units: week

(036) DISCOST=0.4 Units: €/(units*week)

(037) DISWCOST=DISCOST*DI Units: €/week

(038) DLP= 550 Units: €/units

(039) DO=EMO+DID/DIAT Units: units/week

(040) DORR=S Units: units/week

(041) DP= INTEG (CD+PRR,0) Units: units

(042) DST= 2 Units: week

(043) DTCOST=1 Units: €/units

(044) DTWCOST= DTCOST*SD Units: €/week

(045) ED=SMOOTH(D, "a-D") Units: units/week

(046) EDO= SMOOTH(DO, "a-DI") Units: units/week

(047) EMO= SMOOTH(MO, "a-MI") Units: units/week

(048) ERO= SMOOTH(RO, "a-RI") Units: units/week

(049) FINAL TIME=500 Units: week The final time for the simulation.

(050) FP=0.2 Units: Dmnl

(051) ICOST=CCWCOST+RCWCOST Units: €/week

(052) ILI=DILI+ILPI+MILI+PLIR Units: €/week

(053) ILPI=LPP*UIL Units: €/week

(054) INITIAL TIME=0 Units: week The initial time for the simulation.

(055) IT=1 Units: week

(056) k=1/(1+WDR)^Time Units: Dmnl Expression of discount rate for the net current value (NCV). The discount rate is for a period of one week.

(057) Kc1=5 Units: Dmnl

(058) Kc2=1 Units: Dmnl

(059) Kr1=50 Units: Dmnl

(060) Kr2=1.8 Units: Dmnl

(061) lbc=0.05*PD Units: units/week

(062) lbr=0.05*PD Units: units/week

(063) LPP=550 Units: €/units

(064) MBO= INTEG (MO-MOBRR,0) Units: units

(065) MFL=10 Units: units

(066) MI= INTEG (MS-MIL-RS,0) Units: units

(067) MIAT=1 Units: week

(068) MICT=2 Units: week

(069) MIDE=ERO*MICT Units: units

(070) MIDI=MAX(MIDE-MI,0) Units: units

(071) MIL=IF THEN ELSE(MIDE<MFL, MI/MILT, 0) Units: units/week

(072) MILI=MLPR*MIL Units: €/week
(073) MILT= 1 Units: week
(074) MISCOST=0.4 Units: €/units
(075) MISWCOST=MISCOST*MI Units: €/week
(076) MLP= 550 Units: €/units
(077) MLPR=550 Units: €/units
(078) MO=ERO+MIDI/MIAT Units: units/week
(079) MOBRR=MS Units: units/week
(080) MP= INTEG (-PR, 1e+007) Units: units
(081) MS=MAX(MIN(DI, MBO)/MST, 0) Units: units/week
(082) MSICOST=0.4 Units: €/units
(083) MSIWCOST=MSICOST*RI Units: €/week
(084) MST= 2 Units: week
(085) MTCOST=1 Units: €/units
(086) MTWCOST= MTCOST*MS Units: €/week
(087) NCF= (TIP-PTCOST)/(1+0.001) Units: €/week
(088) NPVP=NCF*k Units: €/week. The NCV is calculated for each period; that is, in intervals of a week.
(089) NPVWN= INTEG (NPVP,0) Units: €. The NCV is calculated for the whole of the supply chain.
(090) OB= INTEG (DO-OBRR,0) Units: units
(091) OBRR=SD Units: units/week
(092) OCOST= DISWCOST + UISWCOST + RSPWCOST + WPCOST + CWCOST + RPWCOST + DTWCOST + STWCOST + RTWCOST + MSIWCOST + MISWCOST + MTWCOST. Units: €/week
(093) PARU=CP*(1-FP)/IT Units: units/week
(094) PC=2000 Units: units/week
(095) PCOST=800 Units: €/units
(096) PD=1000 Units: units/week
(097) PLIR= MLP*RIL Units: €/week
(098) PR=MAX(MIN(PC, MIN(MP/PT, EDO-RER+UID/UIAT)), 0) Units: units/week
(099) PRR= CP*FP/IT Units: units/week
(100) PT=2 Units: week
(101) PTCOST=ICOST+OCOST Units: €/week
(102) RCC= CCRR^0.6 Units: units/week
(103) RCCCOST=120000 Units: €/units
(104) RCCR=IF THEN ELSE(RCDE>lbr, MAX(-RPCD*Kr2, 0), RPC) Units: units/week
(105) RCDE=SMOOTH(S*(1-FP), "a-RPC") Units: units/week
(106) RCER=MAX(Kr1*RPCD, 0) Units: units/week
(107) RCIR=SMOOTH(RCER, Tr1) Units: (units/week)/week
(108) RCRCOST= 40000 Units: €/units
(109) RCRR=RCCR/Tr2 Units: units/(week*week)
(110) RCWCOST= RICOST*RCCCOST+RRC*RCRCOST Units: €/week
(111) REP= INTEG (PARU-CD-RPR,0) Units: units

(112) RER= SMOOTH(RPR, "a-RR") Units: units/week
(113) RI= INTEG (RS-RIL-S,0) Units: units
(114) RIAT= 1 Units: week
(115) RICOST=RCER^0.6 Units: units/week
(116) RICT= 2 Units: week
(117) RIDE=ED*RICT Units: units
(118) RIDI= MAX(RIDE-RI, 0) Units: units
(119) RIL=IF THEN ELSE(RIDE<MFL, RI/RILT, 0) Units: units/week
(120) RILT= 1 Units: week
(121) RO=ED+RIDI/RIAT Units: units/week
(122) ROB= INTEG (RO-ROBRR,0) Units: units
(123) ROBRR=RS Units: units/week
(124) RPC= INTEG (RCIR-RCRR,0) Units: units/week
(125) RPCD=IF THEN ELSE(ABS(RCDE-RPC)>lbr, RCDE-RPC, 0) Units: units/week
(126) RPCOST=25 Units: €/units
(127) RPR= MAX(MIN(REP/RPT, RPC), 0) Units: units/week
(128) RPSCOST= 0.4 Units: €/(week*units)
(129) RPT= 1 Units: week
(130) RPWCOST= RPR*RPCOST Units: €/week
(131) RRC= RCRR^0.6 Units: units/week
(132) RS=MAX(MIN(MI, ROB)/RST, 0) Units: units/week
(133) RSKT=4 Units: week
(134) RSPWCOST=REP*RPSCOST Units: €/week
(135) RST= 2 Units: week
(136) RT=RANDOM NORMAL(10, 30, 20, 2, 5) Units: week
(137) RTCOST=1 Units: €/units
(138) RTWCOST= RS*RTCOST Units: €/week
(139) S=MIN(DB, RI)/DCT Units: units/week
(140) SAVEPER = TIME STEP Units: week [0,?] The frequency with which output is stored.
(141) SD=MAX(MIN(UI, OB)/DST, 0) Units: units/week
(142) SI=SP*S Units: €/week
(143) SMPO= INTEG (DIL+MIL+RIL+UIL,0) Units: units
(144) SP=1100 Units: €/units
(145) STWCOST=S*CTCOST Units: €/week
(146) Tc1= 8 Units: week
(147) Tc2= 8 Units: week
(148) TIME STEP = 1 Units: week [0,?] The time step for the simulation.
(149) TIP=SI+ILI Units: €/week
(150) TPD([(0,0)-(600,2000)],(0,0),(10,30),(20,100),(30,800),(40,900),(50,1000),(129,1000),(130,1000),(180,1000),(181,1000),(200,1000),(210,900),(220,800),(230,100),(240,30),(250,0),(300,0),(500,0)) Units: units/week. Expected pattern of demand. Estimation according to the life cycle of the various products.
(151) Tr1=24 Units: week

(152) Tr2=8 Units: week

(153) UD=UP-CR Units: units/week

(154) UDP= INTEG (UD, 0) Units: units

(155) UI= INTEG (PR+RPR-SD-UIL,0) Units: units

(156) UIAT= 1 Units: week

(157) UICT= 2 Units: week

(158) UID=UIDE-UI Units: units

(159) UIDE=EDO*UICT Units: units

(160) UIL=IF THEN ELSE(UIDE<MFL, UI/UILT, 0) Units: units/week

(161) UILT= 1 Units: week

(162) UISCOST= 0.4 Units: €/(units*week)

(163) UISWCOST=UI*UISCOST Units: €/week

(164) UP=SMOOTH(S,RT) Units: units/week

(165) WDR=0.001 Units: Dmnl An annual discount rate of 5.2% has been assumed, which means 0.1% per week.

(166) WPCOST=PCOST*PR Units: €/week

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21

Improving the Supply Chain of Non-Timber Forest Products in Ghana

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1. Introduction

Traditionally, NTFPs play an important role worldwide. In many areas, animal and plant resources derived from forests remain central to **subsistence and local economies**. The FAO estimated that (80%) of the population of the "developing" world use NTFPs to meet some of their health and nutritional needs (FAO, 1997).The importance of NTFPs in supporting livelihood of forest dependent communities has been widely promoted due to the recognition that NTFPs can contribute to improve the livelihoods of forest dependent communities (Belcher et al., 2005; Clendon, 2001; FAO, 2006; Marshall et al 2005; Ros-Tonen & Wiersum, 2005); household food security and nutrition (Clark & Sunderland, 2004; FAO, 1995; Shacleton & Shackleton, 2004); generate additional employment and income (Marshall et al., 2003; Peters, 1996; Ros-tonen; 1999); and offer opportunities for NTFP-based enterprises (Shackleton & Shackleton, 2004; Subedi, 2006). Moreover, NTFPs are more accessible to the poor (Saxena 2003); contribute to foreign exchange earnings (Andel, 2000; Shiva & Verma, 2002); and support biodiversity and other conservation objectives (FAO, 1995, Marshall et al., 2005; Arnold and Ruiz Pérez, 2001; Charlie and Sheona, 2004).
Furthermore, NTFPs can be harvested with relatively little impact on the forest environment (FAO, 2008; Myers 1988; Neumann & Hirsch, 2000). The importance of NTFPs goes beyond meeting **basic needs**. NTFPs are also rapidly growing at the international market. A recent FAO study suggests that at least 150 NTFPs are of major significance in **international trade** (FAO 1995, Shiva &Verma, 2002), including medicinal plants, mushrooms, snails, essential oils, tannin extracts, gums, nuts, rattans and bamboo. The total value in world trade in NTFP is estimated at approximately US$ 11 billion (Ndoye & Ruiz Perez, 1998; Shiva & Verma, 2002), and the **market has grown by nearly 20% annually over the last several years** (Hammet, 1999). Future development of NTFPs offers a potential for increasing income, **expanding opportunities**, and **diversifying enterprises in rural areas**.

Plant products		Animals and animal products	
Categories	**Description**	**Categories**	**Description**
Food	Vegetal foodstuff and beverages provided by fruits, nuts, seeds, roots	Living animals	Mainly vertebrates such as mammals, birds, reptiles
Fodder	Animal and bee fodder provided by leaves, fruits etc.	Honey, beeswax	Products provided by bees.
Medicines	Medicinal plants (e.g. leaves, bark, roots) used in traditional medicine and/or by pharmaceutical companies	Bushmeat	Meat provided by vertebrates, mainly mammals
Perfumes and cosmetics	Aromatic plants providing essential (volatile) oils and other products used for cosmetic purposes	Other edible animal products	Mainly edible invertebrates such as insects (e.g. caterpillars), crabs and other "secondary" products of animals (e.g. eggs)
Dying and tanning	Plant material (mainly bark and leaves) providing tannins and other plant parts (especially leaves and fruits) used as colorants	Hides, skins	Hide and skin of animals used for various purposes
Utensils, handicrafts	Heterogeneous group of products including thatch, bamboo, rattan, wrapping leaves, fibres (e.g. Arouma, Bwa Flo, Silk cotton floss, Screw pine)	Medicine	Entire animals or parts of animals such as various organs used for medicinal purposes (e.g. caterpillars, crab legs, snake)
Construction materials	thatch, bamboo, fibres,		
Ornamentals	Entire plants (e.g. orchids, ferns, philodendron) and parts of the plants (e.g. pots made from roots) used for ornamental purposes	Colorants	Entire animals or parts of animals such as various organs used as colorants
Exudates	Substances such as gums (water soluble), resins (water insoluble) and latex (milky or clear juice), released from plants by exudation	Other nonedible animal products	e.g. bones used as tools

Adapted from FAO, 1995; Shiva & Verma,2002

Table 1. Classification of Non Timber Forest Products

In Ghana, thousands of people across the country produce and market a diverse range of NTFPs on daily basis in the local, regional and international markets (Ahenkan & Boon, 2010). Despite the enormous potential of NTFPs to support rural livelihoods, the NTFPs supply chain has received very little attention from the scientific community. Several constraints hinder an effective management of the NTFPs supply chain for optimizing income generation and improvement of rural livelihoods. The information base of NTFPs in Ghana is still poor because research on them is relatively new and has received very little formal study. There is a serious lack of basic statistical information on their volumes, trade, income and nutritional values. The low representation of NTFPs in policy-making is due to the inadequate statistical information on NTFPs.NTFPs have not been accorded adequate attention in development planning and in nutrition improvement programmes in the country. Existing information sources are dispersed and no standardized system for compiling data on NTFPs is in place.

In today's global market, an effective management of the entire supply chain of NTFPs has become a key factor for their successful commercialization. The NTFPs supply chain is typically comprises a range of actors involved in the production of the products at the farm level to the final consumer. It is a network of producers, gatherers, collectors, retailers, distributors, transporters, suppliers and sellers that participate in the delivery and sale of the products to the final consumer at the local, regional, national and international level. Improving the supply chain of NTFPs has become very important in the efforts of most developing countries trying to enhance the economic empowerment of the rural poor. This chapter seeks to examine the NTFPs supply chain activities, actors and the key challenges of supply chain management.

1.1 Definition and classification of NTFPs

NTFPs are "biological resources of plant and animal origin, harvested from natural forests, manmade plantations, wooded land, farmlands, trees outside forests and or domesticated" (FAO, 1999; Peters, 1996; Marshall et al., 2005; Wong, 2000). NTFPs include fruits and berries, nuts, spices, medicinal plants, oils, gums, resins, honey, mushrooms, weaving and dying materials, aromatics, and recreation (FAO, 1995; Thomas & Schumann, 1993; Shiva &Verma, 2002). These products such as these are vital sources of income, nutrition and sustenance for many forest-based communities around the world. A globally applicably **standard classification system** for NTFPs does not exist (Shiva & Verma, 2002). However, NTFPs can be classified in many different ways: according to end use (medicine, food, drink, etc), by the part used (roots, leaves, barks, etc); or in accordance with major **international classification systems** such as the Harmonized Community Description and Coding System developed under the auspices of the Customs Cooperation Council (Shiva & Verma , 2002). For the purpose of this research, NTFPs are classified according to their end uses as indicated in Table 1.

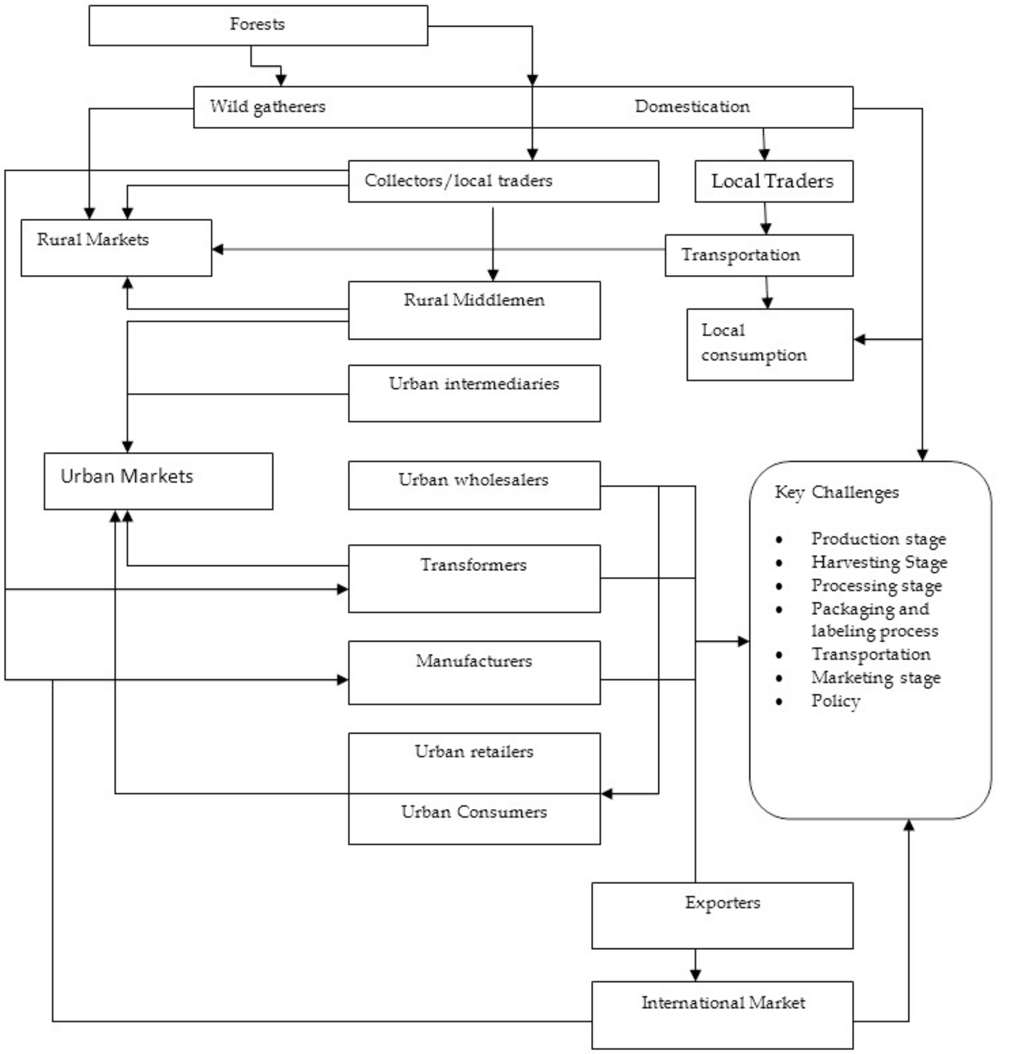
2. Importance of NTFPs in Ghanaian economy

NTFPs play an important role in the Ghanaian economy by way of supporting rural livelihoods. They contribute significantly to the income and food security of many rural households in Ghana (Ahenkan & Boon, 2008; Falconer, 1992; FAO, 2001). Aggregate employment generation in forest product activities in Ghana is estimated to be growing at 6.9 percent per year (Townson, 1995). These products contribute significantly to household food security, nutrition, health, and income, especially during the lean seasons (Ahenkan & Boon, 2008). A considerable amount of food and medicinal plants are gathered from the forest. It is estimated that 20 percent of the economically active population derive income from NTFPs and 38% of the household in Ghana trade in NTFPs (Townson, 1995). In a similar study covering households in villages around the large market centre of Kumasi, Falconer (1994) found that 68% of the households surveyed were involved in supplying NTFPs to the market. Among persons generating some income from forest products activities in households surveyed in southern Ghana, 72% identified this income to be important either in absolute terms, or in meeting particular needs, or because of its timing (Townson,1995). NTFPs are also used by people in Ghana to cure various diseases (Abbiw, 1990; Ahenkan & Boon, 2008). Rural people particularly depend very much on traditional medicinal sources for their health. Falconer (1994) and Abbiw (1990) have tabulated different medicinal plants and animal products used to cure various diseases in Ghana. Trade and use of plant products have assumed a wider dimension with more plant medicinal products being traded in the local markets.

2.1 The conceptual framework of NTFPs supply chain in Ghana

The conceptual framework on which this chapter is anchored is that supply chain management can help to boost the production of NTFPs and improve rural livelihoods through commercialization. NTFPs commercialization is a defined as a process of increasing the value of these products in trade so as to improve income and employment opportunities. The principal premise of this chapter is that the success of NTFPs commercialization is dependent on an effective management of the supply chain challenges.

As is illustrated in Figure 1, NTFPs commercialization involves a complex process that involves farming or wild harvesting, processing, packaging, labeling, transportation and marketing of the products to final consumers. The marketing channels for NTFPs are diverse and in some cases, complex (Marshall et al., 2003). A clear understanding of the commodity chain for specific NTFPs is important if we are to understand where interventions to benefit harvesters would be most successful and productive. The relationship between NTFP producers and the markets they supply range from direct sale to consumers to a complex network of middlemen and retailers. Many hundreds of millions of people across the developing world trade in a diverse range of NTFPs everyday and which are marketed primarily in local and regional markets (Scherr et al. 2004). Building materials, fuelwood, charcoal, indigenous foodstuffs, medicines, craft items (from wood, grass, reeds, and vines), farm and household implements, furniture, and other more specialised products such as resins, honey, oils and alcoholic beverages are examples of just some of the products that may be found for sale in the vast majority of rural markets and in nearby towns and cities. Many of these markets are growing through both the entry of new products and growth in existing trade.



Source: Adopted from Ahenkan and Boon, 2010; IUCN, 2008

Fig. 1. The Supply Chain of NTFPs

3. Materials and methods

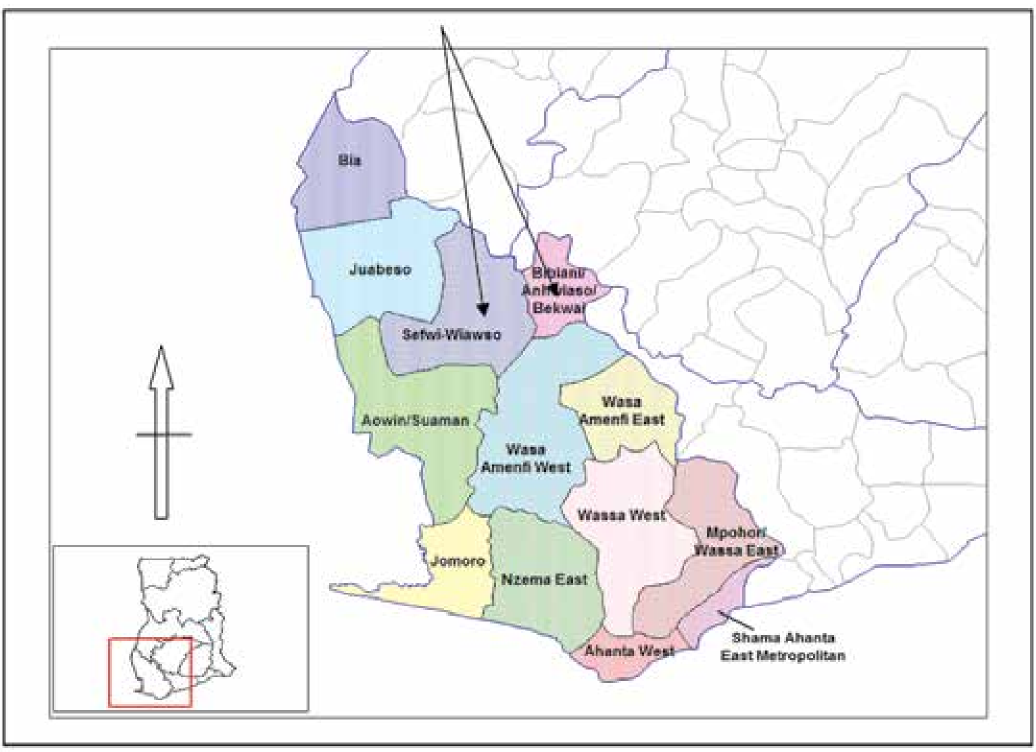
3.1 Study area

The Bibiani-Bekwai and Sefwi Wiawso Districts are located in the Western Region of Ghana. They fall within the moist semi-deciduous forest zone of Ghana, which covers most of Ashanti, Western, Brong Ahafo and Eastern regions. The two districts were selected for the study because they constitute a major area for NTFPs in Ghana and have common ecological, social, and economic characteristics that indicate high forest dependence. Figure 2 is a map of Ghana showing the Western Region and the study locations.

3.2 Data collection

The study was designed as an exploratory and qualitative research because little organised information of NTFPs exist in Ghana. Bibiani-Bekwai and Sefwi Wiawso Districts in the Western Region of Ghana were the study areas. These two districts were selected because they constitute a major area for NTFPs in Ghana and have common natural, social, and economic characteristics that indicate high forest dependence. Previous studies on NTFPs in other part of the world (Belcher, 2003; Greene et al., 2000; Hammett and Chamberlain, 1999; Marshall et al., 2005; te Velde et al., 2004) which used exploratory and qualitative designs provided the inspiration for modeling this study. A field survey was conducted between May 2010 to July 2010 and in March 2011. The survey aimed at understanding the supply chain of NTFPs in Ghana, the existing marketing system and the key challenges.

The data was purposively collected through interviews and adminsistration of questionnaires to 200 actors in the NTFPs chain, including producers, collectors and sellers of NTFPs from 10 communities in the two districts. Non-probability sampling method was also utilised: snowball, where market actors were found as a reference from other respondents. A market survey covering two markets over a period of 6 months was also carried out to collect data about the types of NTFPs marketed, the local and seasonal variations in product prices and supply. The market survey also provided data to fill the gaps in the household survey.



Source: http://en.wikipedia.org/wiki/File:Western_Ghana_districts.png

Fig. 2. Map of Ghana Showing the Western Region and the Study Area

In addition, a stakeholder workshop was organized which brought together 50 participants including traders, agricultural extension officers and NTFPs farmers/collectors from the 10 selected communities. The workshop identified main production, processing, marketing and policy challenges facing NTFPs actors. Participant observation comprising of visitation to NTFPs farms of 50 respondents, market centres and traders during the survey period. The aim was to experience the production, harvesting, processing and marketing of NTFPs and also verify and identify various NTFPs that farmers collect, consume or trade in. The observations and visitations helped to verify and identify various NTFPs that farmers collect, consume or trade in. The data collected through administration of questionnaires, interviews and stakeholder consultations were analysed both quantitatively and qualitatively using statistical methods. The quantitative analysis was done using the Statistical Package for Social Sciences (SPSS version 17) and the results analyzed and presented in the form of descriptive statistics descriptive statistics.

4. Results and discussion

4.1 NTFPs supply chain activities and challenges in Ghana

NTFPs supply chain activities involve a network of activities ranging from production to consumption. A number of critical factors continue to constrain the ability of NTFP producers/collectors to exploit the full potential of commercialization of NTFPs in Ghana. The survey identified a number of factors that hinder effective management of the supply chain of NTFPs during the production, harvesting, processing, packaging and marketing stages. Generally, NTFPs are produced and harvested for both subsistence and commercial use under a broad range of regimes, ranging from strictly wild harvested, semi-domesticated and more intensively managed systems in the study locations. The study reveals that most of the NTFPs are picked freely from the forest during the season they blossom. This is obviously unsustainable since the extraction of NTFPs from natural forests has limited potential. Consequently, sustainable production and supply of NTFPs has been threatened due to inappropriate harvesting practices. In some cases, collectors cut plants that are too young or too close to ground and this inhibits re-sprouting. This over-exploitation is also due to the high demand for NTFPs. Some medicinal plants have progressively become depleted and extinct because their harvesting exceeds annual production. During the focus group discussions it was revealed that most communities in the two districts are losing access to these valued NTFPs either because of over-exploitation and habitat destruction. Three main strategies have been employed to militate against shortfalls in supply of NTFPs in most of the communities surveyed: travel further to find the products, substituting a particular product with a similar one or develop a more intensive or cultivated sources of supply.

As a result of the recognition that the extraction of NTFPs from natural forests has limited potential for improving household income and nutrition, or cannot be harvested indefinitely without proper management practices and domestication to sustain their yield, most of the farmers (54%) have started domesticating some of these products of forest origin, including honey, mushrooms, snails, grass-cutters, medicinal and aromatic plants and fruits. Key challenges indentified during the production and harvesting stages include high cost of production, inadequate supply of inputs and harvesting accessories. In an in-depth with the District Directorate of Agriculture in the Sefwi Wiawso District, he noted that *"any strategy towards promoting and improving NTFPs farming in the district must tackle the issue of high costs* *of production"*. The cost of procuring production equipment or construction of NTFPs domestication structures and inputs for activities such as beekeeping, grass-cutters and snails is very high.

4.2 Processing skills and storage facilities

Another important challenge facing the supply chain of NTFPs in Ghana is the lack of processing and packaging skills. The NTFPs enterprise has not received the kind of support given to agriculture and forestry sectors in Ghana. Producers remain largely neglected by national and local government development strategies. Though a potential international market exists, producers cannot exploit it because of their inability of farmers to package NTFPs to meet domestic and international standards. Most of the farmers lack the necessary skills in processing, packaging and labeling the products. Over 90 % of the producers sell products either in their raw form without adding value. A significant proportion of the respondents (67.5%) cited lack of processing skills, equipment and financial assistance the most important constraints hindering the supply chain of NTFPs in the districts. The lack of processing and storage facilities is a major constraint hindering the sustainable management of NTFPs supply chain in Ghana. Most products like mushrooms get spoilt within a few days after harvesting. The deplorable state of the feeder road network in the country, particularly the roads linking agricultural communities to market centres affect the marketing of NTFPs in Ghana. Absence of local food processing and storage facilities also affects the marketing of NTFPs also affects the marketing of the products both locally and internationally.

4.3 NTFPs Labeling and certification challenges

The imprope Labeling and certification of NTFPs are major challenges to the NTFPs supply chain in Ghana. Compliance with quality standards is one in the marketing of NTFPs in Ghana. While discussions on NTFPs labeling and certification have increased recently, the applicability and its impact as a tool to promote the development of NTFPs remains unclear. Certification is defined by the International Organization for Standardization (ISO, 1996) as a procedure by which written assurance is given that a product, process or service is in conformity with certain standards. Standards for labeling of NTFPs in Ghana are not well developed and are not well developed. This is hindering the promotion of NTFPs in the country. Although, the quality aspects of food products are taken care of by Drugs Board, unfortunately most of the producers are not organized due to their locations. They are isolated and sell these products locally to individual customers without meeting the required international standards. Although there is potential for the international market for some NTFPs in Ghana, farmers have very limited capacity in meeting international standards. Lack of standardization is an important constraint of NTFPs supply chain in Ghana. Moreover, the quantities of products produced are insufficient and fail to meet international market standards. Eighty (80%) of the respondents surveyed have no idea about packaging and labeling requirements of NTFPs. Trade in certified NTFPs is still marginal compared to the trade of non-certified products. Major challenges of NTFPs labeling and certification in Ghana include lack of market demand, high costs of certification system, insufficient product definition and classification system since many NTFPs are not included in international classification or standardization systems.

4.4 Marketing of NTFPs in Ghana

According to Marshall et al. (2005), the most constraining processes of NTFP commercialization are marketing and sales which are also major bottlenecks for many NTFPs farmers in rural Ghana. Thousands of people, especially women, are involved in the collection and marketing of NTFPs in Ghana and for many, it provides the main source of income (Falconer, 1994). It involves a great number of people selling a vast array of products, including mushroom, snails, bushmeat, honey, leaves, medicinal plants, food wrapping leaves, and chewing sticks etc. The NTFPs market in the study locations is also highly characterized by seasonality and differs in social structures. Gender plays an important role in the marketing of NTFPs. The NTFPs trade is dominated by women. However, the sale of some wild food products grass-cutters and other plant products (rattans, bamboo, hides and skins) and other wild animal products are dominated by men. The key actors in the NTFPs market consist of various levels of local collectors, village traders, road-head traders and large traders in the districts.

The results indicate that there is a strong market for NTFPs, especially in urban centres, and there are no signs of any decline. Most NTFPs traders rely on district and urban markets while others bypass markets altogether and sell their products directly to local restaurants and consumers in the district capitals. In most cases, the prosperity of a market depends on good access and the proximity of passing traffic. Most NTFPs traders, especially women, besiege approaching vehicles at the checking points along high ways to sell their products. The commonly exploited and traded NTFPs in the study locations are presented in Table 2.

Foods	Medicine	Household goods
Bush meat	Barks	Baskets
Fruits	Leaves	Mats
Honey	Fruits	Wooden trays
Mushrooms	Animal products	Grinders
Snails	Prepared tonics	Mortars
Spices	Hides	Pestles
cola nuts	Seed	Spoons
Gums	Roots	Chewing sticks
Essential oils	Essential oils	Dyes

Field Survey, 2010

Table 2. Commonly Traded NTFPs in Ghana

Although NTFPs trade is done in both local and urban markets, they have different characteristics and therefore the real benefits of the trade at the local level are unknown. The study shows that NTFPs marketing in the study area often occurs in an informal way, resulting in uncertainty about prices and income effect. Marketing is basically done individually; it is unorganized, dispersed and producers lack the necessary marketing skills and information required for optimal performance. As noted by Ndoye (1998), the process of price setting for NTFPs between the NTFPs farmer (the seller) and the trader (the buyer) involves bargaining to reach an equilibrium price somewhere between the lowest price the seller is willing to accept and the highest price the buyer is willing to pay. The bargaining power of the sellers and buyers is influenced by different factors depending on whether the sellers have brought the NTFPs to the market or at the farm gate. The price received by the collector/producers depends on the length of the chain, location, quality and means of transportation. For NTFPs sold in the communities, the bargaining power of farmers depends on the number of traders coming to the village to buy the product, the accessibility of the village, the supply of NTFPs, the degree of perishability of NTFPs, and the level of market information available to farmers. Producers who are closer to urban markets get higher price than those not closer to the urban markets.

In addition, the lack of market information and difficulty in getting contact with final consumers are identified as some of the major challenges facing the NTFPs supply chain. Fifty-five percent (55%) of the respondents cited lack of attractive product presentation as the most important constraint of the NTFPs supply chain at the marketing stage. This is followed by inadequate access to market information (34%). Eleven percent (11%) mentioned lack of contact with final consumers as an important factor the commercialization of NTFPs. Lack of access to relevant and up-to-date marketing information is a major cause of the low pricing of NTFPs in the district. Inadequate market information, contacts and knowledge consistently constrain NTFPs producers, processors and traders from advancing the NTFPs value chain. Because producers and collectors find it difficult to sell their products directly to final consumers due to their geographical locations, middlemen take advantage and exploit the them. The NTFPs market is also constrained by inaccessible road networks, limited local buying power, poor access to markets centres and high transportation costs.

4.5 Lack of clear policy to promoting NTFPs

The legal and regulatory framework for the development of NTFPs in Ghana has received little attention. The forest policies still categorise NTFPs as "minor" forest products, resulting in less emphasis on these products than timber within forest management programmes and policies. The lack of a definite policy on NTFPs has impacted negatively on their promotion, development and their supply chain management. The forest policies have consistently been dictated by the economic priorities of the successive governments for exploitation of timber resources for foreign exchange generation. Ghana’s forestry policies have failed to acknowledge the importance of NTFPs and the creation of and enabling environment for their promotion and development.

5. Strategies for Improving the Supply Chain of NTFPs in Ghana

A number of recommendations are provided in this section to policy-makers and development agents to help to boost the development and management of NTFPs supply chain in Ghana.

5.1 Improving harvesting, processing and marketing skills

The harvesting, processing and marketing of NTFPs remain major institutional problems in Ghana. NTFPs harvesters use unsustainable harvesting methods. Building the capacity of farmers and collectors in efficient harvesting and processing skills will significantly help to improve the supply chain of NTFPs in Ghana. It is important that processing facilities are provided to promote the commercialisation of these products on a permanent so as to create more sustainable employment and income-generation opportunities, enhance food security and improve the livelihoods of producers, their families and communities. In order to add more value to NTFPs in Ghana, government also needs to facilitate the establishment of local food processing companies to process NTFPs. Farmers should be assisted to procure NTFP processing equipment such as honey extractors.

In addition, the government needs to improve the feeder road network in the country, particularly the roads linking agricultural communities to market centres. The Ministry of Food and Agriculture (MoFA) should facilitate the dissemination of agricultural marketing information to NTFPs producers. General improvements in marketing transport and Communication infrastructure go a long way to facilitate the commercialization of NTFPs of the products. The sale of NTFPs should be well organized by encouraging farmers to form associations so as to enhance their bargaining power. Increasing access to market information can be achieved through information dissemination, empowerment of collectors and establishment of linkages between collectors and traders. The Ministry of Food and Agriculture (MOFA) in particular should facilitate the dissemination of agricultural marketing information to farmers and also encourage farmers and collectors to form farmer-based organisations and foster linkages between farmers and traders.

5.2 Encourage domestication of NTFPs

The domestication of NTFPs should be promoted as an integral part of strategies aimed at halting the depletion of forest products. Sustainable harvesting of NTFPs relies on the ability to reconcile ecosystem productivity with human exploitation**.** NTFPs cannot be harvested indefinitely without proper measures to sustain their yield and availability. It is therefore important that the government introduces strategies to encourage farmers to domesticate NTFPs to redress shortfalls in supply. This will help to reduce pressure on forest resources and enhance the livelihoods of forest communities. Domestication of the products will significantly enhance forest-based livelihoods and help to optimize NTFPs production.

5.3 Provision of credit to NTFPs farmers

Inadequate finance to start up NTFPs farming has been identified as one of the most critical economic challenge facing farmers. The management of farm credit services commercial banks in the country is very complicated and cumbersome. Most farmers rely heavily on commercial banks credits facilities but their rigid character is not friendly to the requirement of farmers of the small-scale farmers. Most of the poor NTFPs farmers also have no collateral to secure credits from the banks. This has limited access by farmers to credit to finance their farming activities. Government should introduce measures to strengthen the rural and agricultural development banks and make them to provide low interest loans to farmers to enable them expand their NTFPs farms.

5.4 Prevention of deforestation

Widespread deforestation in the study locations and Ghana in general has led to ecological deterioration, particularly in marginal ecological zones which habour NTFPs. This is due to reckless farming practices, hunting, bush fires, illegal logging, and unsustainable methods of gathering NTFPs. The continuous depletion of these forest resources point to their eminent loss in the long-term. If efforts are not made to redress the situation, the consequences on the forest and the livelihood of the population will be enormous. Measures must be put in place to halt the perennial bushfires in the country. NTFP farming especially beekeeping provides an incentive to farmers to prevent the outbreak of bush fires. It is also an incentive for farmers to engage in agro-forestry and afforestation projects. It is therefore important that the government capitalises on the opportunity offered by NTFPs farming to sensitise the rural population to actively engage in this activity as a means of redressing poverty and protecting the environment.

5.5 NTFPs construction materials

Any effective strategy towards the promotion of NTFPs must address critically the continuous diminishing of wood products for the construction of NTFPs structures. Wood for the construction of NTFPs farming structures is becoming very scarce and expensive due to indiscriminate logging over the years. Consequently, prospective farmers find it extremely difficult to afford wood products for the construction of bee hives, snails, mushrooms and grass-cutter rearing structures.

5.6 Effective promotion of NTFPs

An effective promotion of NTFPs constitutes an essential mechanism for popularizing NTFPs. Awareness creation on the nutritional, medicinal, and environmental benefits of NTFPs by the Ministries of Agriculture, Health and Environment can significantly help to promote the farming of NTFPs in Ghana. Also, the potential contribution of NTFPs to poverty reduction has to be adequately promoted. Sustainable promotion and development of these products will significantly provide an important opportunity for food security, nutrition and poverty reduction, particularly for the economically marginalised and forest-dependent communities in Ghana.

5.7 Encourage research on NTFPs

There is the need for the government to encourage and facilitate collaboration with and within research institutions in order to document useful NTFPs and their utilization. The identification, evaluation and sustainable utilization of NTFPs requires detailed information on the natural resource system where they originate; biological and chemical properties; geographical distribution; potential uses and values; harvesting and processing methods; the market situation. This can only be possible when research on NTFPs is promoted.

5.8 NTFPs policy

Clear and visible NTFPs policy and management mechanisms are required to catalyze the development and promotion of NTFPs in Ghana.The forestry policy should be founded on carefully organized research on forest products. A clear policy on the development and domestication of NTFPs will help to ensure sustainable harvesting of the products, reduce pressure on forest resources and enhance the livelihoods of forest communities. Table 3 summaries the principal challenges facing the supply chain of NTFPs in Ghana and strategies recommended for their redress and mitigation.

No	Key Challenges	Current Situation and Opportunities	Recommended Strategies
1	Lack of a clear policy to guide the use, management and development of NTFPs	The Ghana Poverty Reduction Strategy Paper (GPRSP). Increasing potential of NTFPs in poverty reduction	Effective promotion of NTFPs farming as a core element of the country's forestry policy-making process and national poverty reduction strategy
2	Inadequate research on NTFPs in Ghana	The surge in global interest in NTFPs	Government should encourage and facilitate collaboration with and within research institutions in order to document useful NTFPs
3	Over harvesting and deforestation	Domestication potentials More farmers ready to engage in the domestication	NTFPs domestication should be promoted as an integral part of strategies aimed at halting the depletion of forest resources.
4	Inadequate finance for NTFPs farmers	The establishment of agricultural development and rural banks in Ghana	NTFPs farmers should be given access to credit facilities to enable them engage in the production of these products Government to encourage agricultural development and rural banks to provide low interest loans to farmers
5	Poor NTFPs harvesting and processing skills	Potential for international market for some products exists	Building the capacity of farmers and collectors in efficient harvesting and processing of NTFPs Establishment of local food processing companies to process and can NTFPs
6	Lack of packaging and labelling skills	Opportunity for international market Growing influence of green economy principles and practices	Build the capacity of farmers in packaging and labeling of their products. Development of standards for labeling and certification of NTFPs in Ghana
7	In adequate marketing information	High demand for NTFPs in Ghana Opportunity for penetrating the international market with NTFPs	Ministry of Food and Agriculture to facilitate the dissemination of agricultural marketing information to farmers. Government should improve marketing, transport and communications infrastructure Empowerment of farmers and collectors to form farmer-based organisations and foster linkages between farmers and traders

8	Lack of inputs and farm construction materials	A number of NGOs are already involved in promoting NTFPs in the country	New and more innovative and sustainable materials should be developed for this purpose. MOFA should set up demonstration farms in rural communities to serve as centres of excellence for educating and training farmers
9	Inadequate awareness creation on the nutritional and health values of NTFPs	The increasing potential of NTFPs in nutrition and health improvement and poverty reduction strategies	Awareness creation of the nutritional, medicinal, and environmental benefits of NTFPs by the Ministries of Agriculture, Health and Environment will significantly help to promote the farming of NTFPs in Ghana

Table 3. Challenges of NTFPs Supply Chain

6. Conclusion

The importance of supporting the livelihoods of forest dependent communities has been widely promoted. The NTFPs supply chain is a sequence of processes involved in the production of these products at the farm level to the final consumer. An effective management of the entire supply chain is a key factor for a successful commercialization of NTFPs in the global market. This will enable most developing countries to empower the rural poor. This chapter examined the various stages of NTFPs supply chain in Ghana, the actors involved in the chain and its key challenges. The study revealed that the supply chain of NTFPs in Ghana faces a number of critical challenges from the production to the marketing stage. The chapter identified number of strategies for improving the management of NTFPs supply chain in Ghana. These include processing and marketing skills, promoting the domestication of NTFPs, provision of credit to NTFPs farmers, prevention of deforestation, effective promotion of NTFPs, up-scaling research on NTFPs and development of NTFPs policy to guide the production, harvesting, domestication and marketing of the products. Improving the management of NTFPs supply chain in the country will enormously help to boost employment and income-generation opportunities, enhance food security and improve the livelihoods of farmers, their families, and communities. To promote the development of NTFPs in Ghana requires that government and development stakeholders effectively treat NTFPs supply chain as core element of the country's development policy-making process and as an integral part of the national development agenda.

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Part 5

Competing Through Information and Technologies

22

Web Technologies and Supply Chains

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1. Introduction

This chapter is concerned with examining the role of web technologies across the field of supply chains and supply chain management (SCM). Supply chains and SCM are growing concerns for organisations as customers become more demanding, cost reduction is becoming more and more important and supply chains are increasingly complex as globalisation and the use of global partners becomes greater.

Supply chains embrace all those processes involved in creating and delivering products and services. They can be characterised as networks of processes and activities that "perform the function of product development, procurement of material from vendors, the movement of materials between facilities, the manufacture of products, the distribution of finished goods to customers, and after-market support for sustainment" (Mabert & Venkatraman, 1998, p538). The inputs that are used in an organisation's supply chain may pass through the supply chains of many suppliers or manufacturers on their way to the organisation and outputs from an organisation may pass through many distributors, retailers or customer's supply chains before it reaches the final customer (Ward & Peppard, 2002). This can be referred to as a supply chain network (SCN). Supply chains and SCNs have become an integral part of an organisation's strategy. As such, organisations have become increasingly interested in the use of web technologies for strengthening supply chains and improving information sharing, collaboration and the responsiveness of their supply chains.

This chapter will examine the developments in web technology over the last 20 years and more recently the emergence of e-commerce, e-business, mobile commerce and web 2.0. It will explore the application of web technology to supply chains and SCNs, its role in transforming business processes, and in particular for collaboration, integrating business processes and developing visibility and information sharing across SCNs. It will highlight a range of challenges related to the use of web technology for supply chains and supply chain management such as trust, security, social and cultural issues and depersonalisation and the chapter will close by discussing future trends in supply chains and developments in web technologies.

2. Evolution of web technologies

The Internet is one of the latest technologies in a series of developments for communicating and disseminating information. It has become an essential business tool and organisations have been applying tools and technologies based on the Internet and www over the last 15 years. A broad range of creative solutions have emerged which have transformed business strategies, business models, supply chains and business processes. It is an exciting field that offers many new opportunities but poses many different challenges (Li, 2007).

2.1 Internet & world wide web

The origins of the Internet can be traced back to a military project commissioned by the US Department of Defence in 1969. The project was initially referred to as ARPANET (Advanced Research Projects Agency Network) and was charged with the goal of developing a national communication system for the US military that would maintain communication in the event of a national emergency. The 70s saw the development of the Transmission Control Protocol/Internet Protocol (TCP/IP) which determined how electronic messages are packaged, addressed and sent over the network. This network later became known as the Internet. In the 80s, Internet access was established across the US through the creation of a backbone referred to as NSFNET, by the early 90s the Internet was commercialised and was extended worldwide through lots of interconnected backbones. The Internet experienced explosive growth and by mid-1994, the Internet had connected an estimated two million computers in more than 100 countries. By June 2010 there was estimated to be 1,966, 514, 816 people using the Internet around the world with a global Internet penetration rate of 28.7% (Internet World Statistics, 2010).

Essentially the Internet is a network of networks belonging to educational, commercial and governmental organisations and Internet Service Providers. The Internet reaches people worldwide, it is very cost effective to access and it is underpinned by a large-scale client-server configuration, supporting different operating systems and networks. In particular, the Internet opens up new perspectives for smaller and medium sized organisations as it is more affordable and accessible. One of the main drivers behind the success of the Internet is the World Wide Web (www) which provides a global information sharing architecture that enables a user friendly means of exploring lots of pages of information residing on different computers and networks. The Internet and the www can be readily used for globally communicating and sharing different types of information across organisations and between organisations.

2.2 Intranets and extranets

Increasingly, organisations have been using web technologies for developing internal networks which are limited to employees within the organisations (intranets) and intranets that are extended to authorised people outside the organisation (extranet). Chaffey (2009) summarises the different types of networks succinctly in Figure 1.

An intranet is a private communication system that exists solely within the boundaries of an organization allowing only authorised employee's access. Intranets are commonly used for communicating corporate strategy, corporate policies, PR and communications, announcements/bulletins, corporate documents, staff lists, phone directories, human resource issues, health and safety regulations, training materials etc. Individual departments may have web sites linked to the intranet which can be used for identifying who's who in the department, what's new in the department, departmental products/services, projects the department are involved in and relevant documents and tools. Intranets can be used for communicating on internal supply chin processes and activities and are particularly beneficial for sharing information that is only of value to people that work within the organisation and/or communicating sensitive proprietary information.

Furthermore, organisations are employing web technologies for allowing selected users outside the organisation to access parts of the intranet eg suppliers, customers or business partners. Extranets use the Internet to link multiple intranets and provide secure connectivity between corporation's intranets and the intranets of its business partners, materials, suppliers, financial services, government, and customers (Turban et al, 2010).
Extranets can be used for supporting supply chain management and activities involving external partners such as procuring materials from suppliers, processing orders and delivering customer service. Dell Computers provide access to their extranet to suppliers and customers alike. Demand forecasting is shared with suppliers whilst customers can use the extranet for entering orders, monitoring the progression of deliveries and accessing customer support and sales reps provide customised presentations about products to business customers. Customers, suppliers and employees of Boeing use an extranet to do everything from perusing company maps to ordering plane parts.

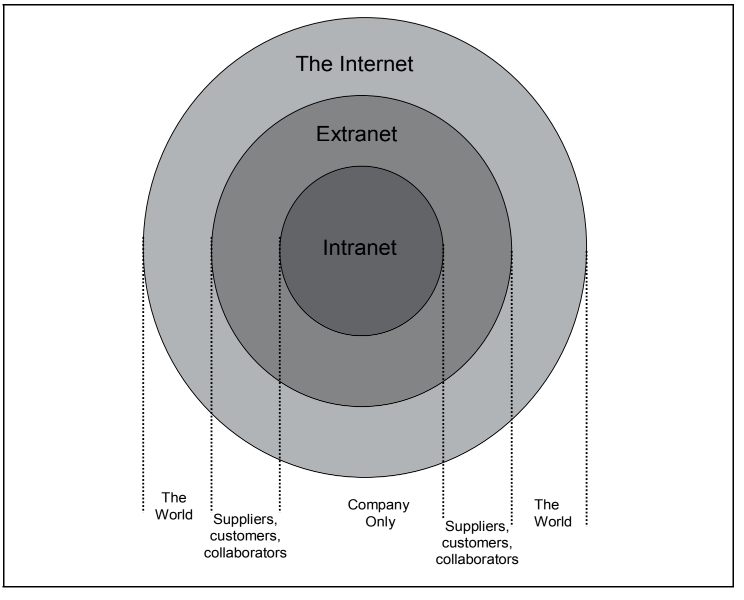

Fig. 1. Relationship between intranets, extranets and the Internet, Source: Chaffey (2010)

Moreover, there are many tools and technologies that have been developed with internet technology as the supporting platform which further enhance communication and provision of information. These include applications such as electronic mail, search engines, portals, collaborative tools, electronic data interchange (EDI), database management systems (DBMS), enterprise resource planning (ERP) systems, supply chain management systems, geographical information systems (GIS), radio frequency identification (RFID) tags, wireless and mobile technologies and more recently, web 2.0 technologies. Some of these will be expanded upon in the following sections.

2.3 Electronic Data Interchange

Electronic Data Interchange (EDI) has been used extensively for inter-organisational transactions and has actually been around since the 70s. EDI was originally used on secure private networks such as Value Added Networks (VANs).

EDI involves the electronic exchange of structured business documents in a standard format between trading partners. It has had many applications and has been used to share documents such as invoices, orders, products specifications and bill of ladings between organisations. It is used extensively within many industries including automobile, consumer goods, transport, retail, chemicals, electronics and health. Supermarkets have used it to order goods to restock shelves and car manufacturers have used it to invoice dealerships.

More recently, though, organisations have started to use the Internet as a channel for EDI as it can be implemented at lower costs. The Internet also supports and enhances EDI in a number of additional ways including the ability to send e-mails with EDI, enabling direct input of information from internet pages and being able to map the contents of an EDI message to an Internet site. This is particularly useful for smaller to medium sized organisations in the supply chain.

2.4 Enterprise Resource Planning Systems

Enterprise Resource Planning Systems (ERP) were first introduced in the 90s as a follow up to the Materials Requirements Planning systems and Manufacturing Resource Planning systems. ERP systems are multi-application systems that automate and integrate various business operations of an organisation eg ordering, manufacturing, finance, distribution. A database management system lies at the core of the ERP system, collating data from one business process of an organisation and sharing it with another business operation. The ERP system is normally made up of areas such as: sales and marketing; materials management; production planning; quality management; engineering; human resources; finance & accounting and; customer relationship management.

There are many advantages associated with ERP systems including their capacity to integrate business processes, provide access to real time data, reduce duplication of data, ensure better accuracy and enforce consistent practices across the entire organisations. There are many key vendors including companies such as Microsoft, SAP, Baan, PeopleSoft and Oracle. As well as generic ERP systems being available there are also industry specific solutions eg airline management, banking, healthcare.

ERP systems have also been greatly influenced by developments in the web. ERP vendors have worked to stay abreast of technology and developed their products to make them compatible with the web and make all front end and back end applications available via the web. In addition, organisations are increasingly providing suppliers and customers within their SCN with access to their ERP system. This enables them to share important information, collaborate more easily and make more informed decisions that are beneficial to the whole SCN.

2.5 Collaborative tools

There are a variety of collaborative tools and technologies that support communication and working together on activities and tasks across the supply chain and SCN. Collaborative tools can be useful for cooperating, coordinating, solving problems and negotiating.

Groupware is a generic term that describes software solutions that enable groups or teams of people to work together and supports them in activities such as collaborative authoring, managing documents, group meetings & conferencing, and project development. The types of tools that these solutions may embrace are e-mail, bulletin boards, discussion groups, audio and video conferencing, groups calendaring and scheduling, document management and workflow systems. They can collectively support collaboration within an organisation and between organisations.

For example, audio conferencing (which supports the transmission of audio data) and videoconferencing (which supports the transmission of live video) can be used in conjunction with shared whiteboard applications to allow two or more people to work on an activity collaboratively from different locations.

Workflow management systems allow documents to be routed through organisations and provide facilities for routing forms, assigning tasks and privileges and monitoring tasks. They are regularly used for supporting supply chain processes eg raising a purchase order, submitting a holiday request, processing a customer complaint. These types of systems ensure that information is directed to the relevant person responsible for completing the next business activity and it is completed in a timely fashion.

2.6 Radio Frequency Identification tags

A further technology that is provoking huge interest in the field of supply chains and supply chain management is Radio Frequency Identification tags (RFID). RFID tags support real time tracking of tagged goods throughout SCN. The tags are attached to products and emit signals containing detailed information regarding what the product is, the size of the product, where it was made, when it might perish, the product warranty etc. They can also be used to track a product as it passes though the SCN eg the factory floor, the warehouse, the distribution chain, the retailer and then at point of sale.

There are many strategic benefits for managing a supply chain including not only the ability to track the products, but also to monitor sales more closely, maintain appropriate levels of stock, reduce the level of stolen goods and enable organisations to launch product recalls more easily. Product recalls are something that particularly affects food manufacturers and pharmaceutical industries and RFID technologies provide them with the ability to withdraw specific batches of products from different parts of the world at a moment's notice.

There are many potential opportunities for using RFID tags for improving supply chain visibility and information sharing. They could provide a huge amount of intelligence and lead to significant developments in supply chain processes. The main factors that have held back the adoption of RFID tags to date have been the price of tags, hardware and IT infrastructure and physics related issues. Once these factors are overcome, further applications are likely to be initiated in other industries. In the retail industry, in particular, RFID technologies are increasingly used across SCN. There are people however, who consider RFID technologies to be an infringement of privacy.

2.7 Wireless & mobile technologies

Wireless networks have emerged more recently as a very flexible method of connecting to the Internet e.g. wireless WANs, wireless LANs, wireless PANs using technologies such as WiFi and Bluetooth which essentially means that people can access the Internet using a network which is not physically wired. Alongside developments in wireless networks, there have been an increasing number of different mobile devices becoming available ranging from mobile phones, smartphones, personal digital assistants (PDAs) laptop, ipods to ipads. A term often associated with mobile internet access is Wireless Application Protocol or WAP phones. They enable people to access information on web sites which has been specifically tailored using Wireless Markup language for display on the screen of mobile phones.

Wireless internet access and mobile devices provide easy access to the Internet, www, intranets, extranets and specific tools and applications. They are extremely popular due to the flexibility and freedom they offer. Employees can communicate from many more different places at convenient times eg employees can work from different locations, salespeople can access company systems when they are at customer premises. They also offer great potential for reaching customers as is evident from research by Wireless Intelligence (2008) which found that by the end of 2007 there were 2 billion subscriber connections (representing half the planets population). Also, mobile phone tracking allows the position of a mobile phone to be tracked even when a user is not on a call. This can benefit organisations who can market products to customers when they are on the move and within the locality of their business. On the downside, the channel capacity in wireless networks can be lower and issues such as security can be exacerbated.

2.8 Richer media

More recently a range of internet applications have been developed that provide a richer interactive experience. Key applications include Aysnchronous Javascript XML (AJAX) and Application Programming Interface (API). AJAX provides a method for exchanging data asynchronously between browser and server and avoids full page reloads every time a web page changes. This creates an impression of it being a richer application and also a more responsive interface. This can be beneficial for enhancing communication with suppliers and customers using applications on the Internet.

API similarly can improve communication by enabling greater interaction and sharing of content between different software. For example a company could display a video on a social networking site of their products and services or a price comparison site can use API to aggregate price data from different web sites in real time.

2.9 Web 2.0 technologies

The most recent wave of web technologies to be adopted across supply chains are recognised as web 2.0 technologies. Web 2.0 is about a shift from users being passively reading information on the web to becoming actively involved in collaborating and participating on the web. Web 2.0 is interchangeably referred to as 'social media', 'social revolution', 'user-generated content', 'collaboration' and 'community engagement'.

Web 2.0 was developed over the last ten years to encapsulate the rapid uptake in the web and associated technologies and applications, following the bursting of the dot.com bubble in the year 2000 (Sheun, 2008). Web 2.0 is also driven by the business revolution in the computer industry caused by the increasing move to the Internet as a platform but also through an attempt to understand the rules for success on that new platform (O'Reilly, 2005). The thrust behind web 2.0 is on "building applications and services around the unique features of the Internet, as opposed to building applications and expecting the Internet to suit as a platform" (Wikipedia, 2008). A range of services, technologies and applications commonly associated with web 2.0 are blogs, wikis, podcasts, RSS feeds, social networking, forums, multimedia sharing services, tagging and social bookmarking, text messaging and instant messaging.

Web 2.0 is about sharing information through linkages with people. It builds on the concepts of collaboration, contribution and community and thrives on openness and relationship building. Nations (2009) highlights that web 2.0 is a social web, with people connecting with other people. It supports a more socially connected society and builds on characteristics such as openness, participation, cooperation, community and collaboration. Web 2.0 necessitates a shift in the philosophy of society to one where we aren't just using the Internet as a tool – but we are becoming part of it.

There are a number of areas that web tools and technologies can be used to enhance supply chain communication. The types of supply chain activities that web 2.0 may be particularly beneficial to include activities such as marketing and advertising; collaborating and strengthening relationships with customers and suppliers, information and knowledge transfer; delivering added value to products and services; networking and research. Examples of specific supply chain applications are provided in Table 1.

Web 2.0 Tool	**Example of Supply Chain Application**
Blog	Blogs can be used for internal and external communication. For example, they can be used for delivering news on business developments, showcasing products and services, sharing expert advice, opinions and frequently asked questions (FAQ), gathering customer feedback and building a loyal customer base.
Wiki	Wikis can support organisations in document sharing and collaboration and for encouraging communication, knowledge transfer and collective intelligence amongst people involved in supply chain.
Forum/Discussion Board	Forums or discussion boards can be used to make business connections, share information, exchange views and seek advice on business-related matters where companies may lack the expertise.
Really Simple Syndication (RSS) Feed	RSS make it more efficient for organisations/people to check for new content on the web. As new content appears on relevant internal and external websites, the user is updated and the information is delivered. This is useful for market research and information/knowledge transfer.
Social Networking	Social Networking sites are particularly useful for organisations adverting products, providing links to company websites, increasing brand awareness, gathering customer feedback on advertised products and building a loyal customer base.
Multimedia Sharing	Multimedia sharing tools and technologies may be used for sharing audio, photos, videos, presentations and documentations. In particular organisations use them for showcasing their products and services or sharing images and videos of best practice across the supply chain.
Tagging & Social Bookmarking	Tagging and social bookmarking can provide organisations with a means for categorising, classifying and bookmarking content and valuable information on the web. These collectively could support gathering business intelligence and undertaking market research.

Table 1. Web 2.0 Tools & Supply Chain Applications

Web technologies have evolved greatly over the last 20 years. Key advantages of web 2.0 applications lie in the potential they offer for establishing more interactive and participative business connections and collaborations. They can be used to build communities based on interest, purpose or practice between business partners, regardless of location. They also offer greater opportunities for customer-centricity as customers are encouraged to openly feedback and share thoughts, experiences and ideas (Wagner & Majchrzak, 2007).

3. E-commerce, E-business & M-commerce

Web technologies have been increasingly applied across organisations over the last 20 years. The first wave of web technologies to be applied across the field of supply chain management has been commonly referred to as e-commerce. Amazon was one of the first companies in 1994 to embrace and take e-commerce forward. e-commerce involves supporting transactions and buying and selling products and services via the Internet (Jelassi & Enders, 2005). The buying and selling can involve a range of processes such as sales, ordering, billing, payment and distribution.

The 90s saw a huge rise in the number of dot.coms appearing on the Internet. However, excess supply and artificially inflated market sizes and revenues led to the dot.com crash of 2000 when many new internet-based firms went out of business. In the period following, organisations realised they needed to return to business fundamentals and craft sustainable business models and concentrate on increasing efficiencies and reducing costs. Many organisations also realised that they could not concentrate on only making front end processes available online and that they had to integrate them with the backend processes, in order to reap the full benefits.

The second wave of web technologies to be applied across the field of supply chain management was entitled e-business. This can be construed as much more than e-commerce. e-business involves the use of the Internet for all the front end and back end applications and processes that enable a company to service a business transaction (Kalakota & Robinson, 2000). This could involve many activities such as channel management, manufacturing, inventory control and financial operations. e-commerce falls under the umbrella of e-business along with the range of processes that make up the entire supply chain.

More recently, a further type of commerce to be widely recognised is m-commerce which is the use of wireless and mobile technologies for undertaking buying and selling on the Internet. This has become particularly popular due to its flexibility and availability. In fact, in some countries the majority of internet access is through mobile phones and m-commerce can be used for information and monetary transactions.

Table II provides examples of different types of online interactions that may typically occur as a consequence of e-commerce, e-business and m-commerce. These may involve business-to-consumer, consumer-to-business, business-to-business and consumer-to-consumer.

There are some companies that exist purely on the Internet (eg Last minute.com), some that use it as an addition to their core business (eg tesco.com) and others that began online but have expanded to incorporate aspects of real world assets (eg Amazon). Nowadays, most traditional businesses have some aspects of e-commerce or e-business eg. online retailing, online ticketing, online banking.

Type of Interaction	Example of Use
Business-to-Consumer	Online catalogues & prices Order processing eg Amazon Online customer service Brand awareness eg. Coco Cola
Consumer-to-Business	Customer Feedback on advertisements eg Irn Bru Selling products/services to organisations eg Priceline.com
Business-to-Business	Electronic Procurement eg Tesco Collaboration e.g product development B2B Marketplace Inventory Management eg. sharing forecasts
Consumer-to-Consumer	Virtual Community Product Recommendations Customers transacting directly Auctions eg eBay Social Networking Sites

Table 2. Different Types of Online Interactions supported by E-commerce, E-business & M-commerce

There are many drivers of e-commerce, e-business and m-commerce. Amongst these are the substantial cost savings that can be achieved through reducing purchasing, sales and operating costs and the efficiencies that can be gained and the speed at which orders can be now be fulfilled. Also, many organisations need to pursue online trading in order to remain competitive. They are under pressure to meet customer demand (many customer expect online availability 24/7), they can use web technologies to enhance their product and service offerings and stay abreast of developments in their marketplace. A key aspect of organisations that is being developed as a result of e-commerce, e-business and m-commerce are supply chain processes. The next section will explore supply chain processes and the impact the web technologies are having on supply chain processes.

4. Web technologies & supply chain processes

One of the main components of an organisation's supply chain are supply chain processes. Bozarth and Handfield (2008) describe supply chain processes as being made up of a logically related sets of tasks or activities geared towards some kind of business outcome and Hammer (2002) indicates that these related activities work together to create a result of value to customers.

Supply chain processes can be categorised as primary, support or developmental supply chain processes. Primary supply chain processes add value directly to the product or service eg manufacturing, customer service. Whilst support supply chain processes don't directly add value to the end product or service, they are necessary for supporting the primary supply chain processes eg human resource management. Finally, the development supply chain processes aim to improve and enhance primary and support processes eg market research.

Supply chain processes can vary substantially in terms of scale and scope. The scale of the supply chain process can range from being a very simple set of tasks to being a very complex related set of activities. Equally the scope of the supply chain process may involve one department within an organisation or it may involve a range of organisations such as suppliers, manufacturers and customers. It is important for an organisation to identify and focus on its key supply chain processes as they will have the biggest influence on the overall supply chain. In particular, the Global Supply Chain Forum identified eight key supply chain processes that make up the core of a typical manufacturing company. These included: customer relationship management; customer service management; demand management; order fulfilment; manufacturing management; procurement; product development and commercialization; and returns. However depending on the nature of the organisation and the type of industry that the organisation operates in, the key supply chain processes may vary.

The accomplishment of core supply chain processes majorly influences the performance of the overall supply chain. Consequently, organisations have been seeking ways to improve or transform these supply chain processes in terms of: productivity; efficiency; customer satisfaction; cycle time; cost; quality; speed; flexibility and competitive advantage. Business improvement methodologies such as Six Sigma Methodology have been employed whilst other organisations have pursued more radical redesign of business processes using Business Process Reengineering.

Technologies have played a major role in the development and transformation of supply chain processes in recent years. The proliferation of the new telecommunications and IT such as the client/server concept, the Internet, intranets and the www has led to the automation and the integration of many supply chain processes and has made real time on-line communication throughout the supply chain a reality.

Cagliano, Caniato and Spina (2003) placed the adoption of web technologies across supply chain processes into three main categories including: e-commerce (sales, customer service & support); e-procurement (purchasing activities); e-operations (order processing, tracking, production planning & scheduling, inventory management, transportation planning). Early adopters focused on e-commerce initially. This tended to be followed by e-procurement and more recently e-operations. The following sections provide examples of the application of web technologies across specific supply chain processes.

4.1 E-Procurement

Procurement broadly entails a company's requisitioning, purchasing, transportation, warehousing and in bound-receiving process. More specifically purchasing can involve: identifying user need for a product; evaluating potential suppliers; bidding, negotiating and selecting suppliers; approving purchases; releasing and receiving purchase requirements; and measuring supplier performance.

E-Procurement essentially involves the application of web technologies to the procurement activities of an organisation. Typically this will involve technologies such as ERP systems, stock control systems, e-catalogues, e-mail, EDI, document management software, workflow systems and accounting systems. There have been many drivers for e-procurement including uncontrolled spending, the processes being very time consuming, costs far too high and organisations using too may suppliers.

The potential impact of e-procurement on competitiveness and profitability is huge as business to business procurement can involve one of the largest costs for an organisation. Some organisations spend 50 to 60 percent of their revenue on buying goods and services.

There are many benefits associated with e-procurement such as cost reduction, reduced inventory levels, improved cycle time, enhanced strategic sourcing and corporate–wide purchasing reporting.

Many companies recognise these benefits and have developed procurement systems. Motorola, for example, developed a procurement system based around an ARIBA web based procurement system and linked to an their oracle financial system, signature authorisation tool, workflow system, EDI and e-mail. The procurement system handled everything from the requisition stage through to the payment stage. The system has streamlined and speeded up the whole process, provided transparency, allowed more controlled spending and made substantial cost savings.

4.2 Inventory management

A further supply chain process that is being developed through web technology is inventory management. Inventory management can be described as "stock or items used to support production (raw materials and work-in-process items) supporting activities (maintenance, repair) and customer service (finished goods and spare parts)" (Bozarth & Handfield, 2008).

Inventory is an extremely valuable resource to organisations and the levels of inventory within their cycle stock, safety stock, transportation inventory, smoothing inventory and other types of inventory have to be well managed. Material Requirements Planning is a business planning techniques that was introduced into manufacturing companies in the early 60s for managing inventory and scheduling replenishment orders. This was superseded by Materials Requirements Planning (MRPII) in the 1980s which moved towards having one integrated system containing a database that could be accessed by different parts of the company. ERP systems went one stage further by better integrating and organising all the information on which planning and control depended upon and, more recently, as indicated earlier in the chapter, web ERP systems have emerged making them more accessible and cheaper. These type of systems in particular play a big role in allowing the exchange of inventory information between organisations and within organisations.

Organisations such as Sun Microsystems use ERP systems to share inventory information across their supply chain and SCN. This includes information such as their forecasted demand, customer orders, production schedules, current inventory levels and bill of materials.

4.3 Transportation management

Transportation management is also being developed through the use of web technology. An early legendary extranet transportation application was Federal Express's shipment tracking service. Fedex is the largest express transportation company in the world and were one of the first companies to make their intranet system accessible to customers for arranging delivery of goods and tracking the progress of goods to their destination. The FedEx site allows customers to log on, type in their package tracking number and view the relevant delivery information.

Coupled with this many organisations are using RFID technology for monitoring the transportation of goods and giving them an up-to-date picture of all 'goods in transit'. Moreover, Geographical Information Systems (GIS) can be used to determine transportation routes, likely weather conditions and a more accurate expected delivery time.

4.4 Customer relationship management

Customers are becoming more and more demanding. There is a greater choice of products and services readily available to them and there is a greater expectation for them to be more personalised. Organisations recognise that they need to take a more cohesive approach to customer relationship management in order to build and sustain long term business with customers, address individual requirements and maintain customer loyalty.

Many web tools can be used for developing customer relationship management. Initially, marketing tools such as e-mail, viral marketing, banner advertising and affiliate networks can be used for acquiring customers. Online customer registration can be set up to create a customer profile and the information used in the future for developing the relationship with the customer. Customer relationships can be developed by providing them with personalised portals that highlight information that they may find useful and allows them access to selected applications and tools. Customer actions can also be tracked (eg enquiries, orders, complaints) and stored in company databases, and analysed to determine customer buying or behavioural trends. Companies can use this information to help them better understand their customers and market their products better. An effective customer relationship management system will provide a 360 degree view of the customer eg content of interactions, frequency of interactions, responses.

One company that has led the way in terms of customer relationship management has been Amazon. Amazon is primarily an online retailer which began through selling books but has now expanded into a huge range of products and services. Paramount to Amazon's success has been employing web technologies and achieving customer loyalty and repeat purchases. Using web technologies, the company provides a secure ordering and payment system, manages and assigns inventory to customer orders, provides fast and reliable fulfilment, ensures proper shipments and provides on-line tracking. The companies web pages are tailored to individual preferences for a personalised service and contain product information, customer reviews, recommendation lists etc. The company uses different tools for analysing the popularity of products and the suitability of web page design.

5. Internet-based industry consortiums

A number of industry consortiums have also being using web technologies to set up joint business platforms or electronic marketplaces that support inter-organisational supply chain processes. The electronic marketplaces make the exchange of information between the different organisations involved in the supply chain more fluid and aim to improve the efficiency of the overall SCN in the relevant industry. Different initiatives have been driven by slightly different concerns in various sectors. A few of these industry initiatives will be highlighted.

DamlerChrysler, Ford Motor Company and General Motors led such an initiative in the car industry. They were involved in establishing Covisint which is based on ANX (Automotive Network Exchange). It is a central hub where the manufacturers and suppliers can do business on a single, secure, global business environment and provides a suite of tools including procurement (catalogues, auctions etc), collaboration, sharing design data, quality and portal facilities (Covisint, 2010). One of its major goals was to develop a highly secure and reliable extranet that members could exchange large volumes of design data.

In the consumer-goods sector, Collaborative Planning Forecasting and Replenishment (CPFR) is an initiative between consumer-package goods manufacturers and the retailers that sell their products. The aim of this initiative is to integrate demand and supply side processes to improve efficiencies, increase sales, reduce fixed assets and working capital, and reduce inventory for the entire supply chain whilst satisfying customer needs (CPFR, 2011). Participants have included organizations such as Wal-Mart, Procter & Gamble, Gillette, Nestle etc. This internet-based industry consortium has been used for sharing inventory data, forecasts and ordering information.

A further initiative that will be mentioned is Rosettanet, part of the high technology and electronics industry. It includes major Information Technology, Electronic Components, Semiconductor Manufacturing and Telecommunications companies working towards creating and implementing industry-wide, open e-business process standards (Rosettanet, 2010). It provides a global forum for supplier, customers and competitors to work together on reducing cycle times, inventory costs, improving productivity and measuring supply chain ROI. For example, it is used to automatically update manufacturer's product information on online catalogues.

All of these specific industry consortiums support and enhance business to business transactions. The next section will explore how the spectrum, of web technologies can potentially transform supply chains.

6. Supply chain transformation

Web technology is being used for developing and in many cases transforming supply chains and SCN. Key areas which are being enhanced include building stronger collaborative links between organisations, providing a platform for integrating internal and external supply chain processes and enabling visibility and real time information sharing. These key developments can enhance product and service offerings and a organisation's competitive position.

6.1 Collaboration

A variety of forces have led to a greater need for stronger collaboration between organisations within SCN. Customers are demanding faster, more specialised responses and organisations need to work more closely together in order to streamline and improve the efficiency of the SCN and be more effective in matching demand with a suitable level of supply.

Lambert et al (1996) suggest that there are different degrees of collaborative relationships among supply network members ranging from arm's length relationships, partnerships to vertical integration. Partnerships are becoming increasingly common for strengthening collaboration across supply networks. They involve a degree of joint planning, joint commitment, mutual trust, openness, shared risk, shared rewards, information exchange, operating controls across organisations and corporate culture bridge-building (Cooper et al, 1997). Partnering provides a way of strengthening supply network integration, exploiting unique expertise of each partner, taking advantage of profit making opportunities and providing sustainable competitive advantage that will enable them to 'lock out' competitors (Lambert, Emmelhainz & Gardiner, 1996).

The duration, breadth, strength and closeness of partnerships will vary between supply network members and probably over time. Factors that will affect the degree of partnership that should be established with other supply network members are whether or not they will be involved with the supply members on a long term or short term time basis, whether or not they are core to the functioning of the organisation and whether or not they contribute to the strategic outcomes of the organisation.

Web technologies have provided many opportunities for widening the scope of inter-organisational and intra-organisational relationships. They offer the flexibility for establishing new collaborations with different suppliers, customers, logistic providers and partners and different tiers of suppliers and customers. For example, organisations can now interact with globally dispersed suppliers that were not possible before due to logistical and practical reasons and organisations can provide electronic customer service and support to medium and smaller sized organisations that it was either too costly or impractical to service in the past face to face. Moreover, organisations can more easily pursue on-line interactions with suppliers and customers that are not in adjacent tiers in the supply network. For example, organisations may collaborate with suppliers a couple of tiers removed on supply chain management issues such as demand replenishment for particular products or the design of a specific product. Furthermore, some organisations are cutting out a couple of tiers completely between them and their end consumers and conducting sales, marketing and customer service and support directly.

There are also opportunities for using web technologies to enable globally dispersed people to collaborate on particular supply chain activities. For example, Testing Engineers within the UK division of Sun Microsystems can now collaborate electronically with Testing Engineers in the USA. In the past these employees may have communicated occasionally on the phone but now they can actually benefit from the advantage of being able to establish and develop a formalised virtual team. This allows organisations to leverage a greater pool of knowledge and develop higher quality products or service. On-line collaboration allows greater flexibility for establishing relationships, interacting and pooling resources.

6.2 Integration

The overall aim of supply chain management is to create value for end customers and organisations in the SCN. In order to accomplish this, organisations need to consider integrating supply chain processes internally and externally with other organisations in the SCN.

Technology can be used to improve the efficiency of individual processes but often the real costs savings are achieved through integrating different processes together. Process integration can reduce customer lead times, reduce inventory, speed of decision making and transactions in ways that are not feasible through focusing on individual process. Currently, the primary enabler of supply chain integration is the Internet which enables many different systems, tools and technologies to be fully integrated into a common network. ERP systems, SCM systems, EDI systems, financial systems, procurement systems, customer service and support systems, document management systems, decision support tools, project management tools and database management systems can be integrated and information can be shared between the different systems.

Integration should begin with internal processes (front and back end supply chain processes) and then extended externally to customers and suppliers. Initially external integration should begin with first tier supplier and customers or critical trading partners but over time this can be extended to 2^{nd} and 3^{rd} tier suppliers and customers and in some case organisations may even support a degree of integration between suppliers and customers. Integration will allow employees to better coordinate supply chain activities and share information and resources. The impact that a decision in one part of the supply chain can have on another part of the supply chain will become much more visible and transparent.

6.3 Visibility & information sharing

Web technologies provide greater opportunities for supporting visibility and real time information sharing within and between organisations in the SCN. This will provide decision makers up and down the SCN with greater information and more detail regarding the operations of the overall SCN and enable them to make more informed decision.

Within an organisation, internal information sharing allows manufacturing departments to draw up capacity plans using order planning information, the procurement department to determine purchase orders using order fulfilment information and inventory level information and customer service can use information from order fulfilment when providing appropriate levels of support to their customers.

Organisations can provide their suppliers with improved information flows containing product updates, online scorecards or detailed materials planning information, enabling suppliers to improve their own inventory management and material flows and thus improve relationships between the two organisations. Organisations are also receiving greater information from customers allowing them to have a better understanding of customer requirements, a greater planning awareness and again improved inventory management. Moreover, customers can also benefit from being better informed with information on the status of their orders, promised delivery dates, invoice totals, return notifications, product updates, software distribution etc. These types of benefits will improve relationships with customers and make them more likely to buy the organisation's products or use their services in the future.

Moreover, portals are increasingly being developed to provide suppliers and customers with tailored facilities, applications, information and resources. Technologies such as cookies, data warehousing, data mining and virtual communities are being used to gather information that will further help organisations to personalise interactions. Personalisation is likely to provide the supply network members with a stronger affinity with the organisation and will potentially make other supply network members more likely to demonstrate a reciprocal level of service or commitment to the organisation.

Web technologies provide opportunities for improving supply network collaboration, integration and information sharing. Stronger collaborative supply networks have greater likelihood of leading to more streamlined, coordinated, specialised and effective product or service offerings that will offer more potential for sustainable competitive advantage.

7. Challenges

There are a range of challenges that are directly related to the use of web technologies across supply chains and supply chain management and may potentially affect the impact of web technologies for supporting and building collaborative supply networks. Amongst these challenges is trust, security, social and cultural issues and depersonalisation. Supply chain managers should identify these challenges and take measures to reduce or eliminate them.

7.1 Trust

Trust majorly influences whether or not collaborative partners openly communicate and willingly share information using the web technology. If one party suspects that the other party will take advantage of them or use information against them there is likely to be a reluctance to work together and share information.

Trust is something that generally grows over time and will take time and effort to build up between business partners.

The parties involved need to agree common goals, clear guidelines and monitoring methods and there needs to visibly be clear and equal benefits in collaborating with each other. "Ethical behaviour comes down to business partners setting expectations initially about the relationship and data sharing and then meeting these expectations" (Wisner et al, 2005).

7.2 Identity

There is also concern that widespread use of technology across supply chains may lead to depersonalision of inter-organisational relationships across the SCN. Regular use of web technology can make it difficult to build cohesive and strong bonds with business partners and consequently trickier to collaborate on activities, integrate business processes, be creative with each other and maintain open communication.

A level of identity and personalisation is crucial for the effective formation and functioning of business partnerships. Identity plays a critical role in developing a level of commitment between the business partners, understanding the meaning and getting the most from the communication that is taking place and enabling the interaction to be more effective.

Research suggests that business partners actively using web technology for communicating should maintain a strong level of identity through periodic face to face interactions, regular communication and periodic social interactions. Stronger bonds with business partners will ensure that partners are more likely to 'go the extra mile' in the future when there are supply chain issues or complexities.

7.3 Security

Supply chains are of critical importance to the success of organisations and by making supply chain processes and key business information available on the web, organisations are making themselves vulnerable. Security is one of the most important issues or challenges affecting supply chains supported by web technology. It is an ongoing concern for all organisations and in particular for those organisations using the Internet for developing inter-organisational linkages. Organisations are sharing a lot of important business information eg payments, client lists, network contacts, finance, orders up and down the SCN.

There are many security threats facing organisations ranging from viruses, phishing, hacking, spam, fraud, identity theft to web vandalism and levels of security are being threatened even further through the uptake in wireless and mobile usage, web 2.0 technology and cloud computing.

Organisations within the supply chain will need to have clear frameworks in place for ensuring a high level of security. Security frameworks are likely to embrace areas such as encryption, authentification, firewalls, regulatory compliance and backup systems. The security frameworks should be well communicated to business partners so that on the one hand they also take appropriate security measures but on the other hand, they have the confidence that inter-organisational networks are secure enough to share business information.

7.4 Social & cultural issues

Furthermore, organisations may actively introduce web technologies into their supply chains and enable or constrain people from communicating regarding supply chain processes and activities in different ways. However, organisations alone, do not determine the actual uptake of the web technologies and the ways in which employees use it e.g. who they communicate with, what information they choose to communicate. Structuration theory proposes that the patterns of communication are not only influenced by the standards and procedures of the organisation but also by the social interpretations of employees (Walsham, 1993). The two influences operate continually and simultaneously to determine the actual uptake of technology. Therefore even if an organisation fully promotes the introduction of web technologies into their supply chains, the actual uptake may be less than anticipated if the contextual environment does not embrace the technologies.

Culture will have an impact on the way that people adopt and use web technologies for supply chain processes and activities. It will influence the way that people tend to communicate verbally and non-verbally and the way that people will perceive things. Although more people are using web technologies there is still a minority who are not as comfortable using the technology and who prefer employing conventional mediums. For this very reason, many customer service and support processes within organisations provide conventional channels such as the telephone as a means of accessing service and support as well as e-business channels. Some people simply perceive the telephone as being more traditional, user-friendly and personal and more suitable when they wanted to talk to someone for encouragement and support.

As well as organisations facing various challenges, there are a number of future developments in supply chains that need to be taken into consideration.

8. Future issues

There are a number of future developments within the field of supply chain management that organisations should be aware of when they are developing web technology across their supply chains and SCN in the future. The Future Supply Chain 2016, published by the Global Commerce together with Capgemini, identifies an array of sustainable paramaters that organisations will need to take into account in their future supply chains including areas such as "continuing to delight customers", "carbon emission", "urban restrictions", "sustainability"," customer satisfaction"," supply chain performance", "financial", "external factors eg price changes", "information technology", "visibility", "working together", "collaboration", "transparency" and "networking". These parameters will have an impact on the design of future supply chains. Issues such as collaboration, networking, working together, visibility and transparency will continue to be at the forefront of competitive and innovative supply chains. Some further issues which are emerging will be discussed, in relations to web technology, under the following headings: globalisation; cost reduction; green issues; technological developments.

8.1 Globalisation

A growing trend in the field of supply chain and supply chain management is globalisation. Organisations are increasingly expanding into new marketplaces, using foreign suppliers, dealing with foreign customers, handling a greater number of tiers of global suppliers and customers and accessing the services of global SCN services. In essence, this means that SCN are becoming even more complex and difficult to manage. However, web technologies can provide opportunities for supporting the process of globalisation, enabling integration and visibility of information and maintaining communication with global suppliers, customers and logistic providers. The web offers opportunities for maintaining 24 hour communication and service across different parts of the world although online services/systems may need to be tailored to suit different countries to take into account different languages, product requirements, website layout, promotional offers and so on.

8.2 Cost reduction

Organisations will continue to be concerned with reducing their costs across their supply chain as a means of improving profits and gaining significant competitive advantage. Cost reduction will typically revolve around areas such as reducing purchasing costs, reducing inventories across the supply chain, reducing waste, improving the efficiencies of business processes and outsourcing business processes that are not regarded as core competences. Web technology will have a big role to play in all of these areas. For example, web technology can enable greater collaboration, integration and visibility of information, which will enable organisations to capture real time inventory data and reduce the levels of stock that need to be maintained. This will in turn reduce warehousing costs and the danger of obsolete products.

8.3 Green issues

There are a range of green issues that have become extremely topical in recent years including being 'environmentally friendly', 'recycling', 'conservation' and 'reducing carbon emission'. Supply chains are increasingly being seen as part of organisations' environmental solutions. Customers are demanding to know where products have come from, how they are made and how they are distributed.

Organisations are under pressure to develop green supply chain programmes and improve environmental standards across different processes such as procurement, engineering, distribution and manufacturing. Organisations are increasingly designing products that can be recycled. For example, Kodak take back and recycle 85% of the parts in their single use cameras. Web technology can support green initiatives in a number of ways: allow organisations to more readily use substitute suppliers that are more environmentally friendly; increase automation of supply chains thus reducing the level of paper used and; support the monitoring and recycling of different product parts.

8.4 Technological developments

Many people are already starting to ask what the future web trends will be and how they will impact organisations. There are a number of key concepts that look promising with regards to the web and are gaining a large amount of interest.

Firstly, the semantic web is being developed in order for computers to be able to understand the underlying 'meaning' of data and to relate and compile information without any human intervention. This will allow computers to make inferences and solve problems and it is anticipated that the technology could be extensively used in areas such as business intelligence. This could have potential application in supply chains and supply chain management and could be used in business processes such as research and innovation and customer relationship management.

Another area under development is the use of more high-powered graphics. Already virtual worlds have emerged (eg second life) and it is likely that 3D graphics will be integrated as part of the web. This could provide organisations with the capability to display documents, including the links between them, in three dimensions and could be useful when working on a business activity or task. High powered graphics could also enhance the richness of communication with customers and suppliers by adding a high degree of visualisation and sophistication.
Organisations need to remain technologically aware and be continually searching for new and innovative supply chain applications.

9. Conclusion

This chapter has covered a range of issues associated with the application of web technologies to supply chains. The chapter began with an account of the evolution of web technology since the Internet began through a military project commissioned by the US Department of Defence in 1969. The Internet developed dramatically since commercialisation in the early 90s and has given rise to the proliferation of intranets and extranets and supports technologies such as EDI, ERP, collaborative tools and RFID. Mobile and wireless technologies have enabled easier access to the Internet and current web developments such as richer internet applications and web 2.0 have lead to greater interaction, collaboration and participation on the web.
The chapter then explored ways in which the Internet has been applied across businesses in terms of e-commerce, e-business and m-commerce and across key supply chain processes that make up the overall supply chains. Examples were provided such as inventory management, customer relationship management and transportation. More revolutionary is the fact that web technologies are being used for enhancing and transforming supply chains through building stronger collaborative links, integrating internal and external supply chain processes, supply chain visibility and real time information exchange.
There are many challenges that may hamper the use of web technologies across supply chains such as trust, identity, security and social and cultural challenges and finally, there are a number of future developments such as globalisation, cost reduction, green issues and further technological developments that must be taken into account.

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Agile Information Systems for Mastering Supply Chain Uncertainty

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1. Introduction

Mastering both demand and supply uncertainty is a key challenge for many companies. Markets are increasingly turbulent and also the vulnerability of production and logistics processes is growing. The management of uncertainty has been addressed as an essential task of supply chain management (among others by Davis 1993 and van der Vorst & Beulens 2002).

For coping with the addressed uncertainties, Supply Chain Management (SCM) literature initially has focused on creating so-called lean supply chains that efficiently push products to the market. Lean supply chains build upon reduction of demand uncertainty, especially by product standardisation. Customers must choose from a fixed range of standard products that are made to forecast in high volumes. Business processes in lean supply chains can be highly automated by Enterprise Resource Planning (ERP) systems (Davenport and Brooks, 2004).

In the late 1990s, the then dominant approach of leanness was criticised more and more. It was argued that in volatile markets it is impossible to remove uncertainty. Companies therefore should accept differentiation and unpredictability, and focus on better uncertainty management. Agility was proposed as an alternative approach that aims for rapid response to unpredictable demand in a timely and cost-effective manner (Fisher, 1997, Christopher, 2000). It is founded on a mass customisation approach that combines the seemingly contradictory notions of flexible customisation with efficient standardisation (Davis, 1989, Pine *et al.*, 1993). Efficient standardisation is realised by fabricating parts of the product in volume as standard components; distinctiveness is realised through customer-specific assembly of modules (Duray *et al.*, 2000).

Until then, SCM focused on strategies for coping with demand uncertainty. Lee (2002) was one of the first who stressed the impact of supply uncertainty on supply chain design. Supply chains characterised by high supply uncertainty require the flexibility to deal with unexpected changes in the business processes. Disturbances of logistics, production or supply of materials should rapidly be observed and lead to process changes including re-planning and re-scheduling, purchasing new material, hiring alternative service providers, or negotiating new customer requirements.

Supply chains that are characterised by a high uncertainty of both demand and supply require a combination of responsiveness to changing demand and the flexibility to deal with unexpected changes in the business processes. Following Lee (2002), we use the term agility to characterise these types of supply chains. In agile supply chains, demand requirements and supply capabilities, *i.e.* products and processes including resources, should be continuously attuned (Verdouw et al., 2011). Therefore, both front-office and back-office systems need to be flexible and smoothly integrated (Verdouw et al., 2010a).
The main objectives of this chapter are to define the requirements to information systems in agile supply chains and to develop strategies for implementation of agile information systems. For the identification of requirements, the concept of mass customisation is applied to information systems.
The chapter first introduces a typology of supply chain strategies and the role of information systems in these strategies. Next, it focuses on information systems in the quadrant of agile supply chains. It is argued that these supply chains information systems should support an ICT (information and communications technology) mass customisation approach and the basic requirements for such an approach are defined. In the next section the role of ERP systems, configurators and Service Oriented Architecture (SOA) to enable ICT mass customisation is described. The chapter concludes with the introduction of three basic strategies for the implementation of agile information systems. The strategies involve different divisions of product configuration, process configuration and management of the order fulfilment among ERP systems, dedicated configurator software and SOA platforms.

2. Information systems and Supply Chain Management

2.1 Typology of supply chain strategies

Fisher (1997) introduced the idea that supply chain design should match the degree of demand uncertainty. Fisher discriminates between functional and innovative products. For functional products, having low demand uncertainty, efficient or lean supply chains perform best. For innovative products, that have a high degree of demand uncertainty, flexible or agile chains are a better match. Lee (2002) extends Fisher's analysis by adding the dimension of supply uncertainty. Lee distinguishes between stable and evolving supply processes. Stable processes are characterized by controllable production, mature technology and settled industry. In evolving supply processes production and technology are under development and more or less unpredictable. Lee matches four supply chain types with characteristics of supply and demand (see figure 1):

Supply Uncertainty	Demand Uncertainty: Low (Functional Products)	Demand Uncertainty: High (Innovative Products)
Low (Stable Process)	Efficient supply chains	Responsive supply chains
High (Evolving Process)	Risk-hedging supply chains	Agile supply chains

Fig. 1. Supply chain strategies and demand and supply characteristics [8] (Lee 2002)

- *Efficient* supply chains focus on cost reduction and match with low supply uncertainty - i.e. a controllable production process - and low demand uncertainty.
- *Risk-hedging* supply chains focus on pooling resources to reduce supply uncertainty; this type of chain matches with high supply uncertainty and low demand uncertainty.
- *Responsive* supply chains focus on flexibility through make-to-order process and mass customization; they match with low supply uncertainty and high demand uncertainty.
- *Agile* supply chains combine risk-hedging and responsive strategies, aiming to cope with both high supply uncertainty and high demand uncertainty.

The present chapter focuses on agile supply chains. A firm operating in such a supply chain lacks information about future demand and cannot reliably plan the order fulfillment process. After having defined the current position, two types of strategic options for dealing with the accompanying uncertainty can be distinguished: i) uncertainty reduction strategies that focus on decreasing the need for information, and ii) strategies for better management of uncertainties that focus on improving the information processing capacity.

Firstly, a firm should determine whether reduction of uncertainty is possible and desirable. Uncertainty reduction would imply a shift toward efficient, responsive, or risk-hedging supply chains in the framework of Figure 1. Reduction strategies aim to reduce differentiation by standardization and to eliminate the sources of disruptions. Demand-related examples are product standardization, sharing demand information exchange for improved forecasting and establishment of long-term contracts. Supply-related examples of reduction strategies are improved production control, sharing supply information for synchronized planning, cooperation with technology suppliers, hubs for supplier-managed inventory, and production standardization e.g. by fixed batch volumes, standard carriers, or fixed delivery schedules. Reduction of, especially, demand uncertainty - for instance by product standardization and reducing available product options – is not always desirable. In particular this is not desirable for firms that find their market niche in flexibly fulfilling specific customer needs.

Firms that cannot sufficiently reduce supply and demand uncertainties must find ways to manage the uncertainties. Such firms can consider possibilities for uncertainty management, which leave differentiation and unpredictability as is, but aim to manage it by better organization, maintaining close relationships with suppliers and service providers, usage of advanced decision support tools and better utilization of information.

The mentioned strategies show that information systems are important means for uncertainty reduction and uncertainty management. However, in particular agile supply chains entails specific information system needs, as discussed below.

2.2 Agile supply chains

In the 1990s Supply Chain Management (SCM) evolved towards an integrated process approach in which the concepts of logistics management were extended to incorporate the integration of firms in its supply chain. In the beginning, the focus in Supply Chain Management (SCM) was very much on so-called lean supply chains. The origins of lean manufacturing can be traced to the Toyota Production System (TPS), which focuses on the reduction and elimination of waste (Womack et al. 1991). Thus, lean supply chains focus on efficient streamlined pipelines that push raw material to the market in order to supply predictable demand in high volumes at the lowest costs.

During the 1990s the focus on supply chains as static physical pipelines was criticized more and more. In definitions from the Supply Chain Management (SCM) literature, the network character of supply chains was emphasized (among others by Christopher 1998): "A Supply Chain is the network of organizations that are involved, through upstream and downstream linkages, in the different processes and activities that produce value in the form of products and services in the hands of the ultimate consumer."

The enrichment of the supply chain concept with the network dimension was no conclusive answer to the criticisms on supply chains as static physical pipelines. Also supply chain networks can be focused on the pushing products efficiently to the ultimate customers. As a consequence, in the beginning of this century there was an intensive debate in the SCM-field on agility as an alternative for the then dominant approach of leanness (Christopher 2000). It was argued that a fundamental shift was required in the dominant underlying approach. According to Christopher (2000), the lengthy and slow-moving "pipelines" have become unsustainable due to the turbulence and volatility of current marketplaces. He suggests that the key to survival in these changed conditions is through "agility", in particular by the creation of responsive supply chains that are market sensitive.

Agility can be defined as "using market knowledge and virtual corporation to exploit profitable opportunities in a volatile market place" (Naylor et al. 1999). Agile supply chains are required to be market sensitive and hence nimble (Christopher and Towill 2000). The primary purpose of responsive chains is to respond quickly to unpredictable demand in order to minimize stock outs, forced markdowns and obsolete inventory (Fisher 1997). This thinking is based on dynamics of business systems, which has been a major issue in management research for a long time, while the concept of agility can be traced back to (Goldman et al. 1995).

From the debate emerged that both leanness and agility are no mutually exclusive strategies. On a strategic level it is a matter of strategic choice (as argued yet by Fisher 1997). There is no one best chain network design ('one size fits all'), but companies continuously have to decide in which supply chain they want to participate, which role they are able to play the best and how they deliver added value in these networks. Furthermore, on an operational level it is always a balancing process between push and pull elements (Naylor et al. 1999; Mason-Jones et al. 2000). Nevertheless, there is a trend towards more agile supply chains because of increasing demand and supply uncertainty.

2.3 Role of information systems in Supply Chain Management

Supply chain management aims to manage the complex of business processes performed by numerous interdependent supply chain actors as an integrated whole. Information systems are vital to make the resulting complex, frequent and inter-enterprise information flows manageable by offering tools to automatically capture, process, transfer and communicate information in the supply chain. They can support the planning, control and coordination of supply chains in the following aspects:

- Communication of goals, plans and orders based on actual demand and supply information;
- Assurance of the required process execution by triggering the right activities and guiding the appropriate usage of resources and material (instructions);
- Continuous and chain-wide registration of monitoring information and effective alert mechanisms;

- Rapid and integrated decision-making based on aggregated and enriched monitoring information and information about external variables;
- Fast communication and implementation of the decided corrective and preventive actions.

As a consequence, one can distinguish between the following roles of information systems in Supply Chain Management (Verdouw et al., 2005b):

1. *Platform for shared communication*: to enable integration of control activities in supply chains, there should be in the first place an integrated technical information infrastructure. This requires an effective integration of the information systems of the individual chain actors, with respect to the information definitions, data exchange, applications and technical infrastructure. Examples of enabling ICT are:

a. Inter-organizational technical communication infrastructures, including the Internet and Virtual Private Networks;
b. EDI/XML based techniques for data exchange;
c. Enterprise Application Integration (EAI): software to integrate the applications of individual chain actors, nowadays based on service-oriented architecture (SOA);
d. Central, mostly web based information systems that are used by all involved supply chain actors to manage the basic information flow;

2. *Exchange of demand and supply information*: if there is a shared information infrastructure in place, demand and supply information can be communicated in the entire supply chain. ICT can help to capture this information, translate it to the involved chain actors and integrate it with the back office systems. Examples of enabling ICT are:

a. Product configuration tools that help to specify customer specific orders in interaction with the customer within the process constraints (guided selling) and convert generated customer orders automatically into detailed production, sourcing or distribution orders;
b. Point of Sales (POS) applications that help to replenish retail stocks on basis of actual consumer transactions;
c. Integrated Planning Systems (CPFR: Collaborative Forecasting Planning and Replenishment), in which the planning of the involved companies is aligned;

3. *Management of supply chain process execution*: the triggering, guiding and registration of customer specific task execution, including early detecting and signalling of (potential) disturbances. Examples of enabling ICT are:

a. Enterprise software for production management, distribution, warehouse management, sales, purchase and finance (ERP systems);
b. Early Warning Systems that continuously measure the process conditions and alert if there is serious risk based on an intelligent reaction on condition changes;
c. Inter-organisational Management Information Systems that translate the basis process information into high-level management information about the realization of Performance Indicators, often in the form of management cockpits or dashboards;

4. *Decision support*: tools to analyse demand and supply information and information about process fulfilment, determine the alternatives of corrective and preventive action and to compare and advice about the best solution. Examples of enabling ICT are:

a. Demand Forecasting Models that help to analyse consumer behaviour e.g. on basis of Point of Sales data and predict future consumer demand in order to improve planning;
b. Chain Process Simulation Models, that analyse the process behaviour in various levels of demand orientation and help to improve the fulfilment of consumer demand;

5. *Process configuration and implementation*: the adjustment of control variables and the supporting information systems in order to support customer-specific process execution. Vital enabling element is the ability to configure and reconfigure ICT rapidly. Furthermore, ICT can support the required changes in human behaviour, e.g. by stimulating problem awareness (diagnosis tools), vision development (gaming and simulation) and intervention design (Verdouw et al. 2005a).

A firm's information systems should match the type of supply chain it operates in. For further analysis we distinguish between front-office systems (coping with the demand side) and back-office systems (coping with the supply side). Front-office systems include order management, contract management, sales configurator, demand forecasting, and customer relations management systems. Back-office systems include resource planning and scheduling, stock management, purchasing, and supplier relations management systems. The type of supply chain determines the required flexibility of front- and back-office systems (Verdouw & Verwaart 2008):

- *Efficient supply chains* require stable, straight-forward planning systems for both front-office and back-office. The systems must be well-integrated to reduce waste of resources. Back-office systems support large volume production of standardized products based on long-run forecasts. Front-office systems support efficient order processing, long-run contracts and demand forecasts. Traditional ERP systems cover the demands of efficient supply chains.
- *Risk-hedging supply chains* require the same type of stable front-office systems as efficient supply chains do. However, they require flexible back-office systems, integrated with production control systems and supplier's systems. Disturbance of production or supply of materials should rapidly be observed and lead to re-planning and rescheduling. The rigid planning and scheduling systems of traditional ERP systems may cause problems in this type of supply chain.
- *Responsive supply chains* place high demands on the ability to combine fluctuations in demand and available supplies with respect to product specifications and lead times. The most common approach to organize responsiveness is mass customization in an assemble-to-order (ATO) production environment. This type of supply chain quickly responses to demand variability by efficient assembling of order-specific products from standard components. It requires stable back-office systems for efficient production of standardized components and rapid assembly. Traditional ERP systems can meet this demand. However, front-office systems require a flexibility usually not offered by traditional ERP systems. A responsive supply chain may require a more sophisticated sales configurator.
- *Agile supply chains* require flexibility in both front-office and back-office systems. They demand flexible ERP in the back-office and sophisticated configurator and customer communications systems in the front-office. Tight integration is required between front-office and back-office and with systems of both suppliers and customers.

3. Requirements for information systems in agile supply chains

This section focuses on the requirements for information systems in agile supply chains. Therefore, it applies the concept of mass customisation to information systems.

In agile supply chains, it must be possible to easily set-up, connect and disconnect information systems needed to achieve a specific value proposition. It must be possible to design and instantiate new or adjusted supply chain configurations rapidly and at low costs. The main challenge in achieving this is to combine flexible customization with efficient standardization in the design and implementation of the logistics information systems introduced above. Mass customization is broadly advocated as a core approach to balance these seemingly contradictory notions (Davis 1989; Pine et al. 1993; Kotha 1995). It is a modular strategy that is intended to accomplish efficiency by reusing standardized components, while achieving distinctiveness through customer-specific assembly of modules (Lampel and Mintzberg, 1996, Duray et al., 2000). Mass-customisation builds on four operational capabilities: i) common building blocks that can be reused maximally, ii) unified architecture providing a structure of the defined components that constrain possible variants, iii) a technical platform for seamless integration of the building blocks, and iv) configuration tools that support the elicitation of customer requirements while considering the possible options (Pine et al. 1993, Duray et al. 2000, Zipkin 2000, Verdouw et al., 2010a, among others).

ICT mass customisation combines the seemingly contradictory notions of efficient standard software and flexible customised software (Verdouw et al., 2010b). It enables customer-specific assembly of information systems from a repository of standard components. As such, mass-customisable ICT can be positioned in the middle of a continuum of standard packaged software and customised software. Software developers pre-design and realise modules based on forecasted functionality. Customers get their own ICT configuration, but constrained by the range of available components, as defined in reference models for the configuration of systems. These components could be supplied by different software vendors, which allows for using best-of-breed solutions in selecting and designing systems.

Following the identified requirements for mass customisation systems, the requirements for mass-customisable information systems are (Verdouw et al., 2010b):

a. *Generic information model:* like product architectures in a mass customisation approach, information models should be set up as generic models, which define the class of architectures that can be assembled. Additional complexity of generic information models is that they comprise different interrelated model types including business process models, product models, semantic data models and ontologies, and information integration standards, e.g. eBusiness messages, web service standards, RFID protocols, and coding standards.
b. *Modular software:* modules in an ICT mass customisation approach must be application-independent services, in which policy, input and output data, and interfaces are well defined (product modularity). They should not impose technical constraints on development of other modules (process modularity). Furthermore, it should be easy to replace a software module of provider A by a module of provider B, and it must be possible to combine modules of different vendors (network modularity).
c. *Information integration platform:* a software platform is required that the modules can easily be plugged into, that can enact the execution of modules upon the occurrence of external or internal events, and that enables the exchange of information between the modules. Contrary to mass-customisable products, this platform has a virtual nature. It is not tied to one place. Especially internet-based techniques enable integration of modules that are located all over the world.
d. *Configuration support:* configuration of ICT elicits the required functionality of specific instantiations of information systems building upon a generic information model. Since

information systems are composed of many interacting components, ICT configuration must be done for different levels of abstraction and different types of subsystems. Consequently, configuring information systems includes many partial configuration tasks that occur at different moments by different people. The dependencies between these different tasks must be well coordinated.

e. *Component availability:* the availability of software modules that, together, provide the desired functionality, including a specification of the interfaces. A specific characteristic of ICT components is again the virtual nature. This implies that components can be duplicated very quickly and at a negligible cost. On the other hand, availability is dependent on service providers, because users have access to the modules via an often complex information infrastructure.

4. Implementation strategies for agile information systems

This section identifies three basic strategies for the implementation of agile information systems. The strategies involve different divisions of product configuration, process configuration and management of the order fulfilment among ERP systems, dedicated configurator software and SOA platforms. Therefore, we first will introduce the role of ERP systems, configurators and SOA to enable ICT mass customisation.

4.1 Enterprise software (ERP)

An Enterprise Resource Planning (ERP) system is a standardized software package that combines functionality of multiple business functions into one integrated system. It is based on a single database and contains functionality to support the main business processes including production, distribution, warehouse management, sales, purchase and finance. The major advantage of ERP is that it provides a stable backbone for the registration and communication of information among business functions, and consequently ensures the timely and accurate availability for integrated business process management. As such, it helps to overcome fragmentation between organizational units (functional silos) and systems (island automation).

ERP has emerged in the early 1990s as a logical extension of the material requirements planning (MRP) systems of the 1970s and of the manufacturing resource planning (MRP II) systems of the 1980s (Akkermans *et al.*, 2003, Jacobs and Weston, 2007). It has been advocated as essential means for implementation of Business Process Redesign in order to improve efficiency and customer service (Davenport, 2000, Hammer and Champy, 2001). Nowadays, ERP has become a de facto standard in many industries. For example, Aberdeen reported in 2008 that 86% of the manufacturing companies has implemented ERP (Aberdeen, 2008).

Early ERP-systems were not primarily focused on the supply chain (Davenport and Brooks, 2004). Consequently, they failed to meet the demands in current dynamic supply chains. In a critical note, Rettig (2007) argues that the ERP concept of a single monolithic system failed for many companies: “But these massive programs, with millions of lines of code, thousands of installation options and countless interrelated pieces, introduced new levels of complexity, often without eliminating the older systems they were designed to replace.” In a study of Akkermans *et al.*, (2003) European supply chain executives address four key limitations of ERP systems in providing effective supply chain support:

1. Their insufficient extended enterprise functionality in crossing organizational boundaries;
2. Their inflexibility to ever-changing supply chain needs;
3. Their lack of functionality beyond managing transactions; and
4. Their closed and non-modular system architecture.

Akkermans *et al.* (2003) argue that the lack of modularity is the root cause for the other shortcomings.

In the research note "ERP is dead – long live ERP II", Gartner was one of the first who put the limitations of early ERP systems on the agenda (Bond *et al.*, 2000). They defined ERP II as a transformation of ERP into next-generation enterprise systems, which are web based, open and componentised. The ERP industry has embraced this new philosophy and started to modularize their systems architectures, in particular by incorporating Service Oriented Architecture (SOA) platforms, e.g. SAP NetWeaver (Møller, 2005). Furthermore, ERP vendors included intelligent modules that go beyond transactions (especially Advanced Planning Systems and Business Intelligence). However, the monolithic nature is deeply embedded in ERP systems. It takes much time to unravel the big jumble of software code into a consistent and coherent set of components. Consequently, the componentizing of ERP is still in progress. This implies that, although valuable advances are accomplished, the basic limitations of ERP systems still exist.

ERP systems perfectly cover the demands of efficient supply chains that are characterized by stable business processes and low demand uncertainty. However, in supply chains with uncertain demand and high vulnerability of production and logistics processes, current ERP is experienced as an obstacle in achieving the required flexibility (Akkermans et al., 2003). The development towards modularized and service-oriented ERP is essential for the implementation of mass-customizable information systems. Such ERP systems ensure the availability of the software modules that, together, provide the desired functionality, including a specification of the interfaces. As such modularized ERP can provide a repository of building blocks that form the heart of mass customizable information systems.

4.2 Configurators

Configurators have emerged from the development of rule-based product design in the field of Artificial Intelligence. A well-known early application was R1, a product configurator for VAX computers (McDermott, 1981). A product configurator is a tool that guides users interactively through specification of customer-specific products (Sabin and Weigel, 1998, Forza and Salvador, 2002). Configurators generate specific product variants by combining sets of predefined components and specifying features according to permitted values. Next, they check the completeness and consistency of configured products based on rules that define the interdependencies between components or features. Product configurators are based on generic product models, which define the class of objects that can be configured (Hegge and Wortmann, 1991).

Currently, configurators play an important role in responsive supply chains, which are characterised by high demand uncertainty and low supply uncertainty (Lee, 2002). They are widely used for product configuration to enable rapid response to customer demands. In interaction with the user, the software generates consistent and complete specifications of customised products, taking into account both customer's requirements (e.g. functional specifications and delivery conditions) and feasibility of production, sourcing and delivery.

Along with the product specification, current configurators can produce commercial offers and draft contracts, and schedules and contracts for support and maintenance of the product. The software can be designed for use either by a sales representative of the supplier, or by a customer, e.g. through the internet. In both cases the configuration process results in a quick and effective order specification that can directly be entered into the production planning and scheduling systems.

Configurators can also be used to manage high uncertainties at the supply-side by supporting the rapid configuration of processes (Verdouw et al. 2010a). This concept of process configuration is introduced by Schierholt (2001), who applied the principles of product configuration to support process planning. Process configuration supports a rapid and consistent specification of the workflow that is needed to fulfil specific customer orders. For example, local deliveries from stock follow a different workflow than exports that are produced to order. Moreover, it supports reconfiguration of the workflow in case of unexpected supply events, e.g. components that were originally planned to be produced can be re-planned to be purchased.

Configurators can provide the configuration support as required in mass-customisable information systems. It helps to elicit the required functionality of specific instantiations of information systems building upon a generic information model.

4.3 Service-Oriented Architecture

Service-Oriented Architecture (SOA) is a software architecture where functionality is grouped around business processes and packaged as interoperable services. The aim is a loose coupling of services with operating systems, programming languages and other technologies, which underlie applications (Newcomer and Lomow, 2004). SOA separates functions into distinct units, or services (Bell, 2008), which are made accessible over a network to be combined and reused in the production of business applications (Erl, 2005). These services communicate with each other by passing data from one service to another, or by coordinating an activity between two or more services. Service providers publish web services in a service directory, service requestors search in this directory to find suitable services, bind to that service and use it, based on information from the directory and standardized procedures (Leymann, 2003; Erl, 2005). So, SOA provides the technology that enables timely and flexible sharing of information demands (Wolfert et al., 2010). It is component-based by nature and widely acknowledged as the de facto standard for information integration. SOA enables the definition of components with standardized interfaces, a central repository of published web services and standardized procedures for selection and implementation of components.

1. A technical architecture based on SOA consists of three layers (Erl, 2005):
2. A business process management layer, coordinating the execution of business services: this is a functional integration layer that groups services from the underlying business service layer into business processes. The process services are typically implemented through generic enactment engines, that execute workflows defined in languages like BPEL or BPML. Following the workflow specifications, the enactment engines invoke services in the next layer. Services in the process layer can be rapidly configured or reconfigured using business process management (BPM) tools.
3. A business services layer, delivering information services to the business processes. The business services implement the information processing functions of the actual business

processes. Business services may be either straightforward data registration or reporting services, or complex services based on extensive business logic. They may implement these functions directly, for instance applying the Business Rules Approach, or use application services that connect the business services to (legacy) information processing application systems.

4. A business application layer, executing the application logic and data storage. Applications are wrapped in application services, offering a standard web service interface to the business services, thus enabling enterprise application integration (EAI).

The advances towards Service-Oriented Architecture (SOA) has been very important to enable mass-customisation of information systems. It can provide a software platform that the web services can easily be plugged into, that can enact the execution of web services upon the occurrence of external or internal events, and that enables the exchange of information between the modules. Consequently, it can support to meet, in particular, the requirements concerning software modularity and information integration platform (Verdouw et al., 2010b). As such, SOA can help to overcome the limitations of traditional ERP systems and achieve the required backend flexibility in agile supply chains. However, SOA does not include the knowledge required to specify services and to configure business processes as a sequence of services. Furthermore, the required software components must be available packaged as application-independent web services. So, even if a company applies SOA, important remaining challenges include the development of: i) generic information models that specify families of business processes and services, ii) tools that support configuration of specific business process and service architectures, iii) repository of software components software that are packaged as application-independent web services (Verdouw et al., 2010b, Wolfert et al., 2010).

In sum, it can be concluded that enterprise software (ERP), configurators and Service-oriented Architecture (SOA) together could meet the requirements of ICT mass customisation (see Table 1). ERP can ensure the availability of the software modules in a repository of building blocks that form the heart of mass customizable information systems. However, the development towards modularized and service-oriented ERP is a crucial prerequisite to achieve this. Furthermore, configurators can provide the configuration support as required in mass-customisable information systems. It helps to elicit the required functionality of specific instantiations of information systems building upon a generic information model. Last, Service-Oriented Architecture (SOA) can help to meet, in particular, the requirements concerning software modularity and it provides an information integration platform.

Requirements ICT mass customization (Verdouw et al. 2010b)	Enterprise software (ERP)	Configurators	Service-oriented Architecture (SOA)
a. Generic information models		X	
b. Modular software			X
c. Information integration platform			X
d. Configuration support		X	
e. Component availability	X		

Table 1. Main contributions of ERP, configurators and SOA to the requirements of ICT mass customization

The next section discusses some strategies on how the strengths of ERP, configurators and SOA can be combined to enable mass customisation of information systems.

4.4 Implementation strategies and challenges

Following Verdouw et al. (2010a), three basic strategies can be distinguished to implement ICT mass customization by combining the strengths of ERP, configurators and SOA. Each includes a different division of product configuration, process configuration and management of the order fulfilment among dedicated configurator software, ERP systems and service-oriented middleware.

In the *first strategy*, process models are defined, configured and executed in a SOA-based process management platform, which intermediates between front- and back office systems, in particular product configurators and ERP systems for planning and scheduling. At this option, the functionality for product and process configuration is provided by different applications. Process configuration is done outside product configurators in service-oriented middleware.

Implementation of such an approach is complex. To mention some difficulties: the constraints arising from the actual availability of the required resources should be taken into account, as well as the dependences between configuration choices; it must be possible to inherit configuration choices from the product requirement definition to detailed process diagrams; and configuration choices must be translated into graphical diagrams. SOA-based process management platforms do not yet provide tool support for the configuration of process models in a manageable and user-friendly way.

Another important challenge of the first strategy is to find solutions for some technical problems that will arise when implementing process configuration in a SOA-based platform. For example, solutions have to be found to solve the problems arising from the redundancy of process knowledge as the defined in the process models of SOA-platforms and the hard-coded process logic in legacy systems. Furthermore, the incorporation of process model configuration into the run-time system will impact systems performance, in particular if the reference models are used by multiple organisations. In the latter case, also security will be an issue.

The *second strategy* is the inclusion of process configuration in dedicated configurator software. For this option, both product and process configuration are incorporated within one configurator and this tool is integrated with external planning & scheduling systems, either directly or via service-oriented middleware. The main challenge of this option is to manage the intensive interactions between the configurator and with external planning & scheduling systems, in particular in case of frequent reconfiguration of the workflow due to unexpected events. The most natural solution direction is to integrate both types of systems via service-oriented middleware. The implementation issues are similar to the first discussed implementation, except that the tool support for process configuration is not included in the SOA-based platform but in an external tool. Consequently, additional challenges include how to translate the output of the process configurator into a process model notation that can be interpreted by the SOA-based platform.

The *third and last strategy* is to include both product and process configuration into the ERP system and thus integrate all features (product configuration, process configuration and planning and scheduling) within one system. In this case, the ERP system is also the front office for customer interaction. There is no need for defining process models in SOA standards like Business Process Modelling Notation (BPMN) and some of the technical problems mentioned above can be solved easier. For example, the redundancy of process logic could be solved by using process models as the basis for system parameterisation. Furthermore, most ERP systems include functionality for product model definition and product configuration. This makes it easier to use process models for linking product configuration to the execution in back office systems. However, to do so, ERP systems should contain functionality for process modelling and the process models should be the basis for system usage. Many available ERP systems do not include such functionality. More importantly, ERP systems are not based on a modular approach, which is a fundamental precondition for the usage of process models to guide the workflow planning and execution in run-time information systems. At the same time, for many companies it is no realistic option to replace current systems with new flexible solutions is for many companies, among others because of the significant investments in legacy and the risks of losing stability. Because of these limitations, it might be preferably to keep the configuration of process models out of the ERP system.

5. Conclusions

The main objectives of this chapter were to define the requirements to information systems in agile supply chains and to develop strategies for implementation of agile information systems.

The chapter has first introduced a typology of supply chain strategies and the role of information systems in these strategies. The type of supply chain determines the required flexibility of front- and back-office systems. Efficient supply chains require stable, straight-forward planning systems for both front-office and back-office. Risk-hedging supply chains require the same type of stable front-office systems as efficient supply chains do. However, they require flexible back-office systems, integrated with production control systems and supplier's systems. Responsive supply chains place high demands on the ability to combine fluctuations in demand and available supplies with respect to product specifications and lead times. Agile supply chains require flexibility in both front-office and back-office systems. They demand flexible ERP in the back-office and sophisticated configurator and customer communications systems in the front-office.

Next, the chapter has focused on information systems in the quadrant of agile supply chains. It is argued that these supply chains information systems should support an ICT mass customisation approach. ICT mass customisation combines the seemingly contradictory notions of efficient standard software and flexible customised software. It enables customer-specific assembly of information systems from a repository of standard components. Five requirements for the enhancement of ICT mass customisation have been defined: a) generic information model, b) modular software, c) information integration platform, d) configuration support, and e) component availability.

In the next section the role of ERP systems, configurators and SOA to enable ICT mass customisation is defined. None of these technologies completely satisfy the defined requirements, but together they could enable ICT mass customisation. ERP can ensure availability of the software modules in a repository of building blocks that form the heart of mass customizable information systems. However, the development towards modularized and service-oriented ERP is a crucial prerequisite to achieve this. Furthermore, configurators can provide the configuration support as required in mass-customisable information systems. It helps to elicit the required functionality of specific instantiations of information

systems building upon a generic information model. Last, Service-Oriented Architecture (SOA) can help to meet, in particular, the requirements concerning software modularity and it provides an information integration platform.
The chapter concludes with the introduction of three basic strategies for the implementation of agile information systems. The strategies involve different divisions of product configuration, process configuration and management of the order fulfilment among ERP systems, dedicated configurator software and SOA platforms. All of the strategies entail order-specific configuration of the process model. The strategies differ in the technology to be used for that purpose and the location of the knowledge required for process configuration. The first strategy is to implement intelligent process configuration in the middleware that mediates between front-office systems (sales and product configurators) and back-office (ERP) systems. This approach would require a considerable advancement of the state-of-the-art in service composition. The second strategy is to include process configuration in the product configurator, thus enabling simultaneous configuration of product and process. This second approach would require the extension of current product configurators. Since process configuration depends on current and expected state of the back-office, it would also entail extensive and frequent information exchange between front-office and back-office systems. The third strategy is to implement order specific process configuration in the back-office ERP system. The latter strategy would avoid redundancy of process knowledge, but many current ERP systems do not support the modular process modelling approach and the dynamic configuration support required to realise this strategy. The first or the second strategy might be preferred depending on (among other factors) the extent of supply uncertainty in a particular branch of industry.

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24

Composite Supply Chain Applications

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1. Introduction

A number of commercial software vendors sell supply chain software suites that cover essentially all needs of the enterprise. For example, a vendor's product can handle everything from creating an order, to logistics planning for that order, to logistics execution of that order, and finally to financial settlement. Allowing a single software suite to enable all supply chain-related transactions has some significant benefits including reduced integration costs, improved data integrity, and increased process optimization; however, the reality is that many organizations explicitly choose not to perform all of their transactions in a single software suite. Instead, supply chain processes are almost always executed across a heterogeneous system landscape, often involving communications among systems that were not designed to communicate with each other.

Akin to the system landscape decision is the decision of how to implement business processes. There are some business processes in which no competitive advantage is gained from "doing things your own way"; for example, Enterprise Resource Planning (ERP) software has optimized the processing of payroll to the point where a customized payroll process probably will not give you much of an edge over the non-customized competition. However, there are other business processes where innovation can provide a competitive advantage; for example, in the 1980s Wal-Mart enhanced its logistics operations with cross-docking and gained an operational advantage over other retailers. Process innovation is widely acknowledged as a means of increasing business value (Davenport, 1992). In such cases, a single unmodified commercial software product might not support the customized process, and the question becomes how to best develop a solution supporting the customized process while keeping interfacing and interface maintenance costs under control.

In recent years, a number of enterprise software vendors have put forward offerings in the genre we call "Model-to-Execution." These offerings provide a viable means of designing and implementing custom solutions in a manner that is economical in terms of both implementation and maintenance costs.

We begin by presenting our hypothesis and briefly introducing the concept of Model-to-Execution. We then discuss the case study that is used to test the hypothesis and the solution that was designed and implemented via Model-to-Execution. Finally, we describe the benefits of Model-to-Execution for organizations and discuss some of our lessons learned from testing the hypothesis.

2. Theoretical discussion

As described in the introduction, modern supply chain solutions are automated. There are two possibilities: the supply chain business processes could be automated with a single software product or with multiple software products from different vendors. Some companies have elected to use a single vendor, but most companies use products from multiple vendors. Our research focuses on an efficient and effective way to implement supply chain software in a multiple-vendor environment.

Our primary hypothesis is that logistics business processes can be described in business terms and fully automated using Model-to-Execution software solutions. To test this hypothesis, we perform an actual implementation project across multiple vendor components. This is the primary scientific contribution of this paper.

3. Model-to-Execution (M2E)

Model-to-Execution (M2E) is a methodology for designing and implementing software solutions that support business processes. “Model” refers to business process modeling, the practice of analyzing business processes and thoroughly documenting them, typically in step-by-step process flow models. However, a business process model does not execute business processes; such models only illustrate how operations “should” work. This is where “-to-Execution” becomes important. Technologies now exist for converting business process models into running workflow code, and these running workflows combined with humans, Graphical User Interfaces (GUIs), and software services can in fact execute business processes.

Figures 1 and 2 show, in part, the similar approaches taken by two M2E vendors: Oracle and Software AG. We note the common elements “Implement,” “Execute,” and “Monitor”, as well as doing either “Model” or “Strategize” and “Design” prior to implementation. We know from experience with the Oracle and Software AG product offerings that many of the software tools in their suites are also analogous across the two vendors. In fact, the same business process modeling tool is used in both vendors’ M2E offerings—the ARIS Platform from IDS-Scheer. (IDS-Scheer was purchased by Software AG in 2009, and the ARIS product is included in the Oracle Fusion Middleware (OFM) suite under the name Oracle Business Process Analysis (BPA) Suite).

A key component of Model-to-Execution is the business process modeling. Business process modeling is performed primarily by business analysts and serves several purposes. First, because a process is executed across organizational stovepipes, it assembles all relevant business process stakeholders into the same room, something that does not occur often enough in many organizations. Second, it drives agreement. Forcing all constituencies to collectively draw a single representation of the solution helps ensure that differences in vision are worked through and agreed upon before the implementation is started. Third, it provides a significant portion of the content for a requirements document for describing the desired solution to the implementation team. If the purpose of a development initiative is to build an executable business process, then a detailed diagram of the business process is necessary to have in the requirements document. Finally, in all Model-to-Execution packages that we have worked with to date, the business process model is transformed into the skeleton around which the rest of the solution is built. Without the business process model the rest of the solution cannot be built using this methodology.

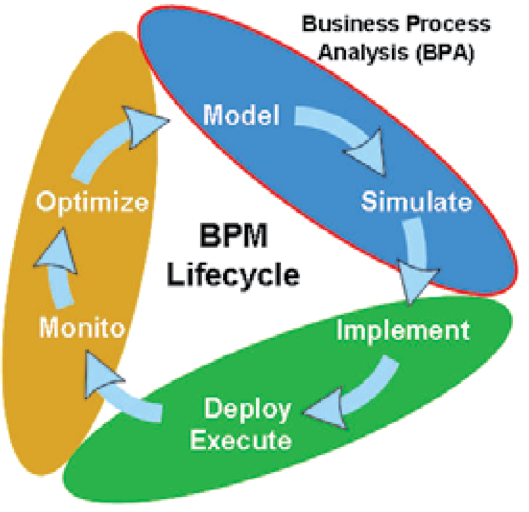

Fig. 1. Oracle BPM [Business Process Management] Lifecycle (Oracle Corporation, 2008)

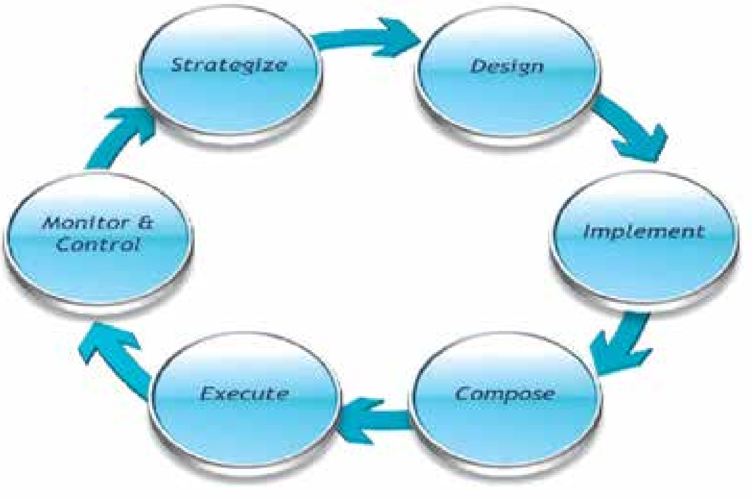

Fig. 2. Software AG BPE [Business Process Excellence] Lifecycle (Jost, 2010)

Conversion of the business process model into executable software occurs in several steps that vary by M2E platform. This conversion is performed primarily by technical staff since the work involved is to some degree (again varying by M2E platform) like “coding” of software. However, as mentioned, the business process model is transformed into the skeleton around which the rest of the solution is built, helping to ensure that the technical resources are building the solution envisioned by the business analysts. An analogy is that the technical resources attach muscles (software engines and services), brains (business rules, software logic, etc.), nerves (“alerts” that monitor Key Performance Indicators (KPIs) and notify people when significant events occur), and skin (graphical user interfaces) to the skeleton.

Figure 3, by Gulledge (2010), illustrates this process of converting a business process model into executable software. The left side of Figure 3 shows the business process model (labeled as "Business BPM"). The business process model is turned into a skeleton, depicted in the center of Figure 3 (labeled "Technical BPM") prior to adding additional functionality (the muscles, brains, nerves, and skin) to it. Finally, the right side of Figure 3 (labeled "Development/ Deployment") shows the skeleton as it is being "fleshed out" with the additional functionality. Whereas the business process model on the left is just a picture and the un-fleshed-out skeleton in the center is also incapable of action, a fully fleshed-out skeleton on the right is capable of executing the business process on which it was based.

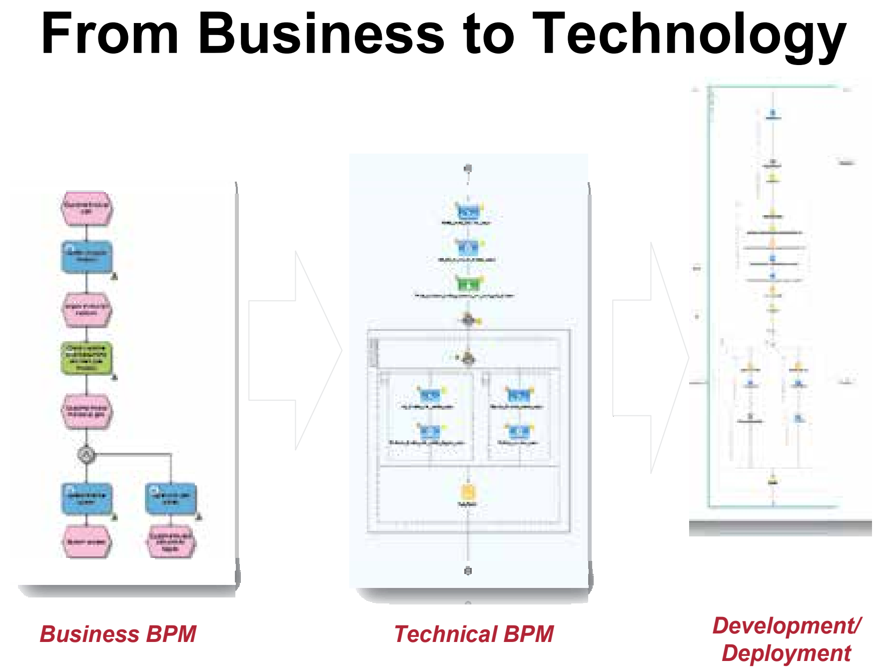

Fig. 3. Going from Model to Execution (Gulledge, 2010)

Although this is not a requirement of M2E, Model-to-Execution lends itself readily to Service-Oriented Architecture (SOA). This is in part because the SOA pattern of breaking down a large software task into smaller tasks performed by reusable Services dovetails nicely with the Business Process Management (BPM) pattern of breaking down a large business task into its smaller component tasks. SOA also embraces the idea of work being performed by multiple systems not under the direct control of the process owner, something that is often encountered in an end-to-end business process. Finally, SOA promotes the idea of loose coupling between systems, which we have found to be a good approach in our M2E implementations thus far as it allows one to quickly swap out one service or sub-process for another.

Model-to-Execution is not the ideal approach to every problem. The following non-exhaustive list contains some of the characteristics that would make a business problem a good candidate for applying the Model-to-Execution approach:

- Possibly a custom or highly specialized business process
  - Routine problems are probably already solved in a commercial software package
- The desired solution is not well-defined (perhaps it is new or innovative) and requires much analysis and agreement before implementation can begin
  - If the solution is already well-defined, then the process modeling effort adds overhead but minimal benefit.
- The business process changes frequently (i.e., the solution requires flexibility and agility)
  - The more frequently an organization desires to change a business process, the more important it is for Information Technology (IT) to adapt quickly to these desires. M2E helps with quickly communicating the desired changes from business staff to technical staff.
  - A frequently changing process leverages the M2E agility advantage more often.
- The business process involves more than one person and/or a heterogeneous system landscape.
  - We leverage the workflow aspect of M2E when we route tasks between different people and systems.
  - The functionality that a system exposes to external callers is typically less powerful and less optimized than what is available to the system internally. M2E solutions will typically call other systems from the outside, so if only one system is involved then perhaps working natively is a better solution.

4. An M2E case study scenario

Cognizant of the fact that supply chain organizations often run more than a single enterprise system, we present a case study examining the potential of Model-to-Execution for executing a supply chain business process within a heterogeneous system landscape.

The proposed business scenario is as follows: Company XYZ is a small printer and fax distributor in the United States (US). It ships printers from several warehouses around the US directly to customer locations. The company's customer delivery performance was deteriorating, and management identified a few issues in the supply chain execution process that were impacting their KPIs:

- Orders were being confirmed and released from warehouses with insufficient inventory. The company wanted to ensure that if orders could not be filled from a particular warehouse location, then inventory would be released from a different warehouse to fulfill that order. This would allow for accurate management of inventory turns.
- Customer delivery addresses were inaccurate, resulting in undeliverable shipments. The company preferred that "the system" confirm a delivery address before orders are released.

Company XYZ automate its logistics and transportation using the Oracle Transportation Management (OTM) product. However, it automate its back-office processes using SAP Business One, making this a heterogeneous system landscape. In addition, the Warehouse

Management System (WMS) is proprietary, presenting unique interfacing challenges compared to commercial products with documented interfaces. Finally, despite the desire to confirm customer delivery addresses in an automated manner, the company only has the ability to manually confirm.

This case study scenario, while not performed for any particular customer, is based on real-world observations. For example, many organizations use OTM for shipment planning and execution, and even though OTM has order-creation capability, they elect to create orders in SAP. The problem of sending items to invalid addresses frequently occurs, as does the problem of interfacing proprietary systems with the rest of the IT landscape. Finally, the integration of multiple disparate systems to enable cross-functional business processes is a problem area that that is well known in the research literature.

5. Applying model-to-execution to the case study scenario

We will now describe in detail the different steps followed in the M2E approach to create the solution. In this case study, the task of taking one from Order to Shipment is accomplished not by a single software application, but rather by a "composite application" made up of the three applications previously mentioned (SAP Business One, proprietary WMS, and OTM) and a fourth application—an address-checking service provided by the United States Postal Service (USPS). Note that the steps followed in this case study are by no means the only way in which M2E could be applied to this problem. Nor are the tools used and systems involved necessarily the tools and systems we would choose today if redoing this case study. The point of the case study is merely to demonstrate that a working solution to a real problem can be developed via the M2E methodology.

5.1 Choosing a technology stack

Model-to-Execution requires roughly the following components:

- A tool for modeling the business process. (The reader will recall that the "skeleton" from our body analogy is created from the business process model.)
- Tools for fleshing out the skeleton, turning what was "just a skeleton" into executable code by:
    - Attaching various software components to the skeleton.
    - Building new software components that are needed but do not exist ahead of time.
    - Writing business rules or other process logic needed to guide the process execution.
- An environment for running the executable code. Just as Mac programs won't run on a personal computer (PC) and PC programs won't run on a Mac, likewise M2E executable code will not run unless it's in an appropriate environment.

The tools we chose for this project are the following:

- Oracle Business Process Analysis (BPA) Suite for modeling the business process, and also for converting the process model into a skeleton.
- Oracle JDeveloper for fleshing out the skeleton.
- Oracle Application Server (OAS) for executing the code produced by Oracle JDeveloper.

These three components are a part of what Oracle brands as Oracle Fusion Middleware (OFM). The inherent integration of the various suite components was one of the primary drivers for choosing to take the development stack from a single vendor (not to be confused with taking the entire application stack from a single vendor). Minimal effort is involved in converting a business process model into a skeleton, and it is likewise easy to move the fleshed-out skeleton into the execution environment. We could have used the same logic to select the Software AG development stack instead, and indeed have done so on other M2E projects. Rarely would we choose to take development stack components from multiple vendors, as this often means extra effort on the part of the development team to make the components of the stack work together.

There is also another problem associated with using components from multiple vendors. Kemsley (2010) says that "using separate, non-integrated tools created a communication barrier between business and IT."

5.2 Assembling a development team

The project team was small: one business analyst (an experienced supply chain consultant), one technical person (an experienced software developer), and a few Subject-Matter Experts (SMEs) (technology consultants, supply chain consultants, former warehouse operations employee). The whole solution was essentially built by two people—the business analyst and the technical resource—in the span of a few months, not by an army of programmers over the course of several years.

The small team size is an advantage of this approach, and is enabled by several factors. Among these is the fact that we are not building an entire solution from the bottom up. Rather, we are leveraging many things that already exist and just building the parts that do not exist. For example, it would take a long time to build a shipment planning feature from scratch, so we instead leverage the shipment planning feature already built in OTM. However, the Warehouse Management System had no feature for rerouting an order in the case of insufficient inventory, so we had to build this feature from scratch.

5.3 Business Process Modeling

The Business Process Modeling effort was led by the business analyst, with the technical resource having only a supporting role in the effort. Through several process-modeling workshops held with the SMEs, the business analyst obtained an understanding of how the SMEs wanted the business process to work, modeled the process in Oracle BPA Suite, and validated the model with the SMEs to confirm that her understanding was correct. Figure 4 shows the result.

Those not familiar with the Event-driven Process Chain (EPC) notation used in this process model can think of a green or blue rectangle as an action ("Function") performed during the business process, and a pink hexagon as an "Event" that triggers the next step in the process. The blue rectangles with gear icons represent fully-automated steps in the process—"the system" should execute these actions without any human interaction. The green rectangle in the middle-right with the person icon is a manual human task—a human must take some sort of action (in this case, reviewing the order and either making corrections or rejecting it outright), often through a GUI. The other green rectangle in the lower-right with the mail icon is a notification step—"the system" sends an email notifying someone of something (in this case, "The order is being canceled").

The short description of the process is as follows: an end-user enters an order into the SAP Business One system. Two process steps are then executed in parallel: the delivery address specified in the order is automatically verified against a system run by the US Postal Service, and an automated check for and subsequent reservation of inventory is made against the proprietary Warehouse Management System. Assuming these process steps encounter no problems, execution follows the left leg of the model where the order is moved into Oracle

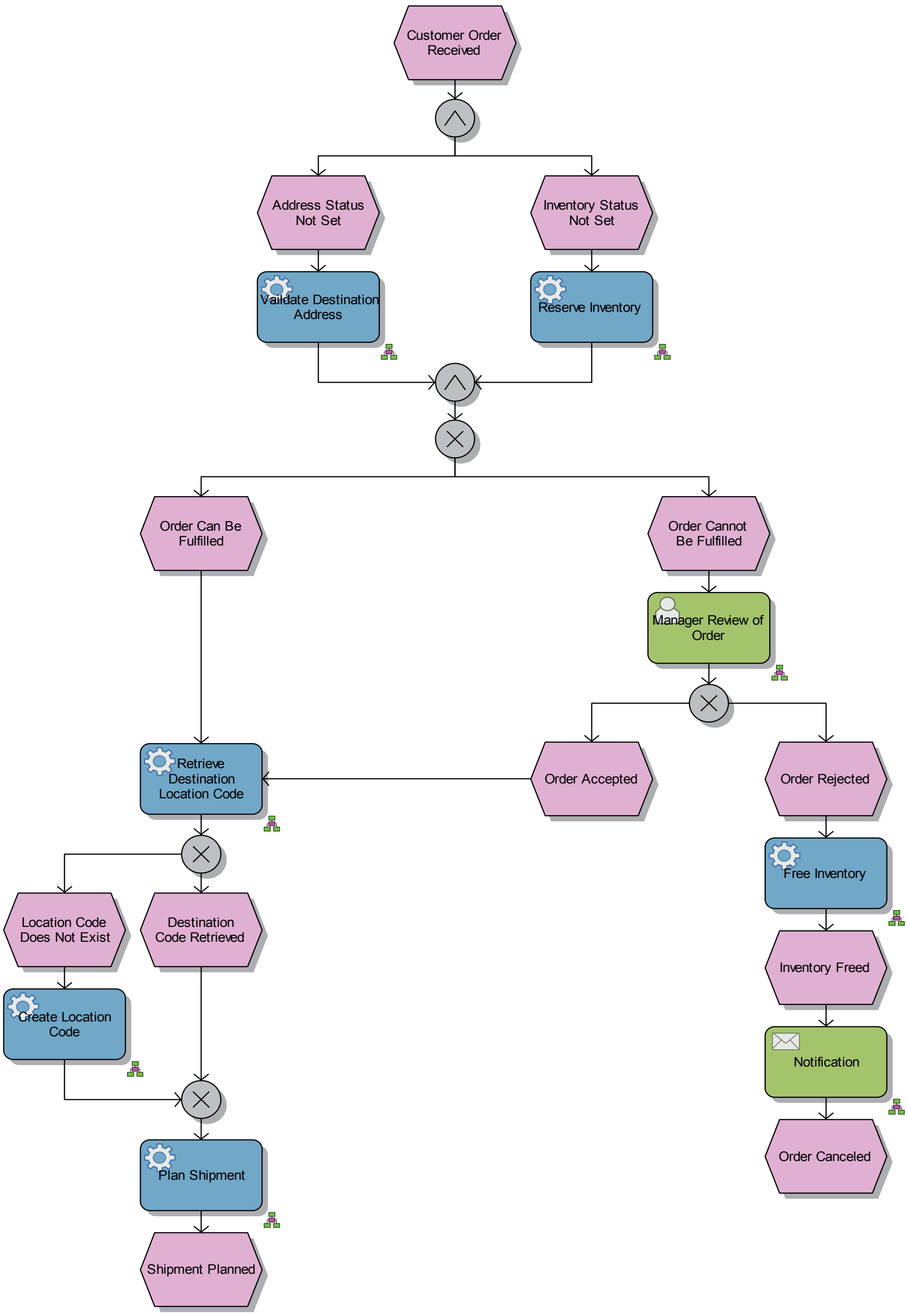

Fig. 4. Business Process Model

Transportation Management (OTM) for shipment planning and execution. (The Functions "Retrieve Destination Location Code" and "Create Location Code" get or create technical information required when putting an order into OTM.) However, if either the address is declared invalid or there is insufficient inventory to cover the order, then execution follows the right leg of the model and enters the Human Step. A screen built specifically for this case study enables human intervention in hopes of resolving the problem. In resolvable cases (e.g., a mistyped ZIP code), the human can make a fix and send the order down the left path to OTM. In irresolvable cases (e.g., a delivery address containing a city, state, and ZIP code but no street address), the order is canceled and order owners are notified accordingly.

Note that various M2E solutions may use different modeling notations. Two that we commonly encounter are the EPC notation used above, and Business Process Modeling Notation (BPMN). The choice of notation is driven primarily by organizational preference and what formats the modeling and conversion tools support. The oracle BPA Suite supports both EPC and BPMN notation, and we have worked on projects where the process modeling was first done in EPC for one audience and converted into BPMN for a second audience. The notation doesn't necessarily matter so long as the SMEs and modelers understand the notation and the model can be converted into a skeleton.

5.4 Moving to the development environment

As mentioned in the previous section, the Oracle BPA Suite was used to model the business process; however, the model is not executable (i.e., one cannot click a "Go" button and watch an order move from SAP Business One into OTM). For a model to be executable, the model must be transformed into a skeleton and fleshed out with technical components. The Oracle BPA Suite is not able to flesh out the model, but it does handle converting the model into a skeleton.

In this project, we created a skeleton in the Business Process Execution Language (BPEL) format, as this is a format that can be easily imported into Oracle JDeveloper. Other tools may use other skeleton formats; for example, if using Software AG's technology stack, we would convert the EPC into BPMN, and the BPMN to XML Process Definition Language (XPDL)—the XPDL would then be imported into the development environment as the skeleton. In the toolsets we have worked with to date, these conversions have been almost entirely automated—simple copies-and-pastes or right-clicks or wizards make for a painless process of creating the skeleton from the business process model. In this case study, the conversion is initiated by choosing the menu option "Share Blueprint with IT" in the Oracle BPA Suite.

Finally, the skeleton must be moved into the development environment. Our development tool, Oracle JDeveloper, provided a menu option for importing the skeletons from the Oracle BPA Suite database. The specifics of moving a skeleton into a development environment will vary by toolset, and we have seen various vendors making this part of the process more streamlined across new toolset releases.

5.5 Working in the development environment

Once the skeleton was in the development environment, the technical resource's work began in earnest. As the reader will remember, the skeleton itself does nothing but provide shape and structure; it is the muscles that do the work, the brain that coordinates the actions of the muscles, and so forth.

5.5.1 The process trigger

One of the first things built was a software component that determined when the business process should execute. In this case study, we execute the process when a new order is created in the SAP Business One system, so we wrote code (or the BPEL equivalent) to occasionally poll SAP Business One and determine when a new record had been written to the Orders table. Once a new order was identified, the relevant information about the order (what was ordered, how much was ordered, to where the order would be delivered, etc.) was queried from the database for use by the rest of the business process.

The above approach to retrieving the order would be considered a "pull" of information. Alternatively, we could have extended SAP Business One software to "push" the new order to us as soon as it was created. The business result is the same: the process is initiated with all the information needed to execute the process. However, there are technical and social considerations that are not the same. For example, the owner of the SAP Business One system might object to your continual polling of her system and prefer to push you the data. Or, alternatively, she may prefer to have you poll the database rather than modify the existing SAP Business One implementation. Thus, while this is a trivial decision from the business perspective, there are technical and social factors that should be considered when determining how the process will "know" to begin execution.

5.5.2 Data considerations

In the executing process, data are passed to each process step; for example, in order for the Address Validation step to execute, an address must be passed in. In some cases, a process step also passes data out; for example, the Address Validation step must signal either "Valid" or "Invalid" so that the process can proceed down an appropriate path. This raises several questions, including:

- What data must I pass in?
- Do I have all the data I need to pass in, or are there missing items that I need to obtain before calling the next process step?
- What data will be passed out?
- Of the data that was passed out, which data do I actually need to execute this process and which are extraneous to this process? (For example, consider listening to the entire weather report when all you really need to know is tomorrow's high temperature.)
- Do I have the data structures needed to hold the data I will work with?
- What data formats are used by the process steps I am calling? What formats should I use for my data structures? If they are not the same, how do I convert between them?

Similar questions arise for branches in the process:

Which field or combination of fields tell me which branch to go down?

- If the decision criterion is complicated or may change in the future, should we employ a business rules engine to, for example, simplify complicated decision criteria into a simple "Go Left" or "Go Right" flag?
- Is such a flag already in my data structure, or do I need to create one?

These questions relate to discussions about enterprise data models, canonical data models, etc. that we will not get into in this chapter. A few of our suggestions relating to data are:

- If your organization has an enterprise data model, canonical data model, etc., then the interfaces (inputs and outputs) to your process should follow the standards defined in them.

- If a field is extraneous to your process, consider excluding it as an input. However, consider including it if it is part of a data structure containing other useful information. The idea is to make it easy to invoke your process, whether that means passing in one Purchase Order data structure or just the minimum number of fields.
- Within your process, use a process-specific data structure to carry the process from start to finish. It may be an unnecessary complexity to carry a hundred-field Purchase Order if you only need five fields off the purchase order. Likewise, you will probably find a need for fields (such as the "Go Left or Go Right" flag) that would not exist on any business process model or enterprise architecture. However, keep in mind that your process will be calling other processes and services, and any such calls made to processes and services created by your enterprise will be expecting data in the canonical data format.
- Expect defining the process-specific data structure to be an iterative process. Despite our best efforts, we rarely anticipate 100% of the structures, fields, and flags needed prior to writing our first line of code.
- When calling other processes or services, accept their input and output formats as given and map to them, even if your data representation is "better." It is rare that the other party will change to accommodate you, especially if they already have other users of that data.
- As you implement, search for opportunities to improve or extend the enterprise data model and canonical data model. It may be that you are the first to use a field or data structure that the rest of the enterprise will soon find valuable, especially if the data model is young or you are entering a new line of business.

5.5.3 Building the executable process

After analyzing the triggering of the executable process and initially defining the data structures, we began implementing the process. In general, it was easiest to start at the beginning and work sequentially. Testing was done after each component was built to ensure that it was behaving as expected, as the outputs of a component or the path chosen by a logic gate affected what happened farther downstream. Several of the different objects we built are described in subsequent paragraphs.

Address validation was performed through a web service hosted by the United States Postal Service (USPS). A "wrapper" web service was created in Oracle JDeveloper to convert the composite application's data into the format required by the USPS web service. Wiring was done in Oracle JDeveloper to connect the composite application and the wrapper web service, and the wrapper web service to the USPS web service

The proprietary Warehouse Management System posed a different challenge: rerouting an order in the case of insufficient inventory was an entirely new feature, so there was no existing functionality to leverage. Rather, since the company owned the WMS, the technical resource modified the WMS and coded this functionality from scratch. He then used Oracle JDeveloper to create a web service interface exposing this and other features of the WMS. Finally, he used Oracle JDeveloper to wire up the composite application to call the new web service.

A GUI was needed to facilitate the human task of reconciling faulty orders (invalid addresses or insufficient inventory). It was decided that the GUI would be displayed in the Oracle BPEL Worklist application, an out-of-the-box application from Oracle facilitating task execution. Figure 5 shows the Oracle BPEL Worklist displaying a list of tasks to be executed, and Figure 6 shows the GUI built for our particular human task. The actual building of the GUI was done in Oracle JDeveloper.

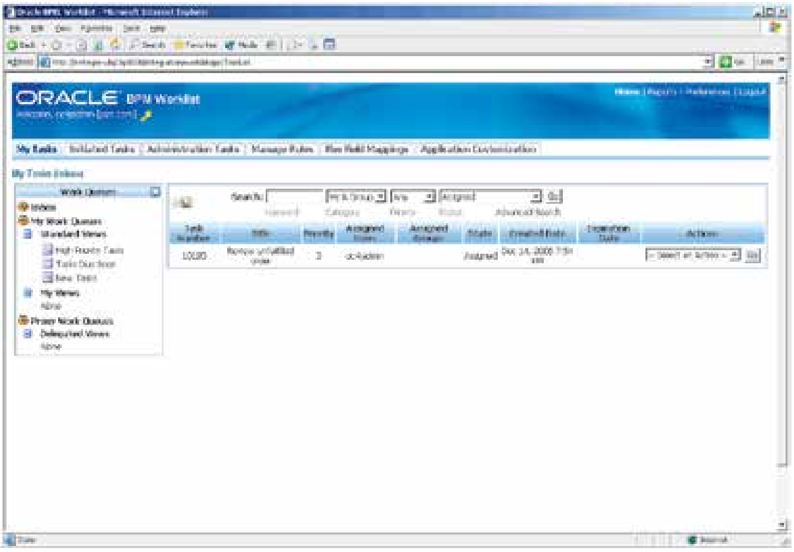

Fig. 5. Oracle BPEL Worklist

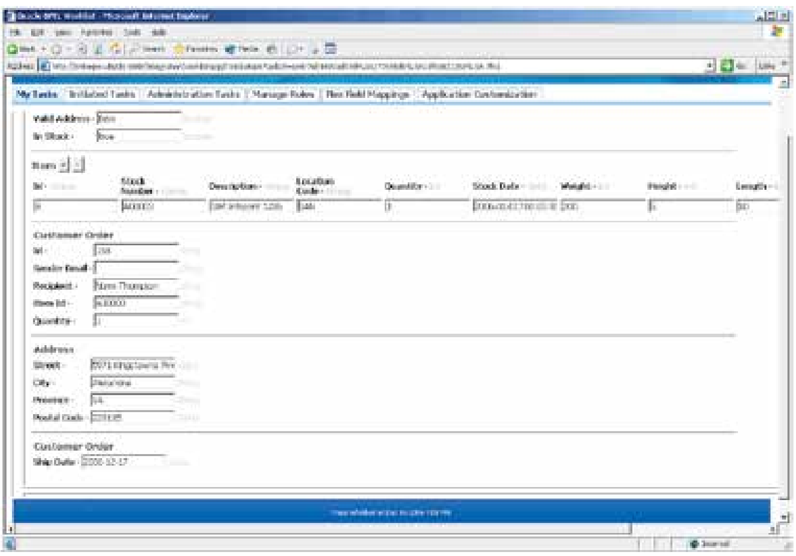

Fig. 6. Human Task as rendered in Oracle BPEL Worklist

The email notification was also created in the Oracle JDeveloper. Oracle Fusion Middleware did not send the email, but instead leveraged an external mail server. Oracle JDeveloper was used to specify the port and address of the email server, as well as any other relevant configuration information. Oracle JDeveloper was also used to define the content of the email.

Interfacing with OTM involved integrating directly with OTM's HyperText Transfer Protocol (HTTP) POST interface. We did this by wrapping the HTTP POST interface in a web service. Calls were made from the composite application to the web service, and the web service created the HTTP POST message and sent it to OTM. All of this work was done in Oracle JDeveloper.

Wiring between the various steps was done within Oracle JDeveloper. This consisted mostly of passing variables into and out of process steps, converting between formats via eXtensible Style Sheet Transformation (XSLT) as needed. When all the components were wired up, the skeleton was fully fleshed out and the composite application was ready for deployment.

5.5.4 Testing

As mentioned, testing was done along with building in an incremental, iterative manner. We would build a feature or component, test it, and remove any bugs prior to beginning work on the next feature or component. This let us catch and fix as many problems as possible upstream, before downstream functionality was built around flawed upstream inputs. Oracle JDeveloper has a built-in feature for executing the web services locally prior to integrating with the Enterprise Service Bus (ESB) for what we might call developer-level testing, but it is recommended that one follow standard software development practice and maintain a separate environments for development and production.

In testing this type of composite application, two types of testing are very important. The first is the component test. Each sub-process or web service should be built such that it can be reused by other processes; thus each sub-process or web service must be tested in a stand-alone manner. The second type of test is the end-to-end scenario test. This runs the composite application—i.e., the executable business process—from start to finish, and ensures that the right things occur as the process is executed. Doing only scenario testing may not detect some component-level bugs if the scenarios do not exercise particular features of the component. Doing only component testing might appear to be sufficient—if all the parts work, shouldn't the whole work as well?—but often mistakes are made in the wiring between components, mistakes that tests of individual components will not catch.

5.5.5 Moving to the execution environment

The execution environment was Oracle Application Server (OAS), an OFM component that was standard at the time but has been replaced by Oracle WebLogic application server as of the 11g release of products. As both OAS and Oracle JDeveloper are Oracle products, Oracle provided out-of-the-box integration for easy transferring of code from Oracle JDeveloper to OAS. A few simple menus and wizards let us easily move each module into OAS. The modules to be moved included the web services we created (not the USPS web service, which was already available on the internet), the human task, and the application definition. Note that the components are moved separately from the application definition; they exist apart from the application definition, such that any composite application (including the one we just built) can use them if the application is so defined. Figure 7 is a screenshot showing some of the components in the execution environment. (Note that there are also other components in the environment, presumably used by other composite applications, which our application does not use.)

5.5.6 Running the composite application

Once the application definition and all application components are in the execution environment, we can run the application. Keep in mind that the application is a composite application—that is, we leverage pre-existing features of other applications rather than building our own from scratch—and that its purpose is to execute the particular business process that we defined in the scenario description.

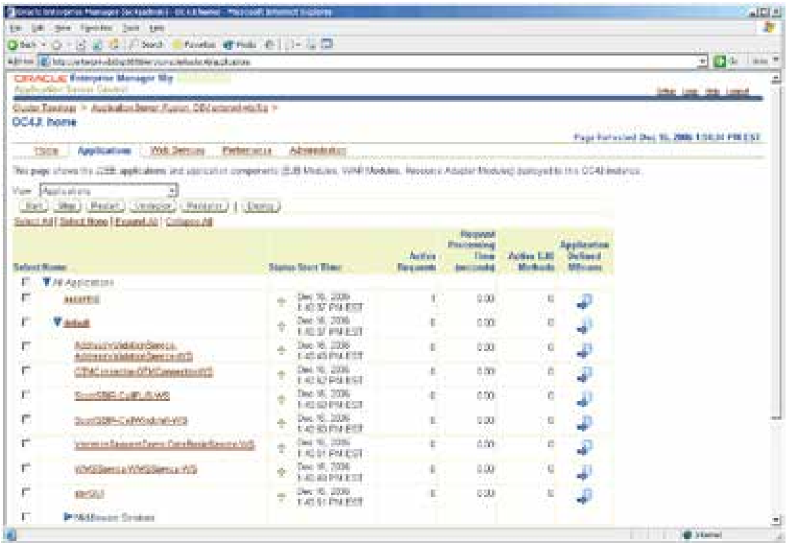

Fig. 7. Components moved to the Execution Environment

Figure 8 shows the first GUI in our application, leveraging from SAP Business One, in which an order is created. When that is completed, the database poll observes the new order and triggers downstream the process. Web service calls are made behind-the-scenes to the Address Validation web service and the WMS web service to validate the delivery address and reserve inventory, respectively. Figure 9 shows the human task that is generated when the Address Validation web service reported the delivery address as being invalid. A company employee uses the human task GUI to correct the delivery address. Finally, the order arrives in OTM, as shown in Figure 10, for shipment planning and execution.

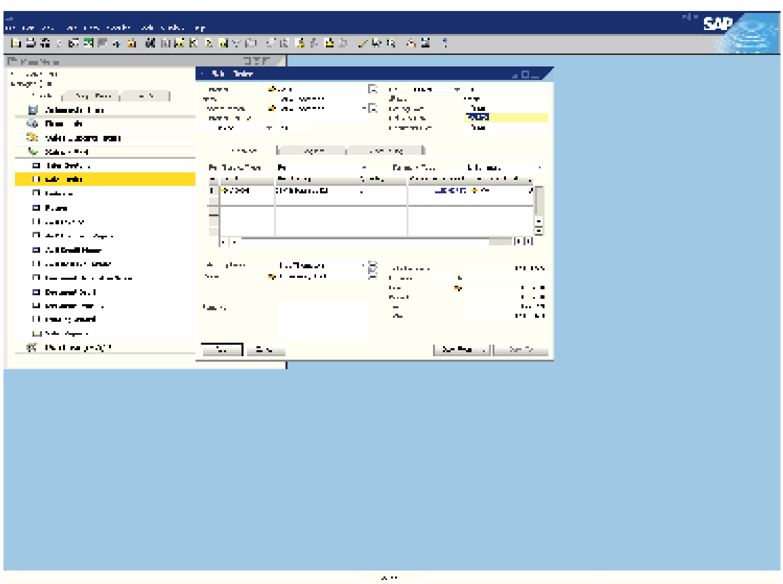

Fig. 8. Executing the process by placing an order in SAP Business One

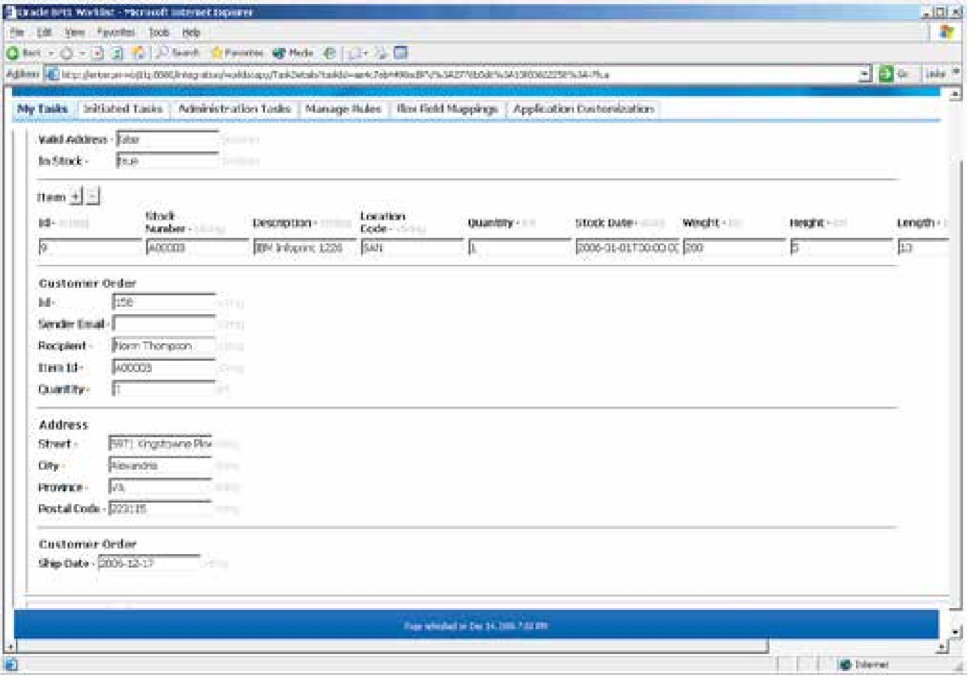

Fig. 9. Using a Human Task GUI to fix an incorrect ZIP code

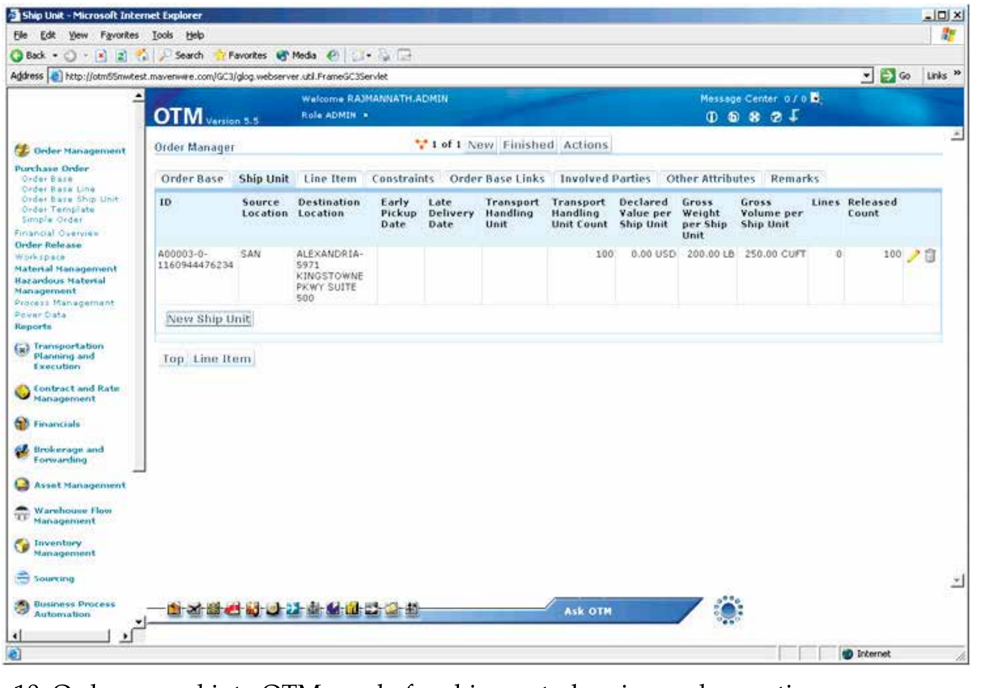

Fig. 10. Order moved into OTM, ready for shipment planning and execution

6. Discussion

In the case study, we did the following:

- Identified problems in the current business process
- Specified changes required to address the problems
- Developed a custom application supporting the changed process

An important point is that the business analyst, not the technical staff and not a one-size-fits-all commercial software package, defined how the business process would work. This let the business focus on its specific problems and do business the way it felt would be best. However, unlike many other custom applications, this application was built not from scratch but by leveraging as much functionality as possible from the existing system landscape. This reduces the time and resources required to complete the project. Finally, the composite application was built with minimal customization of commercial software, avoiding the often great expense incurred in modifying and maintaining a custom solution.

Was this a truly differentiating business process? It was probably not, making shopping for a commercial software solution an acceptable alternative to building the composite application. However, assuming that no commercial solution is found to be a solid or economical fit, developing a composite application using the M2E approach described here is a viable alternative to living with the status quo.

6.1 Benefits for supply chain organizations

We believe that Model-to-Execution offers the following benefits:

- A custom, business-oriented solution; the process executed in the composite application is defined by the business managers, not by the commercial software vendor.
- A feasible means of implementing a "best-of-breed" solution, often argued against because of the high integration costs.
- An agile solution. IT can quickly make changes because any component system or sub-process can be "swapped out" for another comparable system or sub-process with relatively little additional coding. The business can change direction more quickly because IT can change more quickly.
- The Model-to-Execution approach makes the heterogeneous system landscape a workable reality rather than a situation to be avoided.

6.2 Lessons learned

Having now completed several Model-to-Execution projects, the authors offer the following observations as "lessons learned."

6.2.1 Expect to do some wrapping

The ideal M2E (or for that matter, SOA) world has a myriad of plug-and-play web services and sub-processes already existing and available for discovery by composite applications. Many of us do not live in such a world. Rather, the functionality we need is often in legacy systems that are not service-enabled, or are perhaps partially service-enabled, but not in the parts that we want to leverage or at the correct granularity to be useful. Thus, we must first "wrap" legacy systems to expose needed functionality in a service-oriented manner.

One should go into an M2E project prepared to do at least some such wrapping. Consider each such wrapping a one-time investment that will be leveraged by any future M2E or SOA projects needing the same functionality. Initially, most of the functionality you want to use will be unwrapped; however, over time an organization's library of services will grow and less time will be spent wrapping because another project has already done the wrapping work. The natural retirement of legacy systems and activation of more modern, SOA-enabled solutions will also result in more available services and less time spent wrapping.

6.2.2 Understand where the value comes from

In one recent M2E project, the customer asked us to duplicate the existing business process currently carried out entirely in an ERP system as a proof-of-concept for M2E. The project was focused on the technical feasibility of M2E but specified with no reuse in mind, eliminating a key factor in how SOA and M2E reduce development cost. The project also did not allow for any changes in the business process, eliminating the possibility that revenues would increase or operating costs decrease as a result of our work.

Manes (2008) in fact cautions that there will be "big challenges measuring ROI [Return On Investment]" on a SOA initiative. As a result of the experience with this customer, we now know how important it is that organizations pursuing an M2E or SOA solution understand how they should and should not expect to see value. Value comes from increased revenues or decreased costs.

- If no improvements are made to the business process, there is no reason to expect that revenues will increase, regardless of whether you implement a composite application or continue to use your existing systems.
- Costs decrease sharply if you retire a system. However, a system cannot be retired if a composite application is going to leverage its functionality, so "replacing" a system with a composite application is often a misnomer and not a way to decrease costs. (However, if the composite application is designed to leverage the same functionality from a different system instead, then perhaps it is an avenue to facilitate the retirement of a particular system.)
- M2E and SOA solutions cost less to develop because some amount of functionality is reused rather than rebuilt from scratch. The less your solution reuses, the more you should expect its development to cost.
- A solution or component that can be built in a service-oriented way can also be built in a non-service-oriented way. If there is no reuse involved (as is often the case with an organization's first SOA implementation), then it would be incorrect to assume that the service-oriented implementation will show reduced cost over the non-service-oriented solution. It may even cost a little more, considering that any component services being built for the SOA solution should probably be built with both present and future uses in mind (whereas non-SOA solutions need not take other uses into account).
- It is easy to assert that there is some value in the future flexibility and reusability offered by an M2E or SOA solution. Quantifying that value is a more difficult exercise, but one that you will probably have to undertake if pursuing funding for a SOA or M2E solution.
- There is some value—perhaps even synergy—when one thing is "made for" the other. Romantic interests and custom-made suits are two prominent examples. An M2E or SOA solution gives up this value in most places where components are reused. The "made for" value can be retained in things that are not reused—for example, a customized user interface designed to facilitate a particular business task—but in

general there is a trade-off of quality for cost because of the generic-building-block approach to SOA solution design.

6.2.3 Business people and technical people working together

When it comes to creating a new business application, many organizations have a divide—formal or informal—between the business staff who will use the application and the technical staff who will build the application. Often, the business staff will create requirements documents with no input from the technical staff, then hand off to the technical staff who will build the application without any further interaction with the business staff. This situation is often referred to, disparagingly, as “throwing it over the wall.” In other situations, the technical staff has responsibility for gathering requirements from the business staff, with the result being that a lot of business input is missed.
Table 1, recreated from Ellis (2008) shows the results of requirements ownership by either the technical organization (row 1) or the business organization (row 2). Note that both cases result in budget and time overruns—less so for an IT-led requirements process, but in part because the IT-led initiative underdelivered on the desired functionality whereas the business-led initiative delivered far more than was needed (not necessarily a good thing). However, note that a jointly-owned requirements process results in less overrun and more accurate delivery of the desired functionality.

Who Owned Primary Responsibility for Requirements?	Budget % of Target	Time % of Target	Functionality % of Target	Stakeholder time % of Target
IT Organization	162.9	172.0	91.4	172.9
Non-IT Business	196.5	245.3	110.1	201.3
Jointly Owned	143.4	159.3	103.7	163.4

N=109

Table 1. Diagnosing Requirements Failure (Ellis, 2008)

This finding agrees nicely with our experience on M2E projects that we get better results when our business and technical staff work side-by-side to define and implement the solution. This arrangement helps to ensure that requirements are technically feasible and that the nuances of the business are accurately implemented. While the business staff should drive the requirements gathering, involving technical staff allows for better level-of-effort estimates and occasionally ideas about how new technologies can aid the business. However, good requirements do not automatically result in successful solutions. It is ultimately not the requirements document that gets executed in production but rather the code produced during the implementation. Having the M2E skeleton is helpful for keeping the code close to the business requirements, but perhaps more useful is a business person sitting next to the programmer, able to provide clarification and point out where the implementation can be improved.

M2E is not inherently a situation in which requirements responsibility is jointly owned. In fact, the intent of M2E is specifically to make "throwing it over the wall" more accurate. One can see evidence of this in the fact that the menu option in Oracle BPA Suite for skeleton creation is labeled "Share Blueprint with IT," suggesting that IT was not involved prior to skeleton creation. Nevertheless, despite the improvements made by M2E to the "throwing it over the wall" process, we strongly advocate joint requirements gathering and joint development.

7. Conclusion

In conclusion, Model-to-Execution is a viable means of integrating a heterogeneous system landscape. The solution described in this case study is one example, and we expect that in the future other organizations will follow our lead and use a Model-to-Execution approach to develop their own supply chain composite applications. The approach that we present addresses the problem as it actually occurs in industry. That is, our logistics business process is automated using multiple system components, which is the most realistic scenario.

To test our primary hypothesis, we developed an actual composite solution, proving that such an approach is possible. This type of hypothesis test is definitive.

We have explained at a useful level of detail our solution and how we used Model-to-Execution to develop it. We also discussed some of the benefits of Model-to-Execution and some of our lessons learned over various M2E projects.

8. Acknowledgment

The authors wish to acknowledge our customers, business partners, colleagues, and former colleagues that have shaped the way we think about this Model-to-Execution paradigm. We learn something new on every project, and our approach is more sophisticated for it.

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RFID and Supply Chain Management for Manufacturing Digital Enterprise

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1. Introduction

In today's complex and dynamic business environment manufacturing enterprises have to change their business processes to ensure customization of products, flexibility and responsiveness to the customer's and business partner's requirements in order to improve their competitiveness. Globalization of market, growth variants of product, decrease of product life cycles, and increasingly sophisticated customer requirements stress the need for integration with supply chain partners. It becomes necessary to reduce production volumes and make products that satisfy customer specific needs. This can only be achieved by implementing technologies such as enterprise resource planning systems (ERP) and radio frequency identification (RFID) technology to improve operational efficiencies and establish better relationship with their business partners. Enterprises have to integrate information and communications technologies to improve internal processes (within the enterprise) and external processes (with business partners in the supply chain). ERP implementation within the enterprise provides managers with information and enables them to make the effective decisions. Information about events in the supply chain, internal as well as external, must be timely, accurate, complete, adequate and reliable. It is necessary to share real-time information and coordinate all activities of business processes. Lack of accurate real-time information about production status from shopfloor (e.g. Work-In-Process and inventory status) may adversely affect performance, especially of just-in-time manufacturing (JIT) and supply chain planning. Using Radio Frequency Identification (RFID) technology physical objects (raw materials, parts, products, equipment, shipments and personnel) could be integrated by assigned identity (which is typically a number unique to each object) with the Enterprise Resource Planning (ERP) system in the real time and provide information visibility and information sharing in a manufacturing digital enterprise.
Radio frequency identification technology is a remarkable business tool for many aspects of business including Supply Chain Management (SCM). RFID is a growing technology that enables close cooperation of the supply chain partners by real-time information visibility.
Manufacturing enterprises in developing countries like Croatia cope with the quality problems regarding production logistic which is necessary in order to increase capabilities for competitive response to market or supply chain partner's demands. Croatia is making huge efforts to access the European Union (EU) and cannot isolate itself from increasing

globalisation and digitalisation in the environment. EU Initiative i2010 promotes an open and competitive digital economy and emphasises Information and Communication Technologies (ICT) as a driver of inclusion and quality of life. Also, primary goals of a new EU strategy - the Digital Agenda for Europe 2010-2020 are overcoming the crisis, preparing of the EU economy for the challenges of the next period and achieving a prosperous digital economy by 2020. Since Croatia is preparing itself for EU membership, goals of Programme e-Croatia 2007 mostly correspond with Initiative i2010 goals and Digital Agenda. Economy modernisation and increased productivity are crucial to future growth prospects for Croatia. Enterprises tend to achieve complementarities of inter-functional and inter-organizational integration and coordination throughout supply chain. Because of the need for more effective and efficient supply chain management, internal as well as external, in this chapter we propose a conceptual framework for integration of Radio Frequency Identification (RFID) with Enterprise Resource Planning (ERP) system in manufacturing digital enterprise. The objective of our conceptual framework is to enable real-time status information about material, products, workers and other resources needed for management decisions, in the context of hierarchical planning and scheduling according to just-in-time principles. This way we expect achieving a timely and efficient access to information and fast response to requests, in order to achieve coordination of production, procurement and marketing. The system should enhance the visibility of information and material flows in the internal as well as external supply chain, thus a more effective and efficient business processes and real-time information for management support in digital enterprise should be attained. Rapid development of information and communication technology, such as the Radio Frequency Identification (RFID), is one of the important factors for improving the competitive advantages. But, the advantages of RFID system will not be exploited if they are applied only within the enterprise, without the use of RFID system by other supply chain partners (Lin, 2009).

In this chapter authors give a comprehensive overview of RFID technology: an introduction to the RFID technology, principles of RFID and current status of the application of RFID technologies in EU and Croatia with emphasis on application of RFID, especially for supply chain management, both internal and external. The chapter will provide useful information regarding the importance of technology in achieving and sustaining a competitive advantage in today's dynamic market.

2. Problem description

Information inaccuracy can adversely affect supply chain performances by lack of inventories, delay in delivery times, lost sales and decreased customer satisfaction. Real-time information is essential for making efficient and good decisions. Without real-time information about specific requirement or any kind of disturbances in supply chain (machine breakdown, human errors, rush orders, problems supplying required raw material or components, etc.) erroneous managerial decisions occur. Variation in production affects downstream members of internal supply chain (e.g. supply of parts to assembly line) and their planning and scheduling, and consequently could affect partners in supply chain. Coordination, integration and particularly sharing information in real-time about resource constraints, plans and schedules with other supply chain members are very important (Yin & Khoo, 2007). The status and related information about each component in production must be monitored individually through its internal and external supply chain. The most of Croatian enterprises still use labour-intensive methods (enter data manually and using bar-

code systems) for products-related data acquisition. Due to limitations in data acquisition and data interchange between shop floor and ERP system, data is often unreliable and incomplete and needed production status information is unavailable at the right place and at the right time to make effective decisions. As a consequence of problems in existing methods of identifying and tracking parts and products, mislay of parts and products, schedule delay and late deliveries occur and costs increase. To solve this production management problem, automated data acquisition is necessary in order to enable the flow of required information to everyone who needs them through integrated enterprise system and supply chain. There is a need for an integral enterprise integration, and also external integration of enterprise with supply chain partners.
At today's level of ERP systems, the integration of data is organized in data warehouses and new models and methods for data analysis and calculation of expected business trends are the most significant in order to increase the effectiveness of ERP systems. Also, it is very important to increase the speed of data transfer between the systems and to create conditions for the development of digital enterprise. The concept of digital enterprise is related to an enterprise in which the communication (exchange of information, messages, instructions, technical and technological documentation) between workers, workers and machines, and also machines to machines is performed digitally. RFID technology is one of the technologies that enable automatic object-to-object communication which is unique to digital manufacturing enterprises as mentioned previously.

3. Literature review

The most of available literature about RFID technology is focused to application of RFID technology for warehouse management and supply chain management (Attaran, 2007; Poon et al., 2009). Application of RFID technology in supply chain management has become fast evolving area of development and interests of academics and practitioners in recent years. For data collection about RFID authors used literature about technology and also experience of the use of RFID technology in industry environment. Comprehensive review of available RFID and SCM-specific academic literature: papers from journals, conference papers, book chapters, dissertations etc. was conducted in order to obtain a general overview of RFID technology and supply chain management.

3.1 RFID and supply chain management

Information technology has been recognized as an issue of vital importance for RFID system to support supply chain management (SCM) (Angeles, 2009). Zhou (2009) presents different perspective by modeling item-level information visibility in general, unlike most of case study papers about RFID. Various enterprises use RFID to achieve organizational change and manage growth in today’s competitive environment (Chao, Yang & Jen, 2007). RFID technology is essential in order to support real-time decisions in supply chain management (Chatziantoniou, Pramatari & Sotiropoulos, 2011). Tajima (2007) argues that, „RFID is expected to produce many benefits in supply chain management“and unlike other authors he provides insights into competitiveness as the value of RFID. Comprehensive overview of impact RFID on supply chain management is given by Sarac, Absi & Dauzere-Peres (2010). Their survey shows that RFID technology might improve traceability and visibility of products and processes, increase efficiency and speed of processes, improve information accuracy and might decrease inventory losses. Although the authors presented several advantages of RFID technologies in supply chains, they also emphasise limitations of previous research and need for more realistic analysis of supply chains.

The most applications of RFID in supply chain management currently take advantage of the technology with the objective to accelerate processes and reduce costs, but the real RFID features are found in capturing new types of information in real-time and supporting decisions (Chatziantoniou, Pramatari & Sotiropoulos, 2011). The authors consider the need of using RFID technology to improve tactical real-time decisions in supply chain management.

For implementing RFID, enterprises need to address issues of technology development, costs and international standards and rules. Sarac, Absi & Dauzere-Peres (2008) in their study have taken in consideration that there are different RFID systems with different costs and potential profits. The results of their analysis indicate that RFID technologies can improve the supply chain performance at different ratios. Also, the economical impacts depend on the cost of the chosen technology, the tagging level, the price of the products, the income gained using the new technology, etc. There is a novel approach to analyze trade-off potential benefits with installation costs of RFID systems in terms of implementation strategies that determine an optimal location of RFID within a supply chain network (Chang, Klabjan & Vossen, 2010). Results of that analyze clarified the value of increased visibility, which enables the early detection of losses and an increased ability to determine exactly location where the items are lost. Thus, application of RFID technology can considerably increase the efficiency of supply chain. RFID technology could also improve information flow and supply chain control and management in construction project (Wang, Lin & Lin, 2007). Product tracking problem for the large-scale supply chain is addressed by J.M. Ko et al. (2011), the authors have designed product tracking system that can collaborate with the EPC (Electronic Product Code) Network. According to Dias et al. (2009) few enterprises realized flexibility and increased competitiveness over the recent decade through implementation of 'lean' and 'just-in-time' principle. Unlike many analytical studies, investigate the benefits of RFID technology under more realistic setting is presented by Sari (2010); results from the simulation model show that RFID technology integration within a supply chain enables significantly greater benefits when the level of collaboration between the participants is more intensive.

At today's global market enterprises compete between each other no more, the competition has been moved between supply chains instead (D. Zhang, 2006). Integration and coordination of supply chain and ERP system is very important in various industries (Tarn, Yen & Beaumont, 2002; Koh, Saad & Arunachalam, 2006). Zhou (2009) analysed RFID benefits from different perspective by modeling item-level information visibility in general and his results showed that the benefit due to item-level visibility increases with the scale of the information system. Chao, Yang & Jen (2007) applied bibliometric methods and historical reviews from 1991 through 2005 in their research that indicates increasing usage of RFID in various enterprises to improve efficiency of operations.

Study presented by E.Y. Kim et al. (2008) emphasizes importance of RFID benefits of supply chain management to business performance. Overview of the recent developments in RFID and the analysis and aspects of RFID usage in supply chain are given by Dolgui & Proth (2008). Choi & Sethi (2010) divide literature about quick response supply chain systems in three main areas (supply information management, demand information management and values of information and supporting technologies) and present current state of knowledge in each area. They emphasize the supporting technologies for values of information.

The main objective of the supply chain management is integration and coordination of the business activities performed by enterprises associated in the supply chain. The terms 'internal' and 'external' supply chain are widespread in literature, e.g. (Tarn, Yen & Beaumont, 2002; Pagell, 2004; Meijboom & Obel, 2007; Huin, Luong & Abhary, 2002; Bergström & Stehn, 2005; Forgionne & Guo, 2009).Thanks to rapid development of information and communication technologies, enterprises realize a more responsive supply chain.

ERP system with RFID system integrates many business processes which enable fast and accurate data access. Also, integration and coordination of supply chain and ERP system is very important in various industries (Tarn, Yen & Beaumont, 2002; Koh, Saad & Arunachalam, 2006). The enterprises that coordinate and integrate within a supply chain have better operational efficiency, superior quality of products, lower inventory investments, reduction in the cash flow cycle time, reduced cycle times, lower material acquisition costs, higher employee productivity and increased ability to meet deadlines requested by customers (Kannan & Tan, 2005).

The supply chain coordination problem in a just-in time environment with use of RFID technology has been treated in literature (R.S. Chen & Tu, 2009; Huang, Zhang & Jiang, 2007; Poon et al., 2011a; Gunasekaran, Lai & Cheng, 2008). Monitoring of the supply chain processes is one of the most important aspects in supply chain management. Primary purpose of supply chain management (SCM) is effectively integrating the information and material flows within the demands and supply processes between suppliers and end customers, including manufacturers, distributors, retailers, and any other enterprises within the extended supply chain, with the special goal of adding value to the customer (Gunsekaran, Lai & Cheng, 2008, Kannan & Tan, 2005, Soroor, Tarokh & Shemshadi, 2009).

Fig. 1 presents market share by revenue of SCM software vendors, the largest share have recognized worldwide SAP with 20 % and Oracle with 17 %.

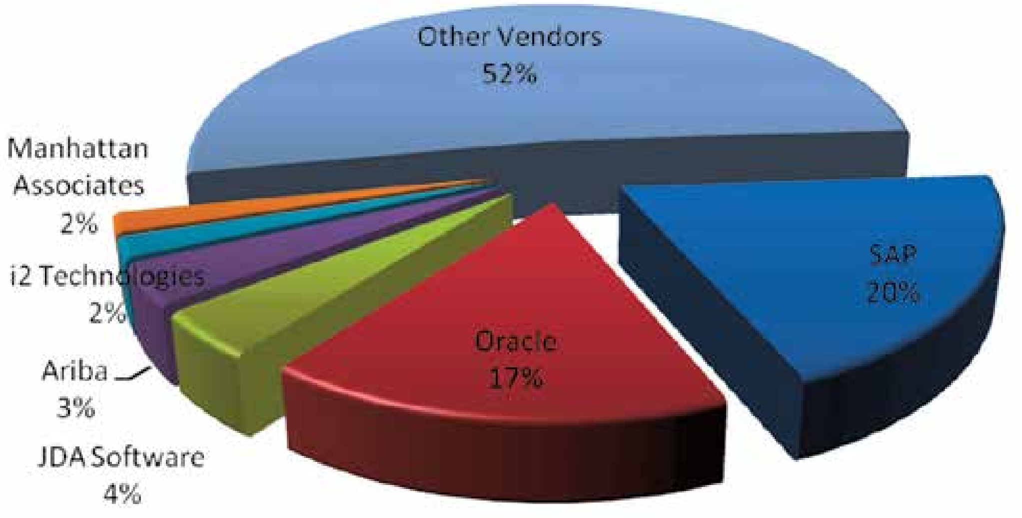

Fig. 1. Worldwide SCM Vendor Software Revenue (Gartner, 2010)

The prevailing opinion in the literature is that the most successful enterprises are ''those that have carefully linked their internal processes to external suppliers and customers in unique supply chains'' (Mitra & Singhal, 2008, as cited in Frohlich & Westbrook, 2001).

4. Overview of RFID technology

Application areas of RFID technology will spread more and more. RFID information about product enables visibility in supply chain by sharing information between supply chain partners. Enterprises must continuously improve the quality of their supply chains with aims to enable visibility of supply chains and reduce operational costs of supply chains. Literature survey presented by Ngai et al. (2008) shows that about a third (36%) of all RFID research is focused on RFID technology and components of RFID system.

4.1 RFID system

A simple RFID system includes three main components: tag, reader and computer or enterprise system (Fig. 2). Tag is composed of a small microchip and an antenna and can be embedded into or attached to objects of any kind (e.g. parts, products, tools, animals, persons). Tags have different shapes and sizes and have a memory for data storage. These are specific data such as a unique identification number, product price, product location, date of manufacturing, current inventory, type, description, dimensions and so on.

There are two basic types of tag:

- passive (without internal batteries),
- active (with battery, self-powered).

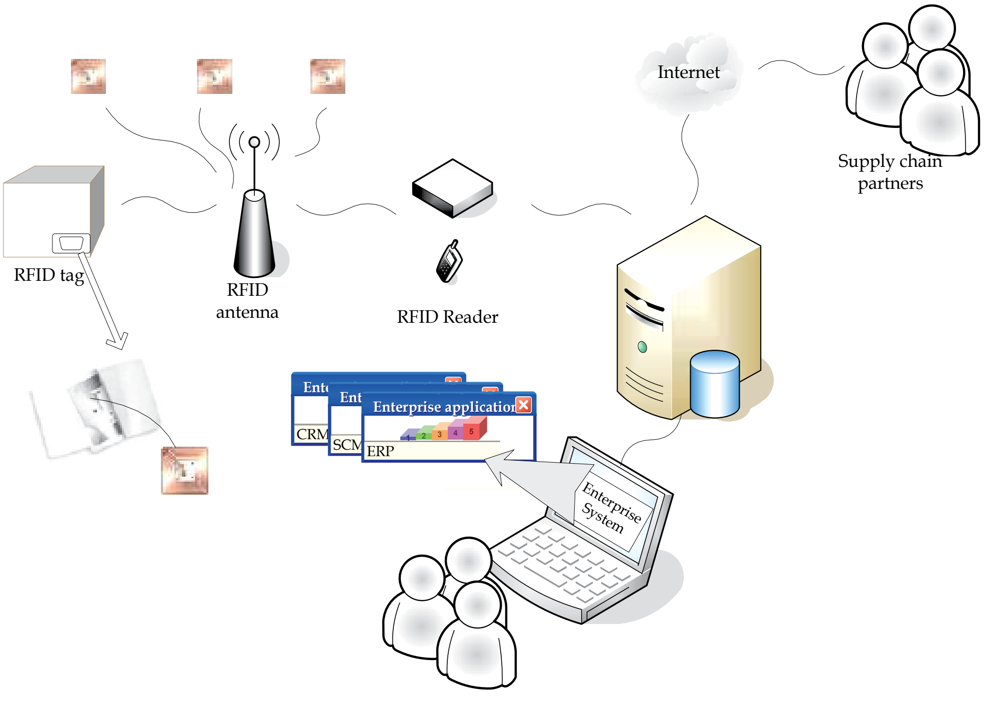

Fig. 2. Components of RFID system

Active tags have feature of read and write data and larger data storage than passive tags. Also, active tags are self-powered and do not depend on the electromagnetic field of the reader in order to be activated. Active tags use their own batteries as a power source that is integrated on the tag, as opposed to passive tags that receive power from the reader when they are within range of reader. Activation of passive tag depends on the electromagnetic field that is induced by the RFID reader. RFID reader transmits radio signals through antenna in order to activate tag and the identification and recording of data. When tag is activated then data transfers according to signals sent from the antenna. Passive tags are much more used in various RFID applications and duration of passive tags is longer than the active tags, but active tags can transmit signals over a longer distance than passive tags. The most common choice of tag for supply chain usage is passive tags that take effect in the UHF frequency range (Tajima, 2007).

Tags also differ by their data storage capability (Domdouzis, Kumar & Anumba, 2007):

- Read-Only tags,
- Read/Write tags.

Differences between active and passive RFID tags are summarized in Table 1.

	Active RFID tags	Passive RFID tags
Tag power source	Internal to tag	Energy transferred from the reader
Availability of tag power	Continuous	Only when found in the range of the reader
Required signal strength from reader to tag	Low	High
Available signal strength from tag to reader	High	Low
Communication range	Long range	Short range
Multi-tag collection	Scanning of thousand of tags from a single reader Scanning of up to 20 tags moving at more than 100 miles/hour	Scanning of a hundred of tags within 3 meters from a single reader Scanning of 20 tags moving at 3 miles/hour or slower
Sensor capability	Ability to monitor continuously monitor sensor input	Monitor sensor input when tag is powered from the reader
Data Storage	Large	Small

Table 1. Differences between active and passive RFID tags (Domdouzis, Kumar & Anumba, 2007)

RFID reader communicates wirelessly with RFID tag that attached to a product when the product is located within range of the reader. RFID reader reads the information stored in the memory of tags and transfers them to a computer or enterprise application. This information can quickly be read by a wireless communication among compatible reader and tags in the readers range.

RFID system has to computerise a large amount of data and improve efficiency of operations. There is need of filtering and processing of large amount of data that captured by RFID system and transforming data into meaningful information in order to be used in enterprise applications, such as enterprise resource planning (ERP), supply chain management (SCM) and/or customer relationship management (CRM). These functions are performed by middleware.
The RFID middleware system between readers and applications is composed of two interfaces, namely the application interface and the reader interface, to communicate with the environment.

4.2 RFID frequency

The frequency used for RFID application is an important characteristic of RFID system. There is diversity through regulation by individual country about RFID frequency allocation (Turcu, Turcu & Graur, 2009). One of the major problems in the application of RFID systems is existence of different standards. The diversity in national spectrum allocation for RFID is an obstacle to wider application of RFID systems in the world and one of the key issues of the RFID technologies is their standardization (D. Lee & Park, 2010).
Presently only a few frequencies are consistent around the world. There are different operational frequency ranges (Gaukler & Seifert, 2007; Oztaysi, Baysan & Akpinar, 2009, Wu et al, 2006):
low frequency (LF) 125–134 kHz,
- high frequency (HF) 13.56 MHz,
- and ultra high frequency (UHF) RFID uses 868–928 MHz.

Higher frequency enables reading at longer distances and also faster communication (Gaukler & Seifert, 2007). Low-frequency passive tags have an effective range of approximately 30 cm, while high-frequency passive tags are useful in the range about 1 m. Ultra high frequency (UHF) passive tags have range about 8 m (Meyer, Främling & Holmström, 2009; Roberts, 2006). Active tags are self-powered and more expensive than passive tags but can reach a range of 100 m (Wang, Lin & Lin, 2007).

4.3 RFID history and trends

RFID technology is not new technology. One of the first papers about RFID is published in 1948 by Harry Stockman (Roberts, 2006). RFID was developed during 1940's, but the use of technology was limited due to high costs of the RFID tags. Commercial use of RFID starts during 1960's (the electronic article surveillance (EAS) system, animal tagging, toll road payment systems, using RFID in automotive industries for assembly lines), but the application in supply chain management is relatively new (Tajima, 2007). RFID usage has increased in recent years in a wide range of various application and we can expect significant growth of RFID market in the next years. The explanation for the growing interest in RFID can be found in reducing prices of passive tags and development capabilities of internet technology (Roussos & Kostakos, 2009).

4.4 Electronic Product Code

The Electronic Product Code (EPC) is a common way for automatic and unique identification of objects (parts, products, pallets, locations, etc.), i.e. „a standard product coding structure for item management applications" (Poon et al., 2011a). The EPC is prevalent method for assigning unique product identification in the modern supply chain environment. The EPC standard is announced by nonprofit organization EPCGlobal Network with aim of facilitate data exchange between supply chain partners through standard interface and without having direct access to the underlying databases (Vrba, Macůrek & Mařík, 2008).

4.5 RFID benefits

Many authors mentioned that RFID contributes to supply chains operations through its unique identification of objects and real-time information, thereby RFID improves the data accuracy, accelerates processes, enables the traceability and the visibility of products throughout supply chains, increases speed of physical flows and reduces of Work- In-Progress and inventories (Dolgui & Proth, 2008).

Use of RFID technology as well as bar codes, facilitates automation of processes and improves operations management through reduction of workload and elimination of human errors.

However, RFID technology has some advantages over the bar code:

- there is no need for line of sight (tags can be read through a different materials),
- suitable for harsh environments (e.g. dirt, moisture, dust, chemicals, high temperatures),
- the RFID reader could interact with multiple tags and automatically receive information from the tags,
- RFID readers greater distances of reading,
- tags contain more data than bar codes,
- form and dimensions of tags could be various, depending on the application.

There are some limitations about RFID application, e.g. physical limitation (difficulties with reading through liquid or metals) and cost of RFID although prices continuously decrease.

4.6 RFID applications

Application of RFID technology is possible in wide area of human activity. An increasing variety of enterprises are using RFID to improve their efficiency of operations and to gain a competitive advantage. The innovation in RFID is not in the technology itself, but in its use in real-business processes. The rapid development of information technology and reducing cost of RFID system components enable continuous expansion of application areas. Applications of radio frequency identification (RFID) technology within supply chain management have received particular attention in the past few years by many authors. In literature some of named applications of RFID are: fashion product development (Choy et al., 2009), real-time warehouse operation planning system (Poon et al., 2011a; Chow et al., 2006), solving production material demand problem in manufacturing environment (Poon et al., 2011b; Huang, Zhang & Jiang, 2007), hospitality (Öztayşi, Baysan, Akpinar, 2009), construction (Wang, 2008; Ergen, Akinci & Sacks, 2007; Wang, Lin & Lin, 2007; Yagi, Arai & Arai, 2005), monitoring quality in a food logistics (Ngai, Suk & Lo, 2008; Vergara et al.., 2007), tracking vehicles in an automotive manufacturing plant shipment yard (J. Kim et al.., 2010), health care (Oztekin et al.., 2010; Katz & Rice, 2009), service sector (L.S. Lee, Fiedler & Smith, 2008), farm management systems (animal identification) (Voulodimos et al., 2010), prevention of collision accidents with heavy equipment (Chae & Yoshida, 2010), libraries

(Coyle, 2005), parking management (Jian, Yang & Lee, 2008), traffic management (Wen, 2010), maintenance (C.H. Ko, 2009; T.L. Chen, 2009), postal services (Zhang, Yue & Wang, 2006), etc. Wal-Mart, the US Department of Defense, Metro, Marks and Spencer, Benetton and Gillette are some of the first, worldwide known users of RFID technology for their supply chains (Ngai et al., 2008; Wu et al., 2006; Roberts, 2006).

Application of RFID technology is increasing in various industries as prices continuously decrease. According to data from Eurostat, the statistical office of the European Union (Eurostat, 2010) the most common application of RFID technology in enterprises in the EU (in January 2009) was in the area of person identification or access control (56%), supply chain management and inventory tracking and tracing (29%), payment (25%), product identification (24%), monitoring of industrial production (21%) and service and maintenance information management (15%).

Fig. 3 presents applications of RFID by purpose in enterprises in the EU and Croatia, first quarter 2009 (Eurostat, 2010; Croatian Bureau of Statistics, 2010). RFID was mostly used by Croatian enterprises for person identification and/or access control and for payment applications (e.g. toll collection). Renko & Ficko (2010) indicate that Croatian retailers do not use new logistics technologies sufficiently; particularly enterprises from studied sample do not use RFID for products labelling. Authors explained that fact with high costs of RFID employment per unit with compare to low costs of labour that retailers employ for product labelling.

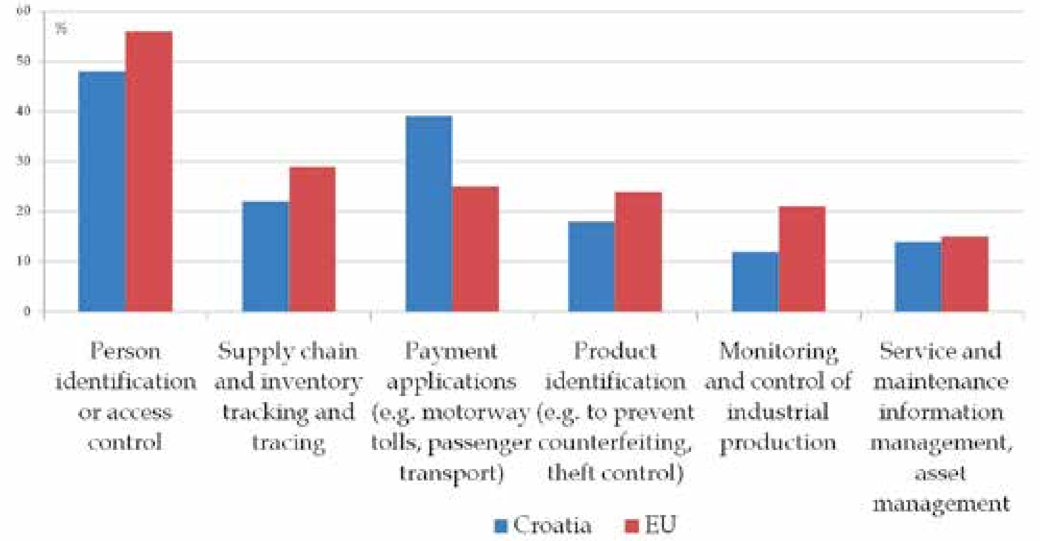

Fig. 3. Applications of RFID usage in enterprises by purpose, first quarter 2009 (Eurostat, 2010)

As seen in Fig. 4 the highest shares of enterprises which used RFID in January 2009, had Netherlands (9%), Finland (8%), Germany, Spain, Austria and Slovakia (all 4%), and the lowest shares had Greece, Cyprus and Romania (all 1%). At the same period Croatia had 4 % of enterprises using RFID which is slightly higher than average use in the EU27 of 3%.

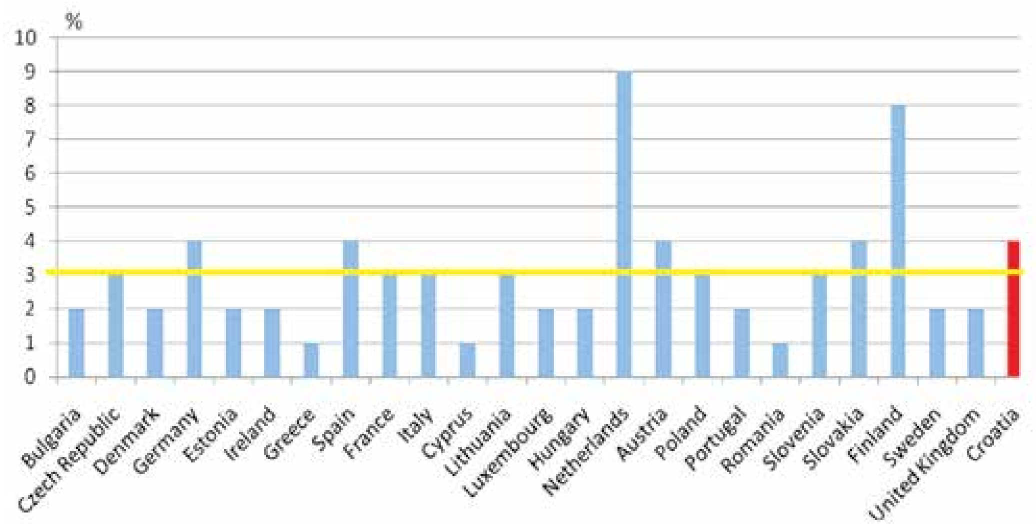

Fig. 4. Enterprises that used RFID in January 2009 (% of all enterprises) (Eurostat, 2010)

5. Conceptual framework

Since RFID technology facilitates collection of data, it is necessary to integrate RFID with ERP system and with various information systems of supply chain partners in order to get a meaningful data. Providing that supply chain operations performed according to plan is a significant continuous activity. With ERP system and RFID any drawback (e.g. material shortages) could be timely identified and corrective action could be taken if necessary. For internal end external supply chain it is very important that the real-time information flow is oriented backwards through the integrated supply chain, as parts, components, products, etc. flow forward according to just-in-time principle. Thereby, it is possible to reduce order delays, lead times and inventory and therefore, increase customer satisfaction.

Our conceptual framework for integration of ERP system and RFID technology with aim of providing information visibility in internal as well as external supply chain is based on just-in-time principles (produce and deliver products or services as needed by customer or required by hierarchically superior level in the required quantities, just in time when needed and at right place avoiding storage whenever possible or using minimal inventories). In order to provide a just in time environment, status information of manufactured parts should be available to all who needs that information within enterprise and also between supply chain partners in real time. Conceptual framework for integration RFID with ERP system includes hierarchical planning model that connects level of sales planning, level of assembly planning and level of production scheduling (Matičević, Lovrić & Čičak, 2007; Matičević, Dabić & Daim, 2010). Hierarchical planning model generates plans and schedules that are consistent with dynamic business processes. Connection of the three levels of planning in compliance with just-in-time principle enables increase of efficiency, timely delivery of finished products/services to the customer (or parts and subassemblies to a product assembly according to hierarchically superior level of plan). The hierarchically superior levels and subordinate levels of planning are interdependent according just-in time principle. Objective of hierarchical planning model is to keep the due date equal to the required date in order to meet customers' demands, thus the solution of a subordinate planning /scheduling level must meet requirements from the superior planning level. RFID tags could be attached on objects (as parts, subassemblies, components, products, containers) allowing us effective tracking of objects in the production process. Fast data acquisition and transfers of data to databases are facilitated by RFID technology. Products with tags have a unique identification number and could store relevant manufacturing information (e.g. material used production status). Collected RFID data have to transform into an appropriate report in order to share information within the enterprise and between partners in the supply chain.

The aim of our conceptual framework (Fig. 5) is to provide visibility of material and information flows, which includes the processes from customer orders through manufacturing and product assembly to delivery of the product to the customer. It refers only to a part of the entire supply chain. Our aim is to facilitate the sharing of information with the integration of RFID technology in the the Croatian solution of ERP system in the digital enterprise, named ERPINS. ERPINS has been designed for metal processing industry, wood and food processing industry and construction industry. For the purposes of developing the conceptual framework we have chosen the local ERP system due to the following reasons:

- local software developers are more familiar with the peculiarities of the market conditions and Croatian law, therefore their ERP solutions are more flexible to legislative changes that often occur in countries in transition such as Croatia;
- local ERP solutions are more competitive due to the lower prices compared with global vendors.

Fig. 5 shows prominent ERPINS screenshot of real-time production status monitoring and data update using RFID Handheld Reader/Writer. Machine worker at shopfloor with the handheld RFID reader can make data entry about quantities of parts processed and this data is available in real-time throughout ERPINS system. This real-time feature of ERPINS is very important for control of deviation in production, as the performance of entire supply chain may be adversely affected by deviation from the production schedule. Integration of RFID and ERP systems enables visibility of information about real-time production status directly from production shop floor (e.g. accurate information about inventory levels, about start time and finish time of operation). This enables dynamic and real-time control of production and adjustment of the production schedule to disturbance in production process. RFID tags are placed on parts to prevent loss of parts and to monitor production status. Using RFID tags, parts and products can be traced through the processes of production and assembly.

Coordination of internal supply chain has been achieved when the parts from the production are transferred to the next stage (product assembly) immediately after the part is completed and it depends on the date required by the hierarchically superior plan (e.g. the level of assembly). Tagging parts, products or containers is useful for each partner in the supply chain due to providing the visibility of material and information flows.

RFID enables real-time access to information and minimizes the time and work needed for collecting information. Real-time automatic identification and data capture system, as RFID system, is highly important for agile production. When integrated with ERP system, RFID provide an online current status of all material inventories and Work-In-Process.

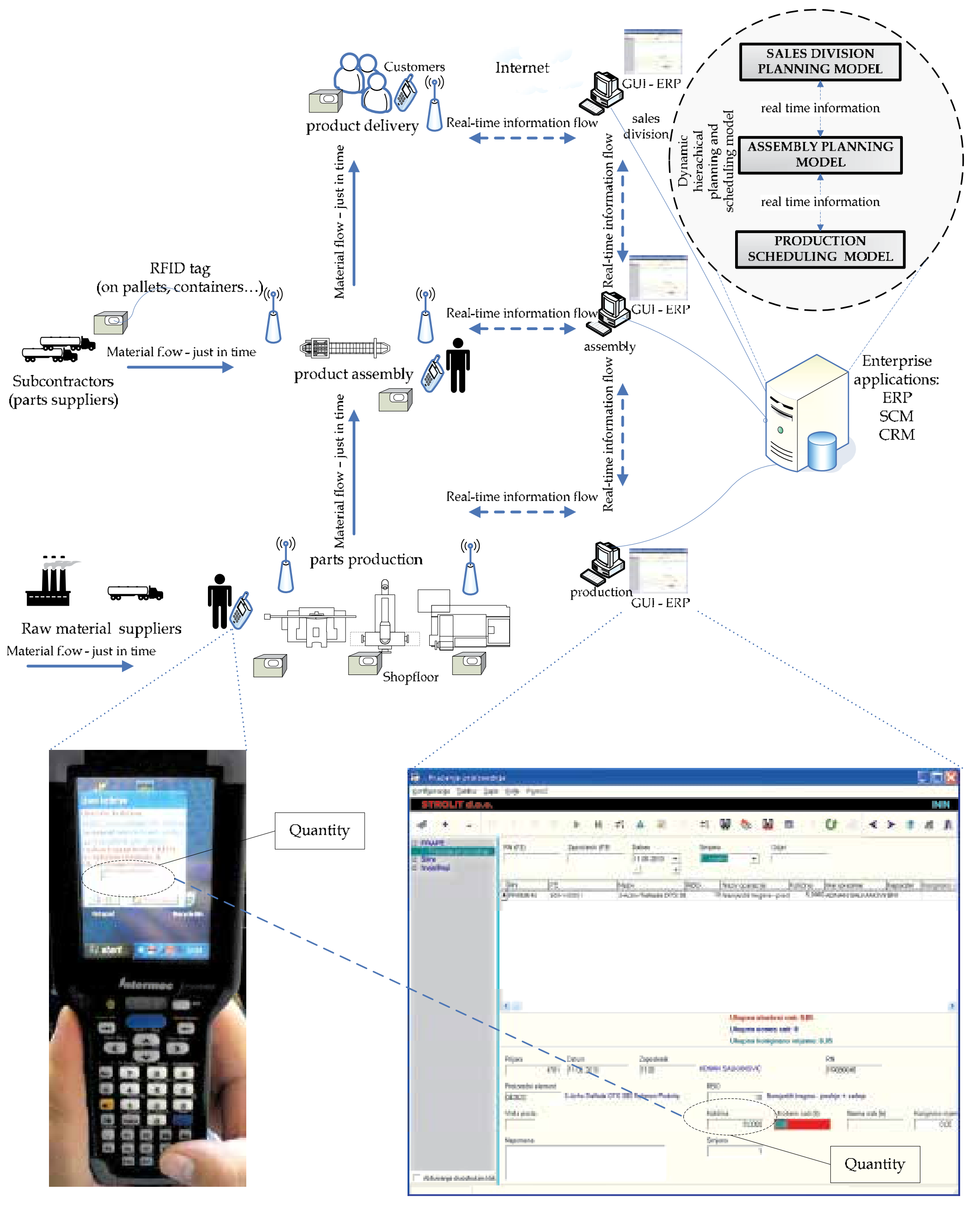

Fig. 5. Conceptual framework of information sharing enabled with RFID and ERP integration, adapted from (Matičević, Dabić & Daim, 2010)

6. Conclusion

Automatic identification and capture data technology like RFID can be useful in order to improve business efficiency. In terms of management, integration of ERP and RFID allows effective decision-making considering customer requirements and efficient use of enterprise resources.

This chapter is the result of literature review and experience of authors about application of RFID in enterprises and provides an overview of the current state of development of RFID technology and its application in practice. The chapter is useful to researchers, practitioners and other interested parties to apply RFID in manufacturing and supply chain to understand the importance of real-time visibility in supply chain management in order to improve operational performance. RFID based identification and data capture is appropriate for overcoming the problems in production and other business processes, which are caused by manual identification and collecting data. Integration of ERP system and RFID technology can provide real-time tracking work orders, parts and products, data accuracy and information sharing through internal and external supply chain. Limitation of research is that validation of the proposed conceptual framework is required through practical implementation in real manufacturing environment.

Future research should include the development of mathematical model based on the conceptual framework described in this chapter.

7. Acknowledgment

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Scientific Data Sharing Virtual Organization Patterns Based on Supply Chain

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1. Introduction

Since 1990s, as technique and social progress more quick, the world economy has experienced significant change. People ask for the varieties and specifications of products according to their own needs of work and life. So enterprises should become highly flexible and response rapidly to fit with constantly changing conditions. Therefore, a new organization mode appeared. Under this mode, the modern businesses make knowledge, technique, capital, materials, market and management resources in everywhere together using information technology. This organizational structure and management pattern was known as Virtual Organization (VO).

Sharing of scientific data is an important contemporary scientific and technical infrastructure construction activity. This activity focuses on how scientific data resources, especially those supported by public research funding to be obtained, are organized, large-scale produced, processed and preserved within the maximum extent. The goal of this activity is to provide useful data services for researchers conveniently, rapidly and efficiently. Many countries and regions, such as USA, English, Germany, China, and so on, are mobilizing the relevant institutions and resources to build the scientific data infrastructure for the whole society. One of the most important organization types is virtual organization, which is a way of structuring and managing goal-oriented activities.

This thesis introduces the concepts, development, applications, research status of virtual organizations, analysed the Scientific Data Sharing Virtual Organization (SDSVO) operation problems. Then the work prompted that supply chain management should be led into SDSVO to solve above problems. In the aspects of champion selection, members choose and IT system design, it would be best for SDSVO managers to supply chain integration. Three theoretical basis includes resources dependences, transaction cost minimization and Gametheory must be considered while supply chain integration.

The paper analysed the scientific data supply chain includes data creators, data centres, data service providers and data users based on three theory, then defined analytical frameworks, then chose two cases, which are German National Science Data Infrastructure (GNSDI) and China National Scientific Data Sharing Program (CNSDSP), to discuss operation mechanism construction, such as champion selection, members composition, IT system development, etc. In the end the similarities and differences between the two modes were compared and discussed.

2. Literature review

The chapter research is involved in virtual organization, supply chain management research.

2.1 Virtual organization

The VO stresses that cooperation partners should make full use of integrated resources to maximize values and profits in competitive circumstances. VO has some charming characters, such as:

- Boundary crossing.
- Complementary Core Competences/the Pooling of Resources.
- Sharing of Knowledge.
- Geographical dispersion.
- Changing participants.
- Participant equality.
- Electronic communication.(above, Wendy Jansen 1999)
- Alternation in the constitution, members can be in or out as context.(Travica 1999)
- Switching assignment with requirement. (Mowshowitz 1999)
- Virtualization. Through the network technology (especially e-commerce) to coordinate and organize activities (Venkatraman and Henderson 1996)

Based on the above characteristics, scholars have done many works on organization pattern, operation mechanism, member management, etc.

In respect of organizational mode, Lethbridge(2001) put forward six patterns of VO from the view of organization communication form and content, which are the virtual interface, the star alliance, market alliance, common alliance, values coalition and parallel alliance. From organizational structure and function, Guo (2004) proposed three VO modes including cellular mode, star mode and federal mode. The cellular structure mode organizes the internal business units as the core, the stars structure model is applicable to grasp the enterprise, federal vertical supply chain structure model is similar to the coordination commission.

About organization management, Zhu&Peng (2003) summarized three patterns that are technical cooperation mode, contract cooperation mode and integration mode based on manufacture-learning-research cooperation. As co-operations became gradually close, technical collaboration would turn to contract cooperation then integration mode at last. And during the VO’s Operation period, incentive mechanism (interest distribution mechanism, dynamic mechanism), management and supervision mechanism (internal supervision mechanism, and external supervision mechanism, operation mode) and update mechanisms should be resolved. Hong, et al (2004) proposed five factors must be considered in R&D VOs, which were coupling between team and projects, each member's resources conditions and associativity, internal communication and coordination mechanism in VO, explicit knowledge system type (recessive/explicit), R&D project innovation levels (mutation/gradual), etc. Xie (2007) put forward three VO patterns in the field of e-government to share information standing by the view of information system architecture.

The patterns are concentrated sharing model (solve data on centralism processing), P2P sharing model (solve department data sharing), and services mode (based on SOA application, solving collaboration problems).

In the side of relationship of member management, Qi Sun (2006) discussed partnership organization structure and work order, partner selection problem, and partnership performance evaluation. He deemed that the host of partnership should better belong to the third party because he or she has no conflicts with VO members. The host's responsibility is to undertake planning, prepare for all the partnership workshops, guide partnership management teams, the relevant training and the implementation process. First of all, partner selection evaluation index should be built.

But the differences of organization mode study are too big and hard to use in practice. And these organizations form in common is that they organize the members according to business relationship along supply chain. So **VOs can be divided into two basic types on the basis of data sharing supply chain. These are vertical VOs along the longitudinal business chain, and horizontal VOs on joint transverse business chain**. And in respect of VOs research, operation mechanism and membership management is concentration.

2.2 Scientific data sharing management and VOs

Scientific data refers primitiveness, basic data which are generated in the procedure of humanity understanding and transformation the world, and data products and related information which produced according to different requirements. The data can come from two main sources: 1) Observation and measurement. 2) Calculation. (Niinimaki1, et al. 2004) The data sources are diversiform. The format each is not identical. Unified standards are lacked in management and storage the data. And the storage is very scattered. (Zhang, 2008) So the use of scientific data is very inconvenience. At the same time, the mass data stored in government funding agencies that are bound by confidential treaty are difficult for the public to access.

Scientific data is not only the scientific research base, the indispensable source for information, but also the traction of modern science. A good database may bring out a new discipline, or re-activate an old discipline to enter a new stage of development. (Lu, et al. 2003) With the scientific data strategic role strengthening, a new science research form has taken shape. That is the strategy of scientific research project driving scientific data accumulation gradually turns into the strategy of scientific data driving project development. In 2000's, some government departments, national institutions and public welfare institutions went into action to promote scientific data sharing.

International organizations. In early 2002, the International Committee on Data for Science and Technology (CODATA) world congress took "data synthesis and data interoperability problems, scientific data applications and sharing legal problems, the information economics of scientific data services and ethics in data acquisition and application process" as the theme of the congress. CODATA and the International Council for Science (ICSU), etc. also constructed the world weather monitoring network, the global resources information database, international disaster information network and international Marine resources system, and so on, using Internet technique. These databases formed a global scale scientific data exchange and sharing service system initially. (CODATA handbook, Honglie Sun & Chuang Liu, 2003)

The United States. The non-profit scientific data "full open" policy is a national strategy in the United States. Since 1990, national science data centres group has established including 9 data centres. In 1995, "G1obal Data and Information System (GCDIS)" project has launched. The project further integrated nine data centres information system to one system (EOSDIS). Its aim is to provide more useful format assembly data to users to fulfill existing datasets potential. (Shi &Cui, 2002; Chuang Liu & Zhengxing Wang, 2002) National Institution of Health (NIH) of USA made data sharing policies about scientific research data produced by NIH supported project to archive and share science datasets to public. (NIH, 2004)

Britain. In 2002, The UK government put forward e-Science plan. One of the key research contents is scientific data sharing based on grid (Chen, 2004). Jung & Yeom (2010) proposed a dynamic bridge for e-Science Grid, implementing Web 2.0 service in order to share experimental data effectively. Sànchez-Artigas & García-Lópezwe (2010) explored the possibility of using the P2P paradigm for data-intensive e-science applications on the Grid. Using that method achieved fast access to the huge and widely distributed amounts of data and proposed e-Science Grid to overcome the scalability barriers in e-science communities.

Germany. In 2003, German Science Foundation launched a project which aim is to make science data open access. First, the action limited in geoscience. The project reached the desired objectives. In 2006, the project executive, the German National Science and Technology Library, extend the scope of data to other areas, such as medical, chemical, crystal structure and grey-literature and other types of content. They have established branches to manage the registration of data sets. (Brase, 2008) The virtual organization became bigger and stronger than ever.

China. In 2003, the State Ministry of Science and Technique of China started the scientific data sharing program. The program has established a leading group, a co-ordination group, experts group, the working group and offices whose responsibility is project design, implementation, oversight, project management, and so on. Program involves meteorological, seismic, hydrological, marine, agriculture, basic sciences, medicine and health care, earth science and other fields. Nine major data centers and three data networks were the beginning of the program.

In conclusion, countries of scientific researching actively are practising in the scientific data sharing field. And virtual organization mode is adopted in above activities. But in the research content, technical scheme discussed mostly and management solutions are lack. In practice, SDSVOs faced many barriers of mechanism, coordination and cooperation such as non-cooperation, copyright infringement, long-term running etc. So management research need to develop and discussion further.

This article discussed SDSVOs management in the view of supply chain management and did the case study. Hope to provide new thoughts to scientific data sharing.

3. Data sharing supply chain and driving factors in SDSVOs

According to the resources dependence and core competence theory, an enterprise's core resources and capacity are limited. In order to maintain long-term competitive advantage, enterprise will highlight the key and develop competitive parts. The result will inevitably lead to the enterprise resource allocation unbalance. Thus enterprise should obtain resources from the external. In this case, the enterprise has to establish cooperative relations with other enterprises to get a stable resources supply (Yajun Liu & Guoxu Chen, 2008). The internal factors driving this co-operation are resource integration theory, transaction cost theory and game theory. These theories are also suitable for scientific data sharing activity.

This paper first analysis scientific data supply chain. Then discuss resource superiority, cost changes and strategy chosen on each link of scientific data sharing.

3.1 Supply chain in scientific data sharing

La Londe and Masters (1994) proposed that a supply chain is a set of firms that pass materials forward. Normally, several independent firms are involved in manufacturing a product and placing it in the hands of the end user in a supply chain—raw material and component producers, product assemblers, wholesalers, retailer merchants and transportation companies are all members of a supply chain. Ma (2000) give a more comprehensive definition in the book of "supply chain management": Around a core businesses, the supply chain controls the flow of information, logistics, capital, procures, raw materials as beginning, then produces intermediate products and final products, final distributes products to consumers through distribution network. This chain forms suppliers, manufacturers, distributors, retailers, even until the end-users to a functional and overall network of chain structure. Supply chain management theory is also suitable for information industry (Rong Wang & Ji, 2008). The principle of supply chain can be used in research scientific data sharing problems.

Since a long time, scientific data in science and technique activities is a subsidiary which is preserved in the hands of individuals. Other people could obtain it through the publication of scientific papers and other opened documents.

By now, with the development of information technique activities, more and more data are collected in science and technique activities, especially in large-scale, high-tech research projects funded by public research funding. (DANS, 2010) These data are unusual wealth which has high research value. Some data are unique. So requirements of processing, preserving data professionally and providing data service created. Therefore, the scientific data have become one of the important outputs in science and technique activities today.

The scientific data process has multiple steps including creating, processing, storage, distribution and service. There are professional organizations on each link. All organizations on scientific data procedure form a supply chain. Ideally, researchers acquire data through experiment, observation activities first. Then they archive data to data centres. Data centres release datasets to public. Meanwhile, researchers can analyse data, then publish research results in publications. In brief, scientific data supply chain has four links, namely suitable data producers, data centre, data services and data user. Each link has its responsibilities. (See also figure 1)

- *Data creator*: may be scientists, or government-owned scientific research institutions, or scientific research projects supported by public funds group. Their responsibility: data harvesting, data production. Costs are from ten thousand dollars to millions, even more than billions. Sometimes costs can't even assessment;
- *Data centre*: or information centre, etc. Its main task is data storage, quality assurance, making metadata, things like that. Costs of production is usually 1% of data creating;
- *Data services*: or information supplier, library, etc. Responsible for providing directory, retrieval results, such as DOI; Costs is only hundreds of dollars;
- *Data user*: using data sets, giving suggestions and opinions to data centres.

3.2 Resources need by scientific data sharing VO

Enterprise resources foundation theory is put forward by Wernerfelt officially in 1984 through a marked publication named A Resource-Based View of the Firm. (Wernerfelt 1984)

Wernerfelt said that resources and products like the pros and cons of a coin, most of finished product needs some resources input and service., enterprise's main mission is to create and grasp resource advantage. Barney (1991) thought that differences among enterprises come from each enterprise strategic resources, the core competence of enterprises relies on value, scarce, not imitate resources.

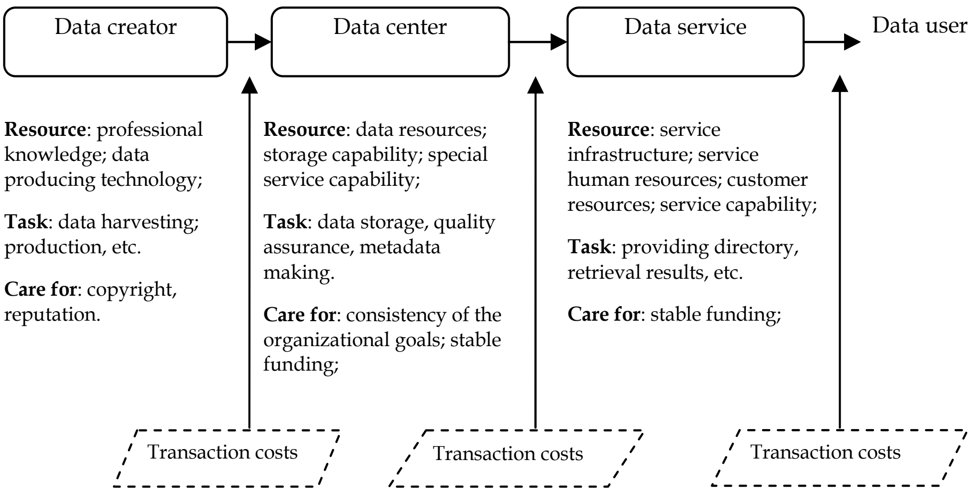

Fig. 1. Scientific data supply chain

In scientific data sharing field, a large number of scientific data resources by observation, detection and investigative is a kind of one-time-gained scarce resources. Efficient utilization of these resources is the basic guarantee for social development. Owing these resources make the organization to have some kind of congenital, special strength in competitive, but not enough. (Lievesley, 1998) The advantages of researchers (data producers) are data obtaining professional knowledge and skills, but they have no data storage equipment and professional knowledge. One of the biggest problems in scientific data sharing field is that data cannot be long-term preservation and identification, but these are data centre advantage and expertise. Data centre has specialized storage equipment and data management skills, can complete the tasks of data resources long-term preservation and identify. But the data centre is shortage of public information service ability and relative human resources, and is good at special subject services. Data service, information service centre, or library for example, is expert in public service. These information institutions are universal channels for the individuals and groups in society. They have rich experiences in interdisciplinary information providing. Otherwise, they can standardize the collecting resources and make resources available by worldwide researchers. And most services provided by information supplier are available to users on the internet. The combination of data producers, data centres and information service providers can maximize the benefit of scientific data sharing.

3.3 Transaction cost analysis in SDSVOs

Transaction cost economics is first proposed by Coase R. H. and Williamson O. E. developed the theory. Transaction cost theory researches economic activity execution efficiency. Williamson (1998) think that, two kinds of factors influence the transaction cost:

one is the principal transactions to humanity hypothesis, another is trading factors including trade frequency, uncertainty, the asset specificity, market environment, etc.

SDSVO mode can reduce the following transaction costs. (1) Break the constraints of human nature hypothesis principal transactions. SDSVOs restrain bounded rationality and opportunism from organization management level, forcing data resource protection turn to data resources opening or service. (2) Reduce the trading uncertainty among data sharing chain. When data resources aren't effective shared, data server and data users are not sure whether transaction was completed in the future. Therefore trade agreement can't be signed. After SDSVOs are established, participators clearly know the transaction rules and limits and data users can quickly find accurate achived data. Thus trade contracts can be signed easily. (3) Lower the assets specificity, such as special equipment of data processing and storage, personnel, etc. (4) Establish a more diverse, transparent trading environment. SDSVO decrease the monopoly of data suppliers by the methods including selecting service members freely through regional advantages, or resources advantage, or service capability. The market offers a variety of options, to reduce the transaction cost.

3.4 Game theory analysis in scientific data VOs

Game theory is the science about people chosen strategy. A complete game generally includes five aspects: participants, game information, game strategy or behavior choice, game order, game earnings. In scientific data sharing field, participants includes data producer, data centre, services provider and data user. All participants disseminate information, such as data requirement, data storage requirement, service capabilities, etc. in the market. Based on profit condition, the data owner decides whether to provide data to others, or private use. If the owner can get more interests from data open than data privacy, he will choose open strategy. If he gets less interest, he will use data in private only.

The barrier of science data sharing is that all data owners want to maintain their own advantages in resources and get other's benefits. One side is data owners want to get more interests, the other side is that interests are higher while the cooperative is disposable, the data owner may choose the strategy not to provide data resource and destroy cooperative basis. And while SDSVO was built, it can change the Nash equilibrium to some extent. First, the SDSVO members need to sign an agreement to join the federation. The agreement can ensure data sharing execution legally. The members who do not abide the agreement shall bear legal risk. Second, SDSVOs can provide funds or other preferential conditions (such as get complementary resources, reduce risk and sharing the cost, etc.) to members. These values can change participants' pay vector which change negative vector into positive one. That makes sharing revenue exceed the not-sharing. Third, during VOs sustaining, there are multiple games instead of disposal game between participants. That can promote parties to take share data resource action.

3.5 Factors comparison between two patterns of scientific data sharing

In section 2.1, we transform SDSVO mode into two kinds. One kind is the vertical VO mode (VVO), and the other is the horizontal VO mode (HVO).

VVO conjoin two or more institutions along supply chain together. The consortium provides services to users as a whole. There are five benefits of this mode: 1) Make scattered data resource centralized storage., That can reduce storage cost, improve storage efficiency; 2) Integrated services can reduce trading opportunities finding cost; 3) Specialized storage and service reduce maintenance and release cost of data producers; 4) Enhance data producer influences, in favour of copyright protection, perhaps have economic gains; 5) Gear up the business professional development of data centre and data services supplier.

HVO is a federation of similar business organizations. The federation have an union catalogue. The user through joint catalogue search resources, but the league according to regional and industry divide customer. Each member provides services to a particular customer group. There are three main benefits of this mode: 1) Integrated information service system to reduce the user's information finding cost; 2) Union catalogue and services reduced resources construction costs and improve efficiency of resource use and services. 3) Improve development efficiency and depth based on resources integration, reduce resources purchasing cost.

The difference between two modes based on three theories shows in table 1.

	Vertical VO mode (VVO)	**Horizontal VO mode (HVO)**
Resource foundation	Mainly rely on resources integration along supply chain;	Mainly rely on services integration on service link;
Transaction cost	Centralized storage can reduce storage costs; Integrated services can reduce trade opportunity finding costs; Specialized storage and service reduce maintenance and release cost of data producers	Integrated information service system reduces the user's information finding cost; Union catalogue and services reduced resources construction costs and improve efficiency of resource use and services.
Game theory	Enhance data producer influences, Copyright protection, had better have economic gains; Promote the business Professional development of data centre and data services supplier.	Improve development efficiency and depth based on resources integration, reduce resources purchasing cost.

Table 1. Comparison of VVO and HVO based on three theories

4. Two cases of SDSVOs

Operation mechanism and membership management of VOS are concentration. As scientific data is a kind of information product, its information management system need to be considered. (Xueping Liu, 2007) Next, the thesis choose two national scientific data sharing projects, Germany's national scientific data infrastructure and China National Scientific Data Sharing Program, to discuss on organization structure, the leader of alliance selection, partnership construction and IT system design, etc.

4.1 Project background

- **Germany's national scientific data infrastructure (GNSDI)**

On 22 October 2003, a group of leading research institutions and research funding institutions published the 'Berlin Declaration on Access to Knowledge in the Sciences and Humanities' (Berlin Declaration, 2003) in order to "promote the Internet as a functional instrument for a global scientific knowledge base and human reflection and to specify measures which research policy makers, research institutions, funding agencies, libraries, archives and museums need to consider."

As a consequence, the German Science Foundation adopted access to data as part of their policy in their 'Recommendations for Good Scientific Practice'. To make this policy effective, scientists themselves need to be convinced that preparing their data for online publication is a worthwhile effort. It would be an incentive to the author, if publishing of data became a citeable publication, which would add to his reputation and ranking among his peers. In 2005, National Science and technique library (TIB) officially became DOI (Digital Object Identify) registered organization of European Union. GNSDI project enters substantive construction phase.

- **China National Scientific Data Sharing Program (CNSDSP)**

In 2003, the State Ministry of Science and Technique (MOST) started the scientific data sharing program. The program has established leading group, a co-ordination group, a experts group, the working group, and offices whose responsibility is project design, implementation, oversight, project management, and so on. Program involves meteorological, seismic, hydrological, marine, agriculture, basic sciences, medicine and health care, earth science and other fields. Nine major data centres and three data networks were the beginning of the program.

By December 2005, the program had integrated and transformed 864 databases, more than one million data form, which involved in about one-third of public welfare, basic scientific data types in whole country.

4.2 Organization structure

Two projects took a different way of organization and structure. The organizational structure of GNSDI has a core institution--TIB, and rely on data supply chain to alliance each link to form a scientific data sharing infrastructure. That is a kind of VVO. The program participants of CNSDSP are mainly data centres. It has a virtual leader group and working group to fulfil top-level design and project implementation inspection. Every data centre paralleled. That is a kind of HVO. The detailed information is below.

4.2.1 GNSDI

GNSDI have three layers of architecture. The first layer is TIB who led DOI registration of scientific data, provided unified retrieval services. The second layer is composed by several Data centres whose responsibility is scientific Data storage, quality assurance and management. The third layer is all scientific data acquisition and production institutions and individuals. The connection among the three layers is through DOI system and the URL system.

In this project, according to the core standards and information system model proposed by International DOI Foundation (IDF), TIB is responsible for scientific data DOI registration and resolution as DOI regional agents of the European Union. TIB have built relationships with earth science, climate, oceans, satellite data centres by the DOI registration. Data centres are in charge of metadata of data sets abiding by DOI standard and submitting metadata to DOI register database. Data centres assure data sets and metadata quality and long-term permanent preservation conditions for registered data sets. TIB is responsible for data sets DOI registered and resolution services. At the same time, TIB established relationship between data sets metadata and the literature resources preserved in TIB that integrated data sets services and literature services at one stop. That function is very useful and welcome by researchers.

In 2006, TIB associated with Thieme Publishing Group launched a project. The task of project is to register research data DOI while researchers publish their paper on SYNLETT and SYNTHESIS. All registered data set of this project is stored in Fachinformationszentrum Karlsruhe and be open access.

The organizational chart is as follows (See also Figure 2). We can see that TIB is the core of alliance. It is a bridge between users and data centres. It also link with publishers and users.

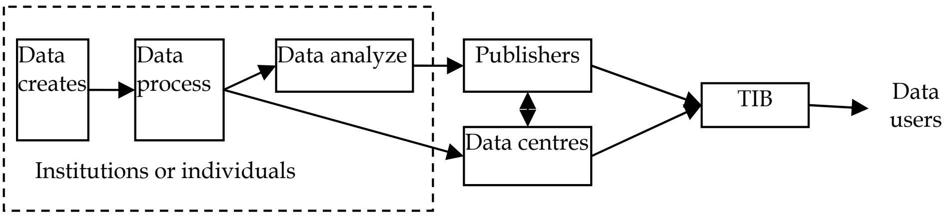

Fig. 2. GNSDI organizational chart

- **Why TIB is the core of VVO?**

There is a core enterprise in VVO mode, which responsible for sales/service. Why TIB became the core institution? Because data centres think that libraries have extensive user group. If TIB provides data sets directory retrieval, data sets can be used more widely. So data centres are very happy to cooperate with TIB to jointly promote the scientific data sharing. Their union is a kind of spontaneous organization and coordination, for the common goals and aspirations.

For making scientific data open access, they have established a virtual organization based on a supply chain with German Science Foundation's support. The core of virtual organization is the National Science and Technique of Germany Library (TIB) who plays the role of data publisher. Others are data author, data centre and data user.(see figure 2)

- **Relationship between TIB and data centres**

TIB signed a contract with each data centre. The contracts states that data centre responsible for solving the data sets copyright conflict. Data centre also is responsible for data quality control, metadata processing, as well as in the contract period to ensure that the data can be access. Data centres pay fees as €1 per data sets when registering DOI because TIB provide extra services to data centres. The services include directory retrieval, related literature recommendation, DOI register and solution, etc. This is a kind of market operation mechanism.

4.2.2 CNSDSP

CNSDSP has two layers of architecture. The upper layer is a virtual leader group and working group to fulfil top-level design and project implementation inspection. The leader group was composed by administrative leaders and executive directors come from MOST, Chinese Academy of Sciences (CAS), Ministry of Education, ministry of agriculture, Natural

Science Foundation of China (NSFC), and so on. The workgroup includes directors of business departments and fields experts. The second layer was project groups composed by data centres. Every group has a core data centre and other data centres delivered data to the core centre. So every group is parallel. Each data centre is responsible for project sponsor and contract. There is no legal restraint between each other inside project group. So this organization mode is a kind of HVO.

- **The role of virtual leading group and workgroup**

Virtual leading group's main function is to play a part in administrative leader and coordination. It is the central of the whole program. It fulfilled top-level design and project implementation inspection. The standard development project and one-stop web portal development are two projects in the program. The undertaking unit is responsible for developing and running IT system and have no contract with data transferring institution. They don't coordinate and communicate officially, but through leading group and workgroup instead, even if there is obvious upstream and downstream relationship between participants of program. Every participant signed a contract with science and technique administration. This pattern reflects the planned coordination mechanism, not market coordination mechanism.

So whether the whole program implement success depends on virtual leadership group management ability and level.

- **Program participants relationship**

The program organization chart is as follow figure 3.

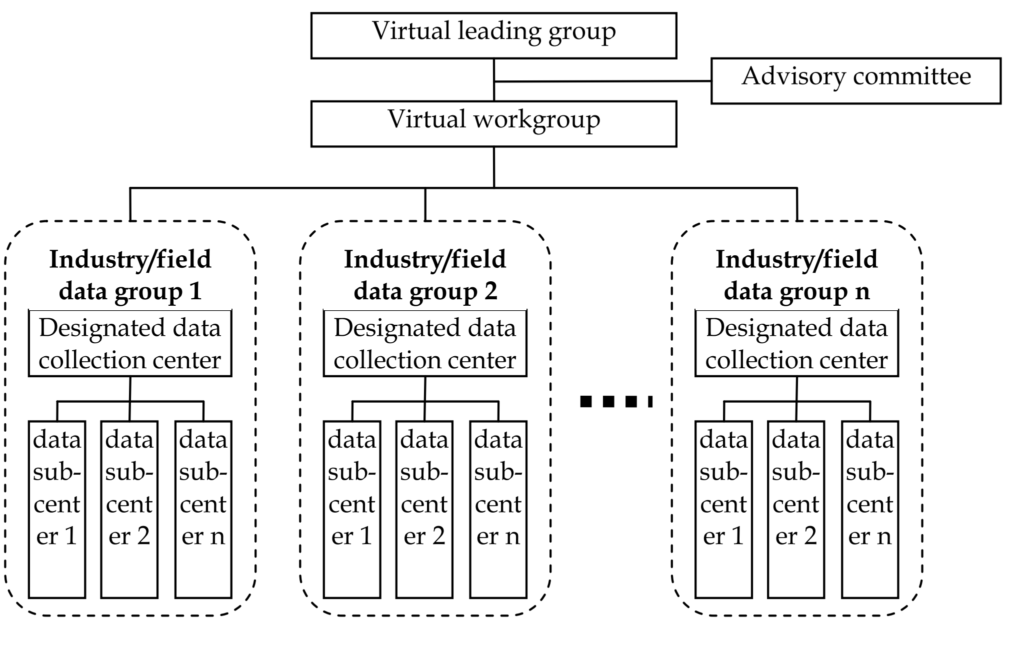

Fig. 3. CNSDSP organizational chart

In figure 3, we know that every industry / field data group is a project group. Project members have technical relationship with each other and no contract relationship with each other. All management responsibility and risk belong to virtual leading group and workgroup.

But the relationship between HVO members also is based on agreement. Just CNSDSP has some particularity.

4.3 IT system design

4.3.1 GNSDI IT system

GNSDI project use DOI standards to develop a unique identifiers register, release and service system. Data centre through the system registered their data set DOI into TIB system and IDF system. Using DOI, registered data sets can be easily located to storage URL and metadata. That is a kind of convenient service for data sets users. The system architecture is as figure 4.

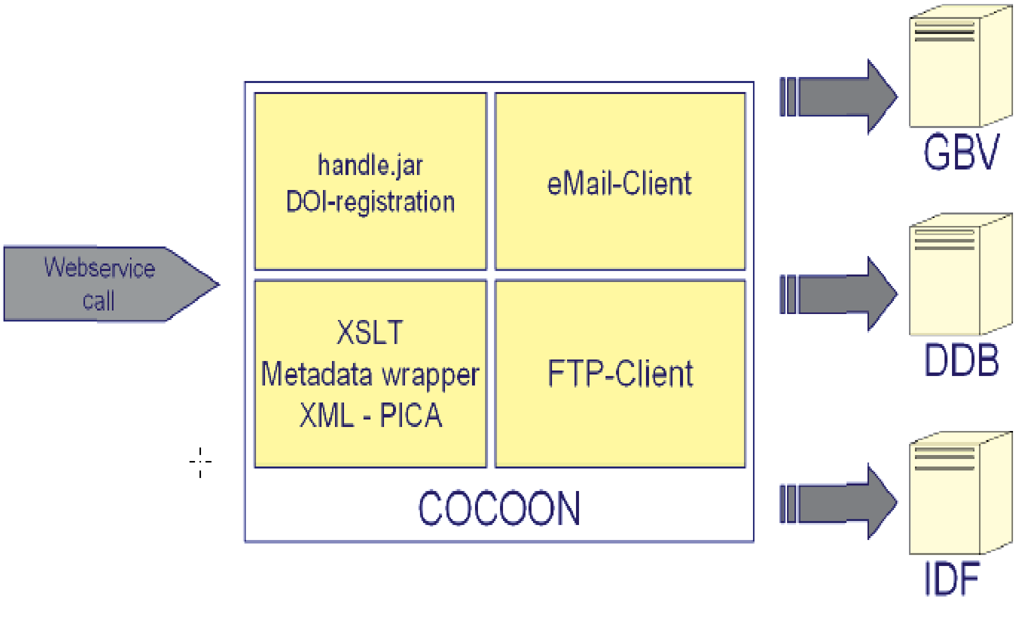

Fig. 4. GNSDI IT system architecture diagram (Schindler, 2005)

The system manages two kinds of data set. One kind is the citable core data set (cited in the literature), the other is a core data set while important, but in the literature not cited. The core data set can upgrade to the citable core data set. The system is a web service system to complete data provider and TIB information interaction.

Data providers submit 4 kinds information to the system:

1. Register DOI information for core data sets (citable and non-citable);
2. Upgrade non-citable core data sets to citable core data sets;
3. If the citable core data set metadata change, create a new record;

4. If the data sets URL change, modify URN register database and IDF resolution database.

TIB have also developed some compatible middleware, such as assist registration plug-ins to decrease integration cost and work load.

However, data centre also make their IT system to suitable for various applications. For example, PANGEA (one data centre signed agreement with TIB) IT system support four data standards for various application including Open Geospatial Consortium (OGC) standard, ISO9115, Dublin Core and science and technique dataset DOI.

This shows that data centre has strong desire to recommend their data sets to public to let more people use these data. This desire and TIB's needs are matching. Therefore, both sides signed cooperation agreements to promote data sharing substantive. This is one important factor to achieve Nash Equilibrium.

4.3.2 CNSDSP IT system

CNSDSP built at least two levels of information systems. The top level is a portal website (http://www.escience.gov.cn/) which function is releasing all datasets metadata uploading by data centres. Users can search datasets by category and keyword. The items of metadata include resource name, resource ID, keyword, resource describe, data centre name, contact information, update date, resource category, etc. When the user click "details" button, he will obtain detail metadata which is stored in data centre's database if the data is open access. Otherwise, he will enter the data collection centre website to get permission to access the data.

CNSDSP IT system is simply for data information sharing, not to provide other information linking service for data centres. And the portal website collected part metadata from data centre. The system of data centre is brand new which is separated from their existing datasets resources service system.

4.4 Two cases comparison

In 2006, TIB extended the scope of registration to other areas, such as medical, chemical, and other like crystal structure and gray literature. They have established branches to manage the registration of datasets. The virtual organization became bigger and stronger than ever. By October 2007, TIB has registered 475,000 datasets, 12,500 scientific movies, 6302 case studies, 342 technical reports, as well as learning objects 112.

By September 2009, CNSDDP have integrated sharable data resources more than 140TB, exceeding more than 3,000 systemization datasets, attracting more than 1.6 million registered users, the download data more than 430TB, have provided scientific data support for more than 1,500 national level projects, such as the manned space flight project, national Marine rights and Qinghai-Tibet railway construction, etc.

Compare the above two cases as following table2.

Though two cases have so many differences, but cooperation member selection for both is similar. After investigating TIB and nine data centres of CNSDSP, four first level index and eleven second level index are identified. The index and their meanings show in table 3 as following.

Competence basis index reflect business capabilities and resources advantages. Information environment basis index show the cooperation desire. Cooperative basis and efficiency can preliminary evaluate cooperation quality.

Feature	GNSDI	CNSDSP
Project implementation environment	Data centre business development is relatively mature, have burning desire and motivation to further expand the operations scale and service channel. Data centres are active.	Data center construction just get started, and data sharing demand is very strong, so data centres were asked to grow rapidly. Data centres is passive to work
Organization structure	VVO Along data sharing supply chain	HVO parallel
the leader of an alliance	TIB (Selected reasons: more massive user base, user influence, Management, planning, implementation capabilities, integration capability, etc)	Virtual leading group (committee) (role: coordinating parties, planning, looking for funding, etc.)
Participants	Data Centres， Library	Data centres only
Relationship between participants	Should sign agreement, library provide extra service for data centres, data centres pay service fee	Have a virtul leading group who is program sponsor; No legel restrain between each data centre
IT system	Library: A datasets DOI register system combined with literature service system;Data centres: integrated datasets service system facing to various application	Have a vitrual datasets metadata integration portal; Data centres: separate datasets sharing system;
Mechanism design	DOI can anounce copyrigh. Cooperation can achieve every participants organization goal and get their due interests	The state financial capital is the important factor to attract cooperation, and the project participants improve their own ability and capability.
accomplishments	All of the participants expanded their business and services. Scientific data sharing virtual organizations develop healthly. The success mode can be extended to regions and countries where data services market is relatively mature.	People become more familiar with the data sharing function and significance. The standardization and regulation level of data centres improved, and the total amount of valuable data resources increases. Scientific data industry has developed effectively.
Opportunities and Threats	1) Is this organization mode applicable to other countries and regions; 2) Scientific data set of long-term preservation and addressable still un-solved fundamentally. 3) How to get long-term operational funds for virtual organization.	1) How scientific data sharing virtual organization steadily develop and long-term sustain? 2) Change coorperation mode from government instructions to the participants voluntary cooperation. 3) Extensions scientific data sharing service chain to deepen service contents and improve service quality.

Table 2. Comparison of two cases

First level	Second level	Meaning of index
Competence basis	The working information system level	If a member have had data processing platform, compatibility should be considered
	Data basis	Data resource scale, type and quality
	Researchers	Support staff structures, scale, etc. for software and hardware
Information environment based	Support extent by leader	Whether there is a combination of desire. If no, the institution can't be a candidate.
	Target harmony degree	If the goal gap between a member and virtual organization is too big, the cooperation cannot reach agreement.
	Business saturation	If a member's business is saturated, the virtual organization’s work will be unable to complete.
Cooperative basis	Cooperation experience and skills	Ever have similar cooperation with other organizations
	Cooperation creditworthiness	The cooperation with other institutions whether smoothly
Cooperation efficiency	Built-up time	
	Built-up cost	
	Cultural compatibility	If cultural compatibility, the cooperation easy achieve success

Table 3. Scientific data sharing virtual organization member selection index

5. Conclusion

In this paper, the driving factors of SDSVO based on supply chain were discussed first. In brief, scientific data supply chain has four links, namely suitable data producers, data centre, data services and data user. Creators work includes data harvesting and data production. Data centres tasks are data storage, quality assurance, making metadata, and so on. Data service responsibility is providing directory, retrieval results. Data users use data and give suggestions and opinions to creators, data centres and services. Every link has its own advantage resources and capabilities. For example, data centres have integrated data resource, storage capabilities. Data creators have data production professional knowledge and they can collect data, but they can’t preserve data permanent. Thus, data centres can cooperate with data creators. Data centres have more data resources. At the same time, data creators get more storage space and don’t worry about the storage device maintain. Their cooperation can decrease both cost—collecting data cost for data centres and storage cost for creators. And so forth, data sharing supply chain form. At the SDSVO operation stage, mechanism based on Gametheory should be considered. Data creators care for copyright and reputation, data centres care for organization goals and profit. If the mechanism can satisfy all the demand, SDSVOs can run fluently. The difference between VVO and HVO based on three theories are discussed following. Then keys of case study are further explicated. That is organizational structure, leader of SDVOs, partnership and IT system.
Cases study shows that GNSDI organizational structure is a kind of VVO. TIB is the core. It integrates various datasets or other forms data resources, provide DOI register and

resolution service, and relative literature retrieval service. Data centres provide datasets metadata to TIB and pay fee for its service. Interests constraints based on agreement. The mechanism is fit for mature science data sharing environment.
Meanwhile, CNSDSP organizational structure is a kind of HVO. There is no core institution, but a virtual leading group. Data centres are participants. They transferred datasets metadata to web portal system on which user can search metadata by catalogue or keywords. Participants shared metadata according to project contract which signed with project sponsor—scientific and technical administration department. This mode is built while data sharing industry is still not mature, need government support and promote.
In IT system developing, system function design should match organizational goal and responsibilities. Integrating platform had better provide more useful functions and tools to improve datasets metadata harvesting efficiency. If platform develop functions which can improve datasets usage and influence, it will welcome.
When the leader of alliance was selected, there are different index. The chairman of VVO should have more massive user base, user influence, Management, planning, implementation capabilities, integration capability, etc. While the committee of HVO forms, optional conditions include: coordination capability, planning, looking for funding, and so on.
The member selection should consider capabilities and resources advantages, cooperation desire, cooperation quality, etc. totally eleven second level index.
For each case, there are some suggestions. GNSDI should look for long-term stable funding to datasets permanent preservation and addressable. CNSDSP partnership should change state-directed to agreement between participants each other, attract information service such as library to join the alliance to extend data sharing service contents and quality.
Although some conclusion were got in this paper, there are many further research should be done. The future work includes: the member selection index empirical study, profit distribution quantitative analysis, and the design of incentive mechanism, etc. These researches can provide more guidance for practice.

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Standards Framework for Intelligent Manufacturing Systems Supply Chain

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1. Introduction

The global market is striving to increase competitiveness among organizations and networks. Nowadays, management of supply chains does not only consider business processes in the traditional value chain, but also processes that penetrate networks of organisations. Indeed, the formation of cooperation and collaboration partnerships between several small organizations can be, in multiple cases, more efficient by comparison with big companies (Rudberg et al., 2002). This way, the research on supply chain management has turned from an intra-enterprise focus towards an inter-enterprise focus with companies looking for enhanced interoperability between computer systems and applications.

Supply chain networks are characterized by different structures such as, business processes and technological, organizational, topological, informational, and financial structures. All are interrelated but following their own dynamics. Thus, in order to ensure a high responsiveness level, the supply chain plans must be formed robustly and extremely quickly in relation to all the structures (Gupta & Maranas, 2003). In fact, with regards to supply chain in the advent of globalization, one of the difficulties enterprises are facing is the lack of interoperability of systems and software applications to manage and orchestrate the different structures involved (Farinha et al., 2007; Jardim-Goncalves et al. 2006a; Panetto et al., 2006). The increasing need for cooperation and collaboration together with the rapid advances in information and communication technology (ICT) have brought supply chain planning into the forefront of the business practices of most manufacturing and service organizations (Gupta & Maranas, 2003). Moreover, there has been a growing interest and research in e-business solutions to facilitate information sharing between organisations in the supply chain network.

However, despite enterprise networks and partnerships are desirable, the automation of processes still suffer some problems mainly in integrating Product Life Cycle (PLC) phases, since manufacturers, distributors, designers, retailers, warehouses, often use proprietary solutions which are, typically, not interoperable with another (Jardim-Goncalves et al., 2007a). The exchange of information and documents between partners often cannot be executed automatically or in electronic format as desirable which creates inefficiencies and unexpected cost increase that might challenge the advantages of the network when not addressed (Brunnermeier & Martin, 1999). With this diffuse range of systems, industry has had its development of trading and supply partnerships restrained, e.g. inhibiting the shared fabrication of products. These barriers are real factors that stop innovation and development.

Therefore, standardization rapidly became an evident priority, and several dedicated reference models (e.g. ISO 10303, also known as STEP, the standard for the exchange of product model data) covering many industrial areas and related application activities, from design phase to production and commercialization, have been developed enabling industrial sectors to exchange information based on common models (Jardim-Goncalves et al., 2006a). STEP Application Protocols have been widely used in industrial environments, to support systems interoperability through the exchange of product data in manufacturing domains. Using them, designers and manufacturers will get a considerable advantage over those that don't (Agostinho et al., 2009). Sending and receiving e-commerce documents in standardised format may get easier access to new markets and facilitate the management of product data through PLC phases, reducing administration costs when handling quotations, orders, as well as the opportunity to have e-catalogues, product customization, user-centric design, etc. Nevertheless, alone, this kind of data representation standards does not solve semantic problems (Jardim-Goncalves et al. 2011; Sarraipa et al., 2009a). Moreover, industrial standards as STEP, often use technologies unfamiliar to most application developers or too expensive for SME-based industries which cannot spend large amounts of time and effort trying to implement standard recommendations and training the employees (Jardim-Goncalves et al., 2006b & 2007b).

Indeed, these kinds of organizations are much liable to use more user-friendly and supported technologies, such as Extensible Markup Language (XML) or Unified Modeling Language (UML). Their simplicity and the large availability of implementing tools make them popular and very well accepted. Therefore, a possible solution to facilitate the use of STEP and promote its adoption, would be to use standard-based platforms capable of applying rigorously defined transformation rules (i.e. morphims) to STEP models, and supplying them to the industrial communities in different languages. This would allow reusing existing expertise and extending STEP capabilities in complementary application domains, like advanced modelling tools, knowledge management and the emergent semantic web technologies (Agostinho et al., 2007a).

More recently, the development of ontologies is promising to provide companies with capabilities to solve semantic issues. Thus, each company is struggling to develop competencies at this ontological level, but inevitably different perspectives will lead to different final results, and achieving different ontologies in the same business domain is the reality. One possible solution is to have a common ontology for a specific domain that all the networked enterprises use in their business. Although, to force manufacturers or suppliers to adopt a specific ontology as reference is not an easy task, since each enterprise does not foresee any outcomes by changing their knowledge. An advantageous solution would be to let them to keep their terminology and classification in use, and adopt a reference ontology,

which will complement the data standard and become the organization knowledge front-end, enabling inter-enterprises communications sharing the same terminology and semantics (Sarraipa et al., 2009b).
Together with standards development, interoperability solutions have enabled a smooth progress of supply chain systems to a next phase, where flexibility, intelligence and reconfiguration should be reached. The 'intelligence' concept becomes more relevant because of the need to maintain effective and efficient operations with minimum downtime under conditions of uncertainty (Molina et al., 2005). Intelligence is taken to mean advanced and efficient manufacturing technologies, management and procedures. Therefore, the solution explored in this chapter to reach such intelligence is exploring the use of data morphims for standards integration and formal ontologies as a way of specifying content-specific agreements for the sharing and reuse of knowledge among software entities (Gruber, 1995).

2. Furniture sector problems and motivations for an intelligent supply chain

Based on the number of people it employs, the furniture industry is the largest manufacturing sector in the world, involving mostly Small and Medium Enterprises (SMEs) (Gaston & Kozak, 2001; Roca de Togores & Agostinho, 2008). To keep its competitiveness, Europe needs to accomplish rapidly the requirements in the digital global marketplace, and push promptly SME-based industry to adopt seamless electronic business services in networked enterprise environments using of modern ICT and standards among all agents involved in the furniture product life cycle (Fan & Filos, 1999; Jardim-Goncalves et al., 2006a & 2008).

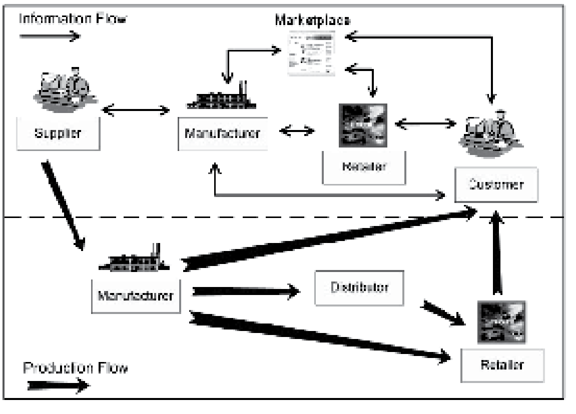

Fig. 1. Furniture supply chain flows (Jardim-Goncalves et al., 2007b)

The furniture supply chain is an end-to-end process required to procure, produce and deliver furniture-related products and services to customers. During this process and, based on the customer's order, raw materials, supplies and components are modified into finished products and then distributed to the customers. Between the different players in the supply chain, there are three main types of flow, namely production and information (represented in Fig. 1) and financial. The first usually involves moving goods while the information flow involves exchanging product data, electronic catalogues and orders, with the information seamlessly exchanged between parties, giving the customer better choices, by offering them a degree of power in customising their own particular product choices.

This way, the problem of data exchange to support the PLC phases of furniture product life cycle when doing business between manufacturers, retailers, suppliers, and customers is well understood (European Comission [EC], 2008a). In fact, the furniture community considers this problem as a major inhibitor of electronic businesses, and although identified as a problem for the furniture industry, there is a global concern in the SME-based industrial sectors.

Historically, companies have managed information flows in a number of ways, including telephone calls, letters, telex, faxes, and electronic data interchange (EDI) managed by a number of proprietary systems. More recently, the availability of reliable high-speed internet connections has become widespread and the cost of implementing technological solutions has dropped. Consequently, companies have begun to make better use of ICT to automate critical business communications. Indeed, furniture industry has become increasingly international, with retailers buying goods from manufacturers all over Europe. Similarly, manufacturers source raw materials from suppliers worldwide (Roca de Togores & Agostinho, 2008).

Product data standards (where they exist) differ across national boundaries, so the development of international product data standards extends business opportunities across the global supply chain. Many separate companies involved in the design, manufacture, sale and distribution of furniture, are requiring the sharing and exchange of huge volumes of information. For this reason, the *funStep* community (www.funStep.org) was setup in the late 90s with the support of European Commission, for implementing an European research strategy for better interoperability in organizations operating in networked environments.

The main objective of the *funStep*'s initiative is to research, develop and demonstrate in industrial environments, an open standards-based framework that supports the complete product life cycle in the furniture supply chain. This should be done adopting secure electronic services, and networked enterprise practices between other organizations, throughout agents, products, and services at 2 levels (Jardim-Goncalves et al., 2008):

- Interoperability among business user applications, and
- Interoperability among electronic commerce platforms.

The SMART-fm and INNOVAFUN[1] projects were two of the *funStep* driven projects that conducted to R&D initiatives pushing forward intelligent systems able to solve interoperability problems. SMART-fm objective was defined to improve effectiveness across the entire furniture manufacturing sector by adoption of a reference method of classification and intelligent information sharing. A major achievement of the project was to reach the enquiry stage for the STEP Application Protocol 236 standard submission, which was approved by unanimous consensus on that time. INNOVAFUN followed to bridge the gap between industry and research developments. It defined use-cases for the standard implementation and detailed a toolbox of intelligent services to enable SME's innovation. It also contributed for the identification of key open research questions, together with the findings and discussions in the international Enterprise Interoperability (EI) research community, that are guiding research nowadays (EC, 2008b & 2010; Jardim-Goncalves et al., 2010):

- Why is there so much effort wasted on the development of dedicated technical solutions for interoperability problems? How can this be reduced?

[1] SMART-fm IMS (IST-2001-52224) and INNOVAFUN (INNOVA-031139)

- How can we predict and guarantee the long-term knowledge and behaviour of interoperability in engineering and manufacturing systems?
- How do we reduce complexity in EI and provide "Interoperability as a Service" (IaaS)? Along these lines, can interoperability services be used as "plug-and-play" mechanisms independently of the EI level for which they are designed (higher levels such as business, or lower ones such as technical applications)?

3. STEP paradigm and ISO 10303-AP236, the *funStep* Standard

Standards play a crucial role in the definition of market conditions in many industrial sectors and not only in high-technology sectors. Their use is accelerating technological and organisational change and thus improving innovation processes. They play a major role in promoting innovative products and services, by providing stable references for the development of new innovative solutions and creating large scale markets. In addition, non-technological standards help shaping new organisational forms and business models and contribute to raising the quality of services and to the efficiency of business processes (Roca de Togores & Agostinho, 2008).

The International Organization for Standardization (ISO) has been pushing forward the development of standards and models. Efforts like STEP have tried to deal with integration and interoperability issues, thus contributing to the reduction of transaction costs involved in the development and application of (new) technologies and of generating positive network externalities by reaching economies of scale. There is evidence to suggest that well implemented standards may contribute to the innovation process and therefore to economic growth (EC, 2008a). However, information must be neutral and unbiased in order to be credible.

STEP is a family of standards for the computer-interpretable representation of product information and for the exchange of product data under the manufacturing domain. It defines a framework which provides neutral mechanisms that are capable of describing products throughout their life cycle. From modelling, through data formats, to industrial data definition and conformance methodologies, STEP is widely used in Computer Aided Design (CAD) and Product Data Management (PDM) systems. It is nowadays adopted by major industrial companies in the world. Among them, are the automotive, aircraft, shipbuilding, furniture, building and construction, gas and oil industries, which use STEP for integration of manufacturing systems, some with significant savings (White et al. 2004).

STEP Application protocols (APs) are information models that capture the semantics of a specific industrial requirement and provide standardized structures, within which, data values can be understood by a computer implementation. This way, ISO 10303-236 (ISO TC184/SC4, 2006), also known as AP236 or the *funStep* standard, is the part of STEP that defines a formalized structure for catalogue and product data under industrial domains of the furniture sector. AP236 is focused on product definition of kitchen and domestic furniture, extensible to cover the whole furniture domain (e.g., bathroom, office, etc.). It is a foundation for data exchange in the furniture industry so that all the software involved in the design, manufacturing and sale of a product, understands the same vocabulary.

3.1 Modular design to enable reuse

As illustrated in Fig.2 (left side), the AP236 standard is designed in order to optimize reutilization of existent standard models through modularization of components. Similar

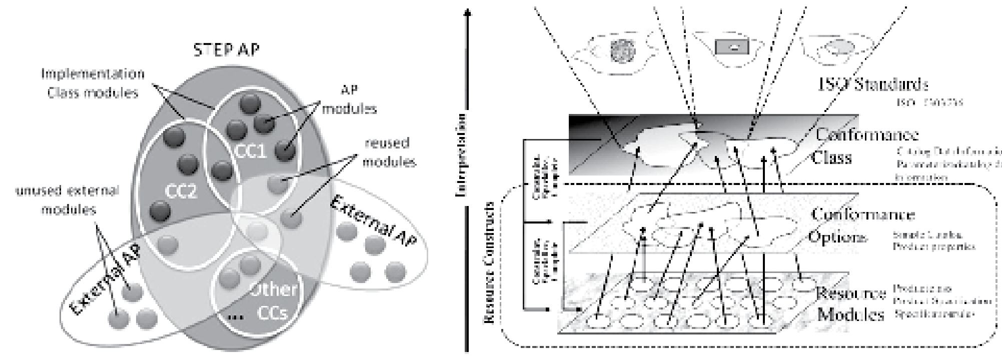

Fig. 2. Modular STEP AP and grouping into conformance options and classes

and common requirements have been identified from existent STEP APs, and subsets of these models (i.e. modules) were selected to be integrated as part of AP236 (Agostinho et al., 2009; Feeney, 2002; Jardim-Gonçalves et al., 2005). This characteristic enables a faster standard development process and guarantees a certain degree of cross-sectorial interoperability since some of the modules are the same. Product and interior designers, as other stakeholders, may now be part of multiple supply chains without greater concerns with interoperability issues since many other STEP industrial standards use some of the same resource models.

However, as illustrated on the right side of Fig.2 in addition to reutilization, modularization in AP236 also enables to define implementation/conformance classes (CCs) and options according to the stakeholder profiles. For example, in the furniture case, modules are grouped in six different implementation classes which allow different stakeholders to implement *funStep* at different levels of compliance namely[2] (Fig. 3):

- Simplified catalogue (CC1), which is still subdivided in 6 smaller conformance options to enable targeted implementations of micro enterprises (INNOVAFUN, 2008);
- Catalogue data and product geometry representation (CC2);
- Parameterized catalogue (CC3);
- Interior decoration project (CC4);
- Parameterized catalogue data and product geometry representation (CC5);
- Full AP236 that encompasses the others (CC6).

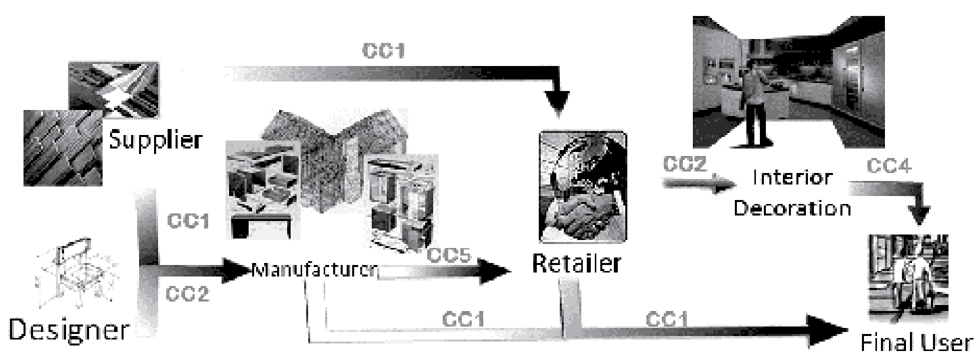

Fig. 3. *funStep* conformance classes needed in stakeholder relationships

[2] The enumerated names are simplified and do not correspond to the official AP236 CC names. Please refer to ISO TC184/SC4 (2006) for the formal designations.

3.2 Use case suite for the adoption and implementation of *funStep* standard

The ideal scenario in the communication between two different furniture stakeholders is that both of them are fully compliant with the *funStep* standard for product data. However, if that is not possible, the stakeholder receiving the information should have the same or higher level of compliance than the sender. Considering the number of CCs implemented: it is possible to define three different levels of *funStep* compliance (Agostinho et al., 2009):

- **Level 0**, the stakeholder has no part of the standard adopted and interoperability is never guaranteed;
- **Level 1**, for the stakeholders that have adopted some CC modules of AP236. Here, in a typical data exchange scenario, interoperability is only assured if the CCs implemented are the same, or if the receiver stakeholder implementations encloses the sender's CCs;
- **Level 2**, for the stakeholders that have adopted full AP236, i.e. CC6.

At present most of the furniture companies have not yet adopted any part of the *funStep* standard and will be on level 0 of compliance. Also, as analysed by Agostinho et al. (2009), many are in different maturity stages of ICT adoption which conditions the way they can adopt and implement *funStep*:

- Maturity stage **"Does not have an ICT Infrastructure".** This is the case where no ICT equipment is used in the organization and all information is stored in paper format. In this case many design specifications are still being sent by fax to manufacturers;
- Maturity stage **"Has an ICT Infrastructure, but is not focused for information exchange"**. This is the case common to the majority of SMEs, where companies have computers, internet connection but have no specialized system to enable creative design, e-commerce or any kind of information management (e.g. ERP);
- Maturity stage **"Has an ICT Infrastructure for information exchange and management"**. This case reflects the situation of companies that have already invested in a system to enable e- business and PLC management. In this situation companies might already be adopting *funStep* (fully or partially), or may use proprietary formats not understandable by all, thus obstructing seamless interoperability.

Considering both the levels of *funStep* compliance and the ICT maturity in SME environments, the authors propose a methodology for the adoption and implementation of AP236 based on a set of 12 use cases which show the actions stakeholders should carry for a fast implementation of STEP standards, namely *funStep*. Table 1 guides the implementors on the order of UCs they should follow, to adopt certain parts of *funStep* and raise the level of compliance. This best practice methodology eliminates part of the complexity of implementing a STEP standard, i.e. where to start.

3.3 An e-marketplace implementing AP236 for the supply chain information flow

To better illustrate how the proposed use-case suite works, its best to follow an example: let's say that a furniture e-marketplace decides to implement the *funStep* standard to regulate his supply chain information flow as in Fig.1. Due to its business scope, the marketplace already uses an ICT system that enables to electronically receive furniture catalogues from different manufacturers, thus has an ICT Infrastructure for information exchange and management (highest ICT maturity level). However, it doesn't implement yet AP236 (level 0) and due to the heterogeneity of the information received, has trouble enlarging its business network.

ICT Maturity	Compliance	Steps (#, name)		Use-case #
Does not have an ICT Infrastructure	Level 0	1	Uptake basic ICT	UC-01
		2	Build data system based on *funStep*	UC-02
		3	Implement system interfaces	UC-03
		4	Populate data system	UC-04
		5	Test the level of *funStep* compliance	UC-05
Has an ICT Infrastructure, but is not focused for inform. exchange	Level 0	1	Build data system based on *funStep*	UC-02
		2	Implement system interfaces	UC-03
		3	Migrate internal data to *funStep* system	UC-06
		4	Test the level of *funStep* compliance	UC-05
Has an ICT Infrastructure for information exchange and management	Levels 0, and 1	1	Find requirements that the current system does not answer	UC-07
		2	Analyse how *funStep* could answer the requirements	UC-08
		3	Discover mapping from internal system to *funStep (if starts from level 0)*	UC-09
		4	Implement functionalities/ services to transform internal data in *funStep* data and vice-versa *(if starts from level 0)*	UC-10
		5	Implement new parts of *funStep* (*if required*)	UC-11
		6	Implement system interfaces for the new parts (*if required*)	UC-12
		7	Test the level of *funStep* compliance	UC-05

Table 1. Use-Case (UC) suite for the adoption of the *funStep* standards

Clearly the e-marketplace is suffering from an interoperability problem, and according to Fig.2 would need the first conformance class (CC1) of the AP236 standard to be able to receive catalogue data from more manufacturers. However, if the marketplace, as a more technologically advanced form of retailer, already includes innovative product visualization functionalities and placement of furniture objects inside a room, would probably be interested in the implementation of CC2 and CC4 as well.

Following Table 1, the marketplace should start by finding and detailing the exact requirements that the current system does not answer (UC-07). Next, the second step relies on the profound analysis of the standard capabilities to see if and how it will solve the problem (UC-08), i.e. decide which conformance options and/or CCs to implement. The procedure continues with UC-09 defining morphims from internal system functionalities and structures to the standard constructs, UC-10, UC-11 and UC-12 for the implementation of the morphisms and new functionalities if required, until it reaches UC-05 where it is foreseen that the organization will check if its implementation has been successful and obtains a compliance level certificate.

Due to space restrictions the full details of the use-case actions are not here detailed and can be found on INNOVAFUN (2007).

4. Framework for the independency of STEP languages

STEP data has traditionally been exchanged using ISO10303-21 (Part 21) (ISO TC184/SC4, 2002), an ASCII character–based syntax. Although it's sufficient for the task, it lacks extensibility, it's hard for humans to read, and it's interpretable only by systems supporting STEP. This is one of the drawbacks STEP faces regarding its use and adoption by a wider community, namely among SMEs. Another drawback is the fact that the STEP modelling language (used in all their APs), EXPRESS (ISO10303-11) (ISO TC184/SC4, 2004), is unfamiliar to most applications developers. Although it is a powerful language, it has been relatively unknown in the world of generic software modelling tools and software engineers (Subrahmanian et al. 2005). As opposed to other modelling technologies, such as UML or XSD, few software systems support EXPRESS (Agostinho et al., 2006 & 2007a & 2007b).

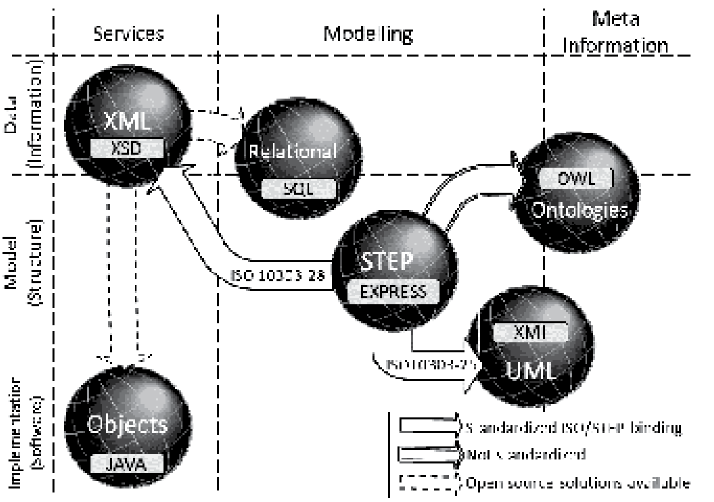

Fig. 4. Integration of STEP with other technologies

In summary, the STEP standard, despite being very powerful regarding the representation and the exchange of product data, is not very popular among the application developer's community. Therefore, and because of the massive adoption and deployment of other standard technologies, like XML and UML, the authors believe that the path to follow is to define morphisms from STEP to these standard technologies, leveraging the cemented knowledge gathered by STEP, with the popularity of the other standards (see Fig. 4). This harmonization among complementary technologies would become a powerful tool for lowering the barriers of STEP implementations and enable to widespread exchange and share of digital data.

Several international research projects, like the Athena IP and the InterOP NoE[3], in addition to the *funStep* driven projects mentioned in section 2, have been supporting the development and validation of similar solutions that apply innovative concepts such as the Model Driven

[3] ATHENA IP (IST-507849) and InterOP NoE (IST-508011)

Architectures (MDA), ontologies or Model Morphisms (MoMo) to solve real industrial interoperability scenarios (Agostinho et al. 2007a; Franconi, 2004; INTEROP, 2005; Jardim-Goncalves et al.,2007b; Kalfoglou & Schorlemmer, 2003; Lubell et al., 2004; Sarraipa et al., 2010).

4.1 Model Morphisms (MoMo)

Morphism is an abstract concept drawn from mathematics for describing a structure-preserving map between two structures. It can be a function linking two objects or aggregations of objects in set theory; the relation between domain and co-domain in category theory; or the transformation operator between two vector spaces, in linear algebra (INTEROP, 2005). Recently, this concept as been gaining momentum applied to computer science, namely to systems interoperability where it specifies the relations (mapping, merging, transformation, etc) between two or more information model specifications (let M be the set of all models). In this context, a MoMo describes a model operation.

MoMo	Formalization	Classification
Mapping: $\theta(A,B)$	$\forall A,B \in M: \theta(A,B) \subseteq Sub(A) \times Sub(B)$	Non-altering
Transformation: $\tau: A \times \theta \rightarrow B$	$\forall A,B \in M: if\ \exists\theta(A,B)\ then\ \tau(A,\theta) = B$	Model altering
Merging: $\lambda: A \times B \times \theta \rightarrow C$	$\forall A,B,C \in M:$ $if\ (\exists\theta(A,C)\ \wedge\ \exists\theta(B,C))\ then\ \lambda(A,B,\theta) = C$ $and\ C \subseteq A \cup B$	Model altering

Table 2. Types of MoMo

INTEROP (2005) was the catalyst for the MoMo research applied to interoperability domains identifying two core classes of MoMo, i.e., non-altering and model altering morphisms. Since then the authors have been formalizing interoperability operations accordingly and classifying them within the morphism types specified in Table 2 (Agostinho et al., 2007a & 2011):

- In the non-altering morphisms, given two models (source model A and target model B), a mapping relationship is created relating each element of the source with a correspondent element in the target, leaving both models intact.
- In model altering morphisms, the source model is transformed using a function that applies a mapping to the source model and outputs the target model. Other relations, such as the merge operation, can also be classified as model altering morphisms since it is a transformation with two input models.

The integration of technologies envisaged in Fig. 4 targets model altering morphims, namely transformations where the source model A is translated into a different modelling language in the target model B, thus accomplishing the harmonization of STEP with other more popular and less expensive technologies.

4.1.1 EXPRESS to XSD transformation

This function translates an EXPRESS schema to XML Schema (XSD) format according to the standardized mapping rules defined by Part 28 of STEP (ISO10303-28) (ISO TC184/SC4, 2007). Adopting the mathematical notation to define the morphism, let:

a. $MEXP$ be the set of all models described by the EXPRESS language, $MEXP \subseteq M$;
b. $MXSD$ be the set of all XML models described in XSD, $MXSD \subseteq M$;
c. $\theta(MEXP, MXSD)$ the mapping defined ISO10303-28;

EXP2XSD is a transformation $\tau: A \times \theta \rightarrow B$, where $\forall A \in MEXP, \exists\ B \in MXSD: \tau(A, \theta) = B$. Its implementation is detailed in section 4.2.

4.1.2 EXPRESS to XMI transformation

This function translates an EXPRESS schema to XMI format of the Unified Modeling Language (UML) according to the standardized mapping rules defined by Part 25 of STEP (ISO10303-25) (ISO TC184/SC4, 2005). Adopting the mathematical notation to define the morphism, let:

a. $MEXP$ be the set of all models described by the EXPRESS language, $MEXP \subseteq M$;
b. $MXMI$ be the set of all UML models described in XMI, $MXMI \subseteq M$;
c. $\theta(MEXP, MXMI)$ the mapping defined ISO10303-25;

EXP2XMI is a transformation $\tau: A \times \theta \rightarrow B$, where $\forall A \in MEXP, \exists\ B \in MXMI: \tau(A, \theta) = B$. Its implementation is detailed in section 4.2.

4.1.3 EXPRESS to OWL transformation

This function translates an EXPRESS schema to OWL format according to a set of customized mapping rules defined by the authors (Agostinho et al., 2007b). Adopting the mathematical notation to define the morphism, let:

a. $MEXP$ be the set of all models described by the EXPRESS language, $MEXP \subseteq M$;
b. $MOWL$ be the set of all OWL models, $MOWL \subseteq M$;
c. $\theta(MEXP, MOWL)$ the mapping defined by Agostinho et al. (2007b);

EXP2OWL is a transformation $\tau: A \times \theta \rightarrow B$, where $\forall A \in MEXP, \exists\ B \in MOWL: \tau(A, \theta) = B$. Its implementation is detailed in section 4.2.

4.1.4 XSD to RDB and XSD to JAVA transformations

As in the previous 3, these functions are also transformations, however, the input model is an XML Schema (XSD) and the outputs are in the form of relational database SQL scripts or object-oriented classes. These morphisms complete the framework of Fig 4 using mappings realized by open source solutions available that can be parameterized to produce the desired results, and enable developers to have access to STEP standards even at an implementable format. The formalization follows the same logic as before.

4.2 MDA-based transformations for STEP models

To accomplish the above EXPRESS-based morphims, a *funStep* research prototype, i.e. the UniSTEP-toolbox, as been developed applying the principles of the OMG MDA methodology[4]. MDA recommends handling of information at different meta-levels for integration purposes (Frankel, 2003; Jardim-Goncalves et al., 2006c). At that level, the effort to define valid transformation morphisms from the EXPRESS modelling language to others is heavily reduced since there is more information available about both the operand model languages (input and output). Hence, for the UniSTEP development, the OMG EXPRESS metamodel (Object Management Group [OMG], 2009) as been used specifying all the possible variations that a STEP data model can have.

[4] OMG Model Drivel Architectures (MDA). www.omg.org/mda/

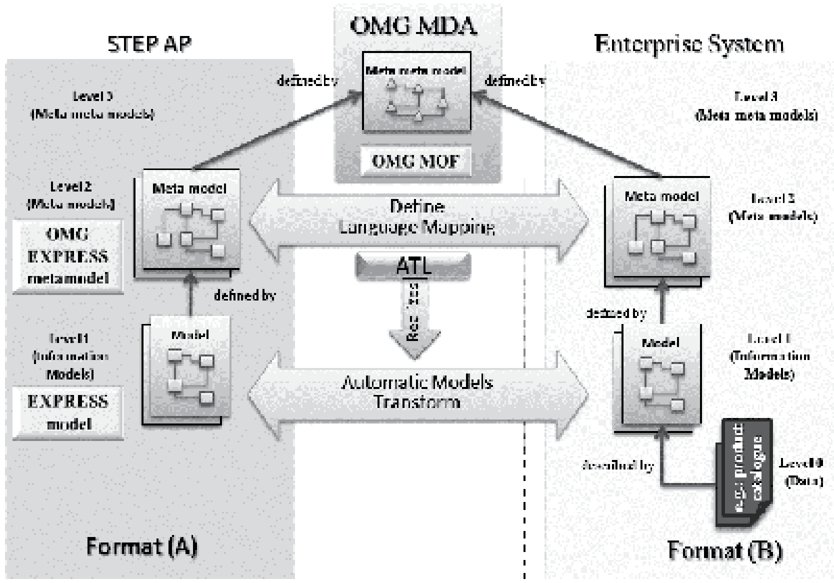

Fig. 5. MDA-based architecture for transformation of STEP models

The proposal to implement the transformation morphisms relies on a four level architecture that structures the relationships between meta-meta-models, meta-models, information models and data (see Fig. 5). The left-hand side of the figure represents the source STEP model, using the EXPRESS language as the information modelling language, whereas the right-hand side represents the organization's internal models. Using a common meta-meta-model, such as the OMG MOF[5] it is possible to define the mappings among the meta-models at the level 2 of the MDA, which are the specifications of the modelling languages. With this, the transformation from any EXPRESS model to the desired format *B* at the Level 1 can be realized, enabling the organization to implement with their preferred technologies, the parts of the AP it requires for a data exchange with other organizations (level 0), as explained in section 3.

Given the context of MDA and MOF based meta-models transformation languages, the Atlas Transformation Language (ATL) is currently the largest user-base and has the most extensive available information such as reference guides, tutorials, programmers' forum, etc. It is the most used language to implement MDA based tools (Jouault & Kurtev, 2007), having a specific Development Toolkit plug-in available in open source from the GMT Eclipse Modelling Project (EMP)[6]. Since the ATL can be applied to OMG meta-models (Grangel et al., 2008; Wimmer & Seidl, 2009), automatic model transformations at the information model level are attained if the mapping of level 2 is written in ATL.

Consequently, using the proposed architecture, the language mapping procedure is a manual process, but the language transformations are always automatic and repeatable. Considering that the number of languages used for information modelling is not so high, it is an acceptable cost since each map is done only once for each language, independently of the number of times it is used / executed.

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[5] OMG Meta Object Facility (MOF). www.omg.org/mof/

[6] http://www.eclipse.org/modeling/

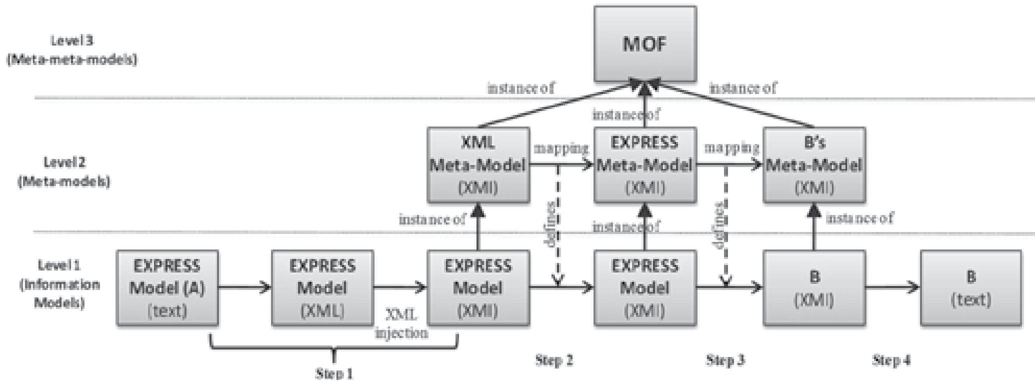

Fig. 6. ATL execution steps

Although ATL transformation input models can be represented in plain text like EXPRESS, it is preferable to use previously validated serialized XMI and EXPRESS meta-model (OMG, 2009) conforming models. Yet to achieve this, a number of steps have to be followed (Fig 6):

Step 0. **(prerequisite)** – All mappings from EXPRESS meta-model (format *A*) to the format *B* meta-model need to be properly described in ATL;

Step 1. **(from plain text to XML tagged file)** - Eurostep EXPRESS Parser (EEP)[7] is a command line parser which allows EXPRESS models (level 1) in text format to be validated against the published STEP standard, and can export an XML form of the validated models. The use of XML simplifies the process of representing the input models as instances of the EXPRESS meta-model, since XML can be natively injected by the ATL modelling tools, creating a valid XMI serialised instance;

Step 2. **(EXPRESS meta-model injection)** – the XML representation of the model has to be injected to the EXPRESS meta-model conforming model, and to accomplish that a transformation from the XML representation of the model must be executed, i.e. from the tags generated by the EEP to the ones used in the EXPRESS meta-model. This step can use specific ATL;

Step 3. **(transformation)** - After a successful EXPRESS injection, an instance of the EXPRESS meta-model, XMI serialized, is obtained. Using the EXPRESS mapping previously defined it is possible to execute the ATL rules automatically;

Step 4. **(deserialize)** –The result of step 3 provides a serialized XMI output according to *B*'s meta-model. Therefore, in order to implement the STEP standard using language *B*, a model to text transformation must be written (ATL can also be used).

The number of steps might cause the impression of great complexity. However, that is not the case and those have only been here included to guide readers in their implementations. Also, in the future probably the steps will reduced to the fundamental step 3, with the further development of ATL frameworks.

5. Semantic enrichment of standard-based product data

Data can exist in multiple ways, independently of being usable or not. In the raw format, it does not have meaning in and of itself. However, information is data that has been given

[7] http://www.eurostep.com/global/solutions/download-software.aspx

meaning by way of relational connection to a context (Breiter & Light, 2004). Still, in information, this "meaning" can be useful for some, but not necessarily to all. It embodies the understanding of a relationship of some sort, possibly cause and effect, thus, people might "memorize" information (as less-aspiring students often do). Nevertheless, they would still be unable to understand it since they require a cognitive and analytical ability, i.e. knowledge (Bellinger et al., 2004).

Nonaka et al. (2001) define two kinds of knowledge: 1) Tacit, that people carry in their minds, which provides context for people, places, ideas, and experiences; 2) and Explicit, that has been or can be articulated, codified, and stored in certain media such as a STEP standard. In an ideal semantic based interoperability framework, both should be addressed and processable to achieve more advances stages of knowledge, such as understanding and wisdom (Bellinger et al., 2004; Jardim-Goncalves et al., 2009a or 2009b; Syed & Shah, 2006). Since the explicit form has been handled by the industrial product data standards, the major research challenge nowadays is to gather the tacit knowledge domain stakeholders hold, in interpretable knowledge bases, thus transforming it to explicit knowledge stored in a structured organized way (Boudjlida & Panetto, 2008). For reaching that purpose, literature suggests the usage of knowledge representation technologies such as dictionaries (domain, technical and natural language), glossaries, taxonomies, thesaurus and also ontologies, to build sustainable knowledge bases.

In the furniture industry, explicit knowledge is handled by the AP236 standard. However, as explained above, the use of the AP236 or any other STEP Application Protocol alone does not solve all the interoperability problems. Each supply chain stakeholder can have its own nomenclature and associated meaning for their business products. Therefore the information exchanged, in spite of sharing the same structure, still may not be understood by all business partners (Sarraipa et al., 2009a). Semantics interoperability is of major importance, and as such it is still to be solved, thus the authors, under the *funStep* initiative, are proposing the semantic enrichment of the furniture product data as a solution. The main objective is to organize the knowledge associated to the furniture products in order to enable a full understandable business messages and supply chain data exchange.

5.1 Reference ontology for interoperability within enterprise networks

An ontology produces a common language for sharing and reusing knowledge about phenomena in a particular domain. It is an agreed specification of how to describe all the concepts, (objects, people, processes, relationships, transactions, etc), of a particular domain of interest. Indeed, by defining concepts and relationships used to describe and represent an area of knowledge it provides a common understanding of the same, that before may have had different views and interpretations from the different practioners (Berners-Lee & Fischetti, 1999; Guarino & Oberle, 2009; Gruber, 1995). Following very simple modelling principles, it uses classes, properties and relationships to define a hierarchical view of the world (designated by taxonomy). An ontology is engineered by members of a domain which try to represent a reality as a set of agreed upon terms and logically-founded constraints on their use (Mika, 2005).

The development of ontologies has lately been widely adopted by companies. However, if all were to develop one of their own, all semantic issues would remain. This way, as a standard is needed to harmonize different information models existing in a supply chain, a reference ontology is needed to harmonize semantics. This reference ontology will be the knowledge front-end, enabling inter-enterprises terminology sharing (Jardim-Goncalves et al., 2009a or 2009b). Its building process is long and involves gathering human knowledge from many organizations.

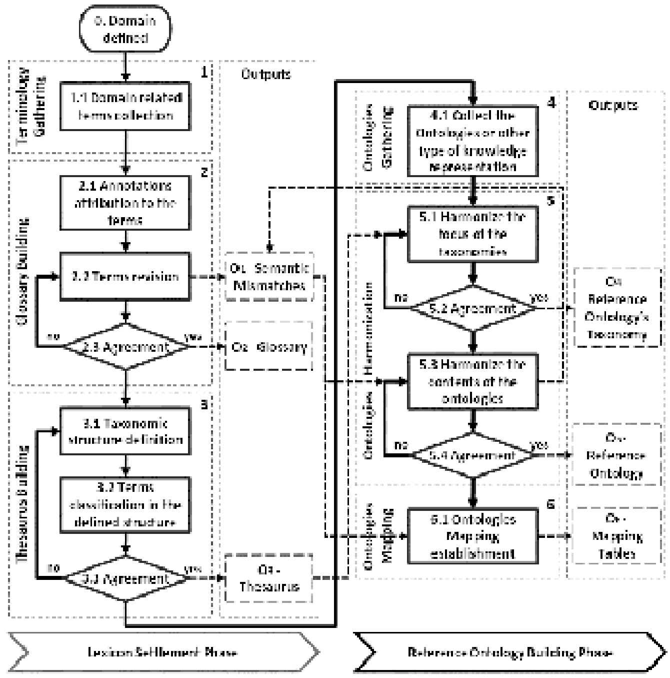

Fig. 7. MENTOR methodology (Sarraipa et al., 2010)

In this context, the development of an enterprise reference ontology can follow the MENTOR methodology (Fig 7). MENTOR – Methodology for Enterprise Reference Ontology Development, is a collaborative methodology developed for helping a group of people, or enterprises, sharing their knowledge with the other in the network, and provides several steps as semantic comparisons, basic lexicon establishment, ontology mappings and some other operations to build a domain's reference ontology. It aims to combine the knowledge described by different formalisms in a semantic interoperable way (Sarraipa et al., 2010).

The Lexicon Settlement, or Phase 1, represents the knowledge acquisition by getting a collection of terms and related definitions from all participants. This phase is divided into three steps: Terminology Gathering, Glossary Building, and Thesaurus Building. The first step is a very simple one, and represents the knowledge gathering from all participants in the collaborative network in a form of a list of terms. In the Glossary Building step, a glossary is built after a series of discussions about the terms that every participant contributed to the network on the previous step. These discussions are followed by a voting process, with all participants deciding which corresponding terms and definitions compose the glossary. Beyond the glossary, the semantic mismatches record is another output that results from this step. Finally, the last step of this phase is composed by a cycle where the knowledge engineers define a taxonomic structure with the glossary terms. If there is an agreement in both structure and classified terms, the thesaurus is defined. If not, the cycle

starts again for another iteration. In this first phase, it could be valuable to have a multi-language dictionary for situations where a common language is not shared by all participants.
The Reference Ontology Building, or Phase 2, is the phase where the reference ontology is built, and the semantic mappings between participant's ontologies and the reference ontology are established. This phase, just like the first phase, is divided into three steps: Ontologies Gathering, Ontologies Harmonization, and Ontologies mapping. The first step comprehends the acquisition of ontologies in the defined domain. In Ontologies Harmonization step, it is needed to proceed for taxonomic harmonization and contents harmonization. First, a discussion and voting process about the reference ontology structure takes place where the common classes are defined by unanimity. This process of discussing and voting is then repeated for the contents harmonization. The final step of this phase, the Ontology Mapping, attempts to relate the vocabulary of two ontologies that share the same domain. In this case, the idea is to establish mappings between each participant's ontology and the reference ontology defined on the previous step (Sarraipa et al., 2010).

5.2 The *funStep* knowledge representation elements

As evidenced in Jardim-Goncalves et al. (2010) *funStep* endeavours to gather the tacit knowledge that furniture supply chain stakeholders hold into machine interpretable knowledge bases. For reaching that objective, the authors are proposing to integrate the *funStep* standard (AP236) with the reference *funStep* Lexicon, which embodies the reference concepts and semantics, and with a *funStep* reference ontology, which embraces product classification to its related properties. This leads to the knowledge architecture definition where the integrated knowledge is composed by four Knowledge Representation Elements (KREs): the *funStep* Ontology; the *funStep* Thesaurus; the *funStep* Dictionary, and the *funStep* AP236 (Fig 8).

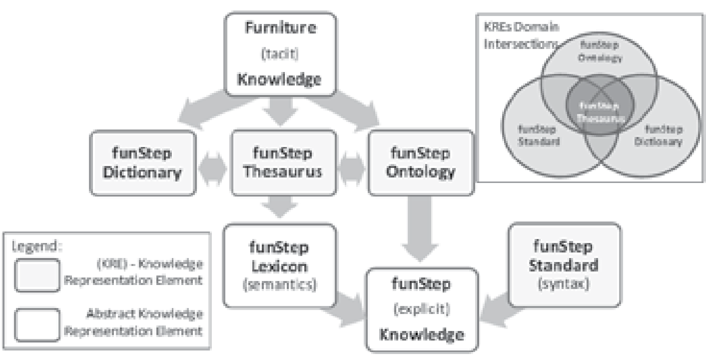

Fig. 8. *funStep* knowledge architecture (Sarraipa et al., 2009a)

For a good explicit knowledge representation, it is needed to have significant input from the tacit source (i.e., domain experts). Thus, such characteristic requires a knowledge architecture enabling the management of the evolution between the KREs:

- The evolution of the first three KREs leads to the *funStep* Lexicon establishment which is an abstract KRE because that it is composed by thesaurus contents;
- On the other hand, the *funStep* explicit knowledge KRE is another abstract KRE since it is composed by the addition of the *funStep* Lexicon with the ontology and the standard

itself. The *funStep* explicit knowledge represents all the furniture machine interpretable knowledge where the *funStep* dictionary and the thesaurus are supporting KREs to the *funStep* Lexicon establishment and maintenance.

5.2.1 *funStep* dictionary

A domain dictionary has been found to be one of the most useful tools for a domain analysis. The use of a dictionary reduces miscommunication by providing users an easy access to information about terms and abbreviations that are completely new to them. The *funStep* dictionary supports a multilingual collection of terms, thus enabling a correct coordination between international partners. Also, the terms are associated to other related terms.

5.2.2 *funStep* ontology

The *funStep* ontology is being developed thanks to some of the *funStep*-driven research projects such as SMART-fm. It started by being a set of reference data for furniture product classification in electronic commerce, but nowadays, it is being evolved according to the MENTOR methodology and gifted with functionalities such as semantic comparisons, basic lexicon establishment, harmonization among other ontologies, etc.

5.2.3 *funStep* thesaurus

The basic lexicon establishment is reached by the development of a thesaurus on the domain. It is composed by a set of domain reference terms and concepts, clustered on the basis of their similarity, and organized by means of semantic relationships (e.g., equivalence, subsumption, generalization, disjunction) to enable a better retrieval process of semantically related terms (Missikoff et al. 2004). A thesaurus can serve as a controlled vocabulary where terms are constrained to its domain-specific meanings, avoiding the problem of ambiguity (Gatlin, 2005). The *funStep* thesaurus envisages a multi-national scope of vocabulary, where terms with the same meaning coexist in multiple languages. Therefore, the thesaurus can be seen as a collection of parts of the dictionary, ontology and AP236 as illustrated on the top right part of Fig 8.

5.2.4 Semantic modules of the *funStep* AP236 standard

As described earlier in this chapter (section 3.1) the AP236 standard has been developed following a modular approach to optimize reutilization and harmonization with the other STEP application protocols. In fact, some of these common structures are the modules that enable a direct link with knowledge representation elements to semantically enrich standard data. The set of modules of *funStep* standard (conformance options) that enable product classification and multilinguism are examples of relevance for semantic enrichment.

External Classification

Each company in a supply chain has its own product nomenclature and structure. This is easily verified not only in the way catalogues are arranged, but also in the different designations companies use for the same concept. However, for an improved business, networks of organizations may define, or use shared reference ontologies or thesaurus, instead of legacy taxonomies. In this case, when exchanging product information, they should classify their products using that reference nomenclature. AP236 provides a mechanism for that, i.e. the external classification conformance option.

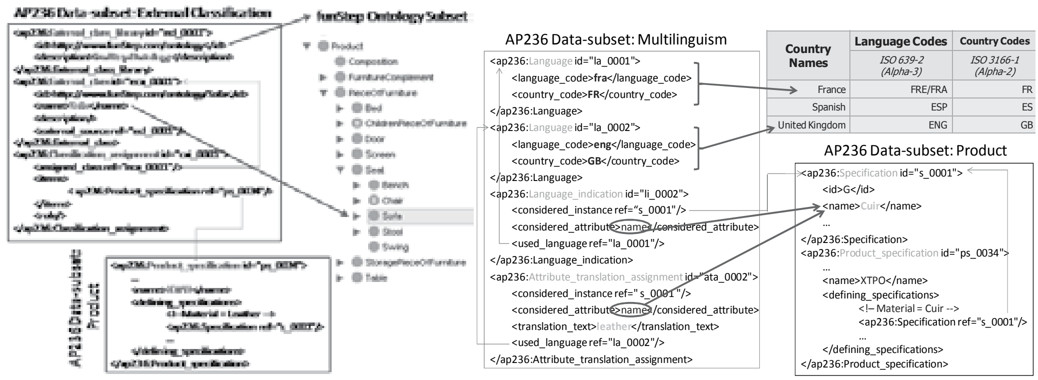

Fig. 9. AP236 semantic link examples

External classification enables a direct link between the context and the classes of products. Nevertheless, the mentioned link uses meanings that are expressed in libraries physically described in remote locations. The left side of Fig 9 illustrates how external classification works: the product manufacturer links with the *funStep* reference ontology, using the AP236 entities: "external_class" and "external_class_library", to identity the externally defined concepts, and "classification_assignment" to establish the link with the product in the catalogue.

Multilinguism

For a better internationalization of the market, companies must be able to send their products and associated information in several languages, especially in the language the receiver company speaks. The multilinguism conformance option of AP236 addresses such need, so that any organization could receive data in their native language independently of where it was introduced or manufactured.

Multilinguism allows the translation of the attributes of AP236 entities in any number of languages. In the right side of Fig 9, it is possible to notice that the AP236 entity "language" is used to indicate the reference language. The entity "language_indication" points to the attribute that one wants to translate, and the "attribute_translation_assignment" specifies the translation itself. In the example, it is the value of the attribute "name" that is being translated from the French "cuir" to the English "leather".

5.3 The *funStep* knowledge framework

Semantics is the study of language units meaning and their combinations. Therefore, semantic enrichment is the act or process of adding specific meaning elements to some knowledge representation structure in a domain, to help on the information clarification. This way, the *funStep* standard semantic enrichment is characterized as being performed at two basic levels: Terminological annotation, by using the terms identified in the Lexicon (Thesaurus); and semantic annotation, by using concepts and expressions drawn from the reference ontology.

Both levels are conducted through a knowledge framework as illustrated on Fig 10, which is based on the KREs identified before. It is built up on web services technology enabling interoperable open services over the internet between the *funStep* knowledge client systems and the *funStep* knowledge server. This architecture is composed by three parts:

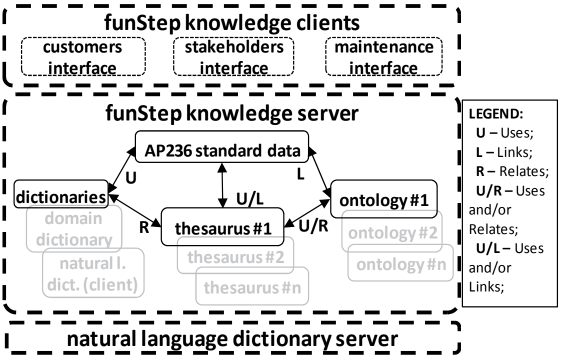

Fig. 10. *funStep* knowledge framework

- The *natural language dictionary (NLD) server* that complements the domain dictionary in the translation procedure of natural language information used within the AP236 multilingual data. For instance, let's imagine a request for quotation for a special request of a 2,5 meters long bed, sent by the e-marketplace of section 3.3 to a Portuguese manufacturer. He would need to translate something like "Bed 1452 with a length of 2,5m" and would use the domain dictionary for the translation of "bed" and possibly "lenght", but the rest needs to be handled by a NLD.
- The *funStep knowledge server* which is composed by the four *funStep* KREs described in the previous section, whose relationships enable the semantic enrichment of the standards data;
- The *funStep knowledge clients* that can be administrators, customers, or stakeholders. The role of the first is mainly related to KRE's evolution and maintenance, while the second are provided with functionalities that go beyond simple product search, namely enabling software developers with skills to develop enhanced intelligent products search engines based on knowledge reasoning. Finally, stakeholder interfaces are related to standard semantic enrichment itself.

6. Conclusions

To solve interoperability problems in the furniture supply chain, consisting mostly of SMEs with heterogeneous needs, *funStep* has created an ISO standard which defines a formal structure for catalogue and product data under industrial domains of the furniture sector.
Due to the modularization properties of STEP it is possible to establish direct cross-sectorial links with other ISO standards. Among them are the automotive, aircraft, ship-building, building & construction and other relevant sectors to the furniture segment, e.g. many furniture manufacturers and designers act as suppliers sub-contracted by other sectors, like automotive (refurbishment), ship-building (luxury Yates) or building & construction (wood-made houses).
However, the main benefit of adopting the ISO *funStep* standard is the increased efficiency that results from sharing data between different ICT systems seamlessly bringing additional benefits without the need for re-enter information. Thus, there is a reduction of human errors and end-to-end transaction time (lead-time). Using standard compliant systems means that, component or products suppliers can provide full technical information about their products to the retailer or e-marketplace, who in turn, can publish catalogues, operate

e-commerce systems, manage stock control systems or supply data to interior designers in an interoperable manner, all without the need to enter any data more than once. Customer orders placed with retailers can be communicated back up the supply chain immediately, enabling components, materials and manufacturing resources to be allocated at the earliest opportunity. Furthermore, it enables to combine catalogue data from several sources in a single retail management system by importing component specifications from multiple suppliers to a furniture design or manufacturing system.

Nevertheless, due to the complexity associated with the implementation of standards, especially STEP standards, the SMEs require a push. Mechanisms to facilitate and accelerate the adoption task and simultaneously minimizing the costs are required and are proposed in this chapter. Indeed, an example of which steps an e-marketplace should take to implement AP236 and become rapidly integrated with more manufactures has been demonstrated and used successfully during the INNOVAFUN project. Also, due to being an unfamiliar technology and lacking support from open or free solutions, in that situation the company decided to go for a XML-based implementation instead of using the native STEP formats.

Information and communications technology combined with the use of open-standards can be a very powerful tool to improve enterprise competitiveness via a wider adoption of STEP APs. However, with so many different modelling and implementation standards being used, interoperability problems arises when the chosen product model is described using one particular technology (e.g. EXPRESS) and is required to be integrated with systems that use totally different technologies (e.g. XML). Being ISO10303 STEP acknowledged, by most of the major industrial companies in the world within different sectors, as one of the most important family of standards for exchange of product data under the manufacturing domain, it would be expected to be broadly used. However, that is not so, especially on SME-based environments because the technology is unfamiliar to most application developers.

Based on that requirement, MDA technology can be used to enable automation of model morphisms, and therefore, translation at the information model and data levels (level 1 and 0 of MDA). The first translation (level 1) is used exclusively to obtain language independency, providing a neutral ground for implementations and to define the necessary mappings to enable supply chain systems interoperability (level 0), which is realized by the real link between two enterprises. The proposed MDA-based architecture enables gradual and sustained system interoperability, since allows incremental AP236 implementations (using the conformance options and classes) without the need to rewrite the full system from scratch. Once the mappings are defined, the standard modelling language is no longer an issue, and the same MDA principle can be applied to the actual data to be exchanged, i.e. if its internal system already has the capabilities implemented but they are not integrated with the standard, only additional mappings need to be defined to transform internal data into AP236 format. The results presented in this part of the work have been applied and validated in several European/International industrial research projects such as IMS SMART-fm, Athena-IP, and InterOp NoE.

Finally, apart from being a technical issue, interoperability challenges also appear in the enterprises at organizational and semantic level, underlying the need for patterns and solutions that support the seamless cooperation among ICT systems, information and knowledge, organizational structures and people (Tursi, et al 2009, Jardim-Goncalves et al., 2009; Jardim-Goncalves & Grilo, 2009a & 2009b). Indeed, Schrage (1990), emphasizes that the issue in collaboration *"isn't communication or teamwork, it's the creation of value"*. By this definition, it is possible to conclude that he was looking at collaboration from a perspective of people and not systems. Therefore, if instead of just looking at the software systems perspective, one could generalize to the everyday's experience, it is possible to conclude that even though people have different cultural backgrounds or education, they can communicate (at least at basic level) if they speak the same language. The authors use this premise and apply it to the systems inter-enterprise level proposing a knowledge framework for semantic enrichment of supply chain data. The proposed *funStep* knowledge framework provides enterprise and manufacturing systems a semantically seamless communication with other stakeholders up and down the supply chain.

The authors, under the *funStep* initiative which is continuing the activities begun by the IMS SMART-fm project, propose the semantic enrichment of standardized product data as a solution for making interoperable intelligent manufacturing systems a reality. They endeavour to gather the tacit knowledge that furniture domain stakeholder's hold into machine interpretable knowledge bases, which should be stored in a structured organized way, where syntax and lexical semantics are integrated as explicit knowledge. This allows enterprises to keep their internal terminologies and classification systems, and still remain interoperable with their business partners, through the usage of knowledge mapping procedures. Together, the domain dictionary, the thesaurus, the reference ontology and the AP236 standard itself act as explicit knowledge repository and reference lexicon for the application domain.

In the past, the *funStep* framework was able to deliver two levels of product data exchange interoperability compliance: (level 1) - *not funStep compliant* – where the messages exchanged are following any kind of format other than the AP236 standard; (level 2) - *funStep compliant* – where, the exchanged messages were compliant with the AP236 standard. From the research results presented in this chapter, the *funStep* Knowledge framework is extended adding semantics compliance to it, i.e. (level 3) - *funStep knowledge compliant*. With level 3 compliance, systems communications would be syntactically compliant with the AP236 standard and as well semantically compliant with the reference *funStep* knowledge.

Besides what has been here detailed, *funStep* provides a permanent support to the furniture supply chain with a set of services available to the end user in the form of: a) Software Services; b) Training Services; c) Validation Services and d) Consultancy Services (INNOVAFUN, 2008). The services have the objective of assisting on the *funStep* standard comprehension, implementation process, and also on development and design of new business practices on SMEs. They offer new opportusnities for innovation and content management, while also achieving lower costs and more rapid deployment

6.1 Future work

Manufacturing and retailing systems are becoming more and more complex and dynamic. They need to be constantly adapting to new market and customer requirements who demand a faster and better quality service. Even standards need to be adjusted from time to time. This behaviour is reflected in a constant fluctuation and evolution of business networks and system models, which makes interoperability difficult to maintain.

The open research questions raised in the introduction are not completely answered, and despite of the importance of enterprise interoperability (EI) in the global economy, there is not yet an established scientific base for EI. Due to this fact, situations such as loss of interoperability have a great impact on the enterprise turnover. Indeed, it is of paramount

importance to identify an EI science base that embodies lessons learnt from the neighbouring domains such as complexity or services science. The aim in the future is to formalise interoperability problems and solutions such as the ones here discussed, ultimately guaranteeing reusability and repeatability.
The authors intend to address this non-linear problem in future research involving feedback, monitoring and prognosis mechanisms as part of the business network solutions. With these, they intend to include dynamism in the morphisms maintenance among systems, thus allowing automatic readjustments in the information flows without the need to reprogram the full systems. In this line, the ENSEMBLE FP7 project (http://www.ensemble-csa.eu) is already providing the framework to validate such results and considerations, working within the Future Internet Enterprise Systems (FInES) community to develop and implement a systematic approach to the establishment of EI as a science.

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Intelligent Value Chain Networks: Business Intelligence and Other ICT Tools and Technologies in Supply/Demand Chains

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1. Introduction

All business sectors are witnessing the trend of increased global competition, which forces companies to improve their efficiency. Reduction of costs, improvement of operations, improvement of relationships with customers, suppliers, and partners, shortening of delivering times, streamlining and optimization of business (logistics) processes and operations always have been the main reasons for the adoption of new technologies. As a result of globalization and integration of different economies, and the formation of international global supply chains and clusters their importance has increased further.

The use of new technologies undoubtedly contributes to improved efficiency of supply chain management. *Supply chain management* (SCM) focuses on the inter-organizational management of goods flows between independent companies in a supply chain, such as raw material suppliers, component manufacturers, finished product manufacturers, wholesalers, and retailers. The Global Supply Chain Forum (Lambert et.al., 1998) has defined supply chain management as the integration of key business processes from end users through original suppliers that provide products, services, and information that add value for customers and other stakeholders. This integrated approach to planning, control, and monitoring of product flows, from suppliers to end users, aims at improved customer service at reduced overall costs, and leads to the development of important relationships with logistics providers, suppliers, and customers in order to enhance information exchange and the coordination of business activities, which are the key advantages of an integrated supply chain. The coordination of management processes and activities in a supply chain requires efficient information exchange between companies involved in the supply chain. The processes involved in SCM extend far beyond the domain of one company or decision-maker, so a collaborative system is essential to ensure that all interests are realized, sustained, and/or improved. As a result, collaboration among all participants in the value (supply and demand) chain is essential. To improve communication, data, information, and documents exchange between customers and suppliers, proper and effective information and communication technology (ICT) is a necessity.

ICT is generally seen as supportive technology (a tool) to human activities or human performance of business actions. The proper use of ICT enables faster completion of tasks and activities, accelerates data preparation and transmission times, increases reaction speed to market needs, automates and thus lowers the costs of supervision and information processing, supports the decision-making processes, enables distributive operations enhancing efficiency, reduces data entry errors, improves the quality of customer service, reduces delivery times between the date of the order and availability, facilitates payments, and improves inventory management. Companies using advanced ICT are more capable of responding to a dynamic environment, and can reduce operation costs more easily. ICT technologies also constitute an essential aspect of the relationship with external partners in that they change the nature of the relations between companies by allowing for real-time exchange of information and documentation in electronic form.

In the context of maximizing supply chain visibility and agility various IC technologies, techniques, systems, strategies, their use and benefits will be presented. A classification based on their characteristics (functional tools and technology, integrative technologies) and their way of use and purpose (organizational, inter-organizational, core business systems, decision support systems, mobile computing, e-business technologies, web-based technologies, SOA (Service Oriented Architecture) strategy, cloud computing, A^3 (Anytime, Anywhere Availability) strategy, social networks, and others) will be designed and explained.

One of the strategic and most important goals of every business subject is timely and accurate decision-making. Right decisions depend on the availability of timely and accurate information and reporting environments. We have to cope with vast amounts of business data (from disparate operating systems and applications), rapidly changing customer needs and market conditions, but also with vast amounts of hidden information (documents, e-mails, know-how, voice records, external sources, etc.). Therefore, in order to create an intelligent value chain network, it is essential to integrate our core business information system with a set of modern analytical and artificial intelligence tools that enable the extraction of relevant knowledge from all of these sources, management of uncertainty, and creation of business intelligence as our main competitive advantage. In present chapter also the concept of business intelligence and business intelligence tools (scorecards, dashboard, analysis, OLAP tools, data marts or data warehouses, data mining, knowledge discovery and other), some artificial intelligence tools and technologies (expert systems, artificial neural networks, fuzzy logic, voice-based technology, robotics, etc.), and their use in SCM will be discussed.

Therefore, the scope of the chapter is the presentation of the most popular and the most frequently used examples of the broad range of information and communication technologies, techniques, strategies, software applications, and systems, and their possible uses as support to effective, accurate, and real time management of large amounts of business data, acquisition of information from these data, and data and information exchange among business partners involved in the supply/demand chain, operations like queries, reports, analyses, forecasts, and data mining which enable users to identify and analyze ongoing business trends and patterns (Shobrys, 2003) as well as provide support to decision-making, and other techniques and technologies that represent "added value" to the business. In addition to the presentation of each of these ICT tools, their use and role in advanced value (supply/demand) chain management and benefits are discussed.

2. Information technology in the supply chain

2.1 The purpose and benefits of information technology

Information communication technology (Vatovec Krmac, 2007) includes the application of hardware, software and networks to enhance information flow and facilitate the decisions-making. It is one of the few aspects of supply chain that simultaneously offers both improved performance and lower cost. It enables companies to maintain key information in an accessible format, process requirements, and make operational and planning decisions. The adoption and successful implementation of important hardware, software and network technology is a prerequisite for supply chain success. The supply chain information capability that facilitates a seamless flow of information is a very important element in further enhancing the efficiency of supply chain activities.

Key activities in the supply chain are the logistics activities. They include planning, designing, implementing and managing the flow and storage of materials and information exchange in order to support basic logistics functions such as procurement, distribution, transportation, inventory management, packaging, and manufacturing. One of the strategic features of logistics service providers is the employment of customer service. In order to optimally achieve this goal they must use modern logistics tools and processes. ICT is the most important technology for improving logistics systems, because with its proper use the productivity of constituent activities of logistics systems could be significantly enhanced. Information technologies are seen as a resource of a company, as a source of its competitive advantage, and serve as a catalyst of change in a company. They are tools for control and management of all resources, internal and external. Adoption and successful implementation of ICT (hardware, software and network technology) are certainly prerequisites to logistics success.

With the growing trend toward the use of international supply chains and e-commerce, logistics service providers for product warehousing, transportation and delivery are placing greater emphasis on ICT in order to remain competitive globally. In the last decades, innovative ICT have deeply affected the way business is performed and the way that companies compete. Innovations in electronic commerce play a key role in managing inter-organizational networks of supply chain members. The internet represents a powerful technology for commerce and communication between supply chain participants as well as a technique for the improvement of supply chain management.

The fact that ICT has a positive impact on efficiency as well as the overall performance of every company that uses it, regardless of its primary activity, is already well known. Therefore, supply chain companies can also greatly benefit from the use of ICT. Nevertheless results depend mostly on the level and type of ICT usage, which are correlated to a company's size and availability of technology, the integration of business processes along the supply chain it's still possible just with proper use of right ICT tools and technologies. And a fact that the use of ICT requires redesign and reorganization of logistics processes, which can be seen as one of the most important barriers to ICT usage, can also be overcome in the same way.

Today's challenges and opportunities are so big and important that companies should be able to quickly adapt their business to changing end evolving markets, policies, regulations, and business models. So, the companies should be agile enough. (Oracle, 2008)

And again, one of the most important factors in this adaptation is information technology. Today we have a plenty of various technologies, tools and systems (solutions) on our disposal, but there is not one universal system or technology ("one-size-fits-all" (Tohamy, as cited in Stackpole, 2011) solution that covers all information and decision support needs of the company. Therefore, we have to combine or orchestrate various different technologies and make them converge to the same strategic business goals or objectives. The complete solution should be an integration of tools such as ETL, ERP, SCM, CRM, BI/Reporting,

vertical core applications, SOA based pools of accessible internal and external web services, and legacy systems. (UC4, 2010)
But before we start to select the right or appropriate set of tools, systems and technologies we have to know how each of them works, what are the prerequisites for its implementation, what are the associated benefits and risks, and obviously which of our business goals the solution covers. One of the important facts we also have to consider is the maturity of the solution.
According to (Slone, et.al, 2008 in Oracle, 2008) one of the "five pillars of excellence that form the foundation of the new supply chain agenda" is the technology. The success and efficiency of supply chain functioning depends on the fact if the right supply chain technology was used and if its implementation was successful.
Basic supply chain functions are steel transportation, warehousing, inventory management, and reverse logistics. But these functions or processes today extends end-to-end and also outside the company and include also the relationships with suppliers and customers on a global basis. (Dittmann, 2010) With globalization and outsourcing supply chains become more and more complex and therefore the need of supply chain visibility increase. So the way companies think about the modern supply chain has changed dramatically. Supply chains are becoming multi-tiered networks of suppliers, partners, customers, and other companies. Therefore new technologies and tools are required to gain and/or obtain stability and effectiveness of the supply chain.

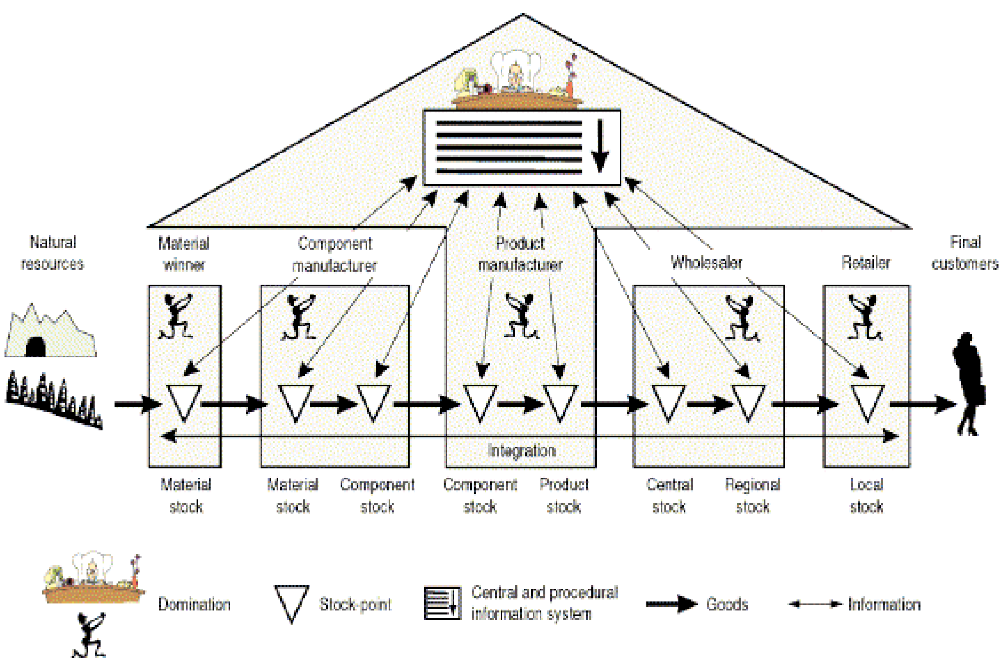

Fig. 1. Classic supply chain management (by domination of one organization over others). (Verwijmeren, 2004).

According to the (Chatterjee & Tsai, 2006) the objective of transportation logistics, as one of the key components of integrated supply chain management, is to compress time along the whole supply chain. It means a reduction of delivery time in shipments from suppliers of raw materials, intermediate goods and components to factories, distribution of final products from factories to wholesalers, retailers and end users, and the distribution of spare parts for after-sales services. Nevertheless, transportation logistics has ceased to be limited only to the movement of goods across space and reducing time and costs along the supply chain. Its scope has expanded and now it is influencing decisions on what to produce, where to produce/store, in what quantities, who to choose as the logistics provider, etc., which are parts of strategic management. These improvements in transportation logistics are in great part results of new transportation and information technologies.

The benefits of an integrated supply chain are numerous, but on the other side the implementations of such a chain are very costly, time consuming and represents a great challenge not only for the individual company but also for all its partners in the supply chain. The partners have to make up a common strategy; there must be a high level of confidence among them. To achieve greater information exchange successful supply chain management requires effective management of strategic alliances, extensive data management capabilities and advanced inter-organizational information systems. Information communication technologies facilitate the transfer of more accurate and up-to-date information, which results in better visibility of demand and inventory throughout the supply chain, and are essential in the use of international supply chains and e-commerce.

ICT can have a positive impact on both front-end and back-end processing in a supply chain, because it provides to all parties in a supply chain better and real-time access to information, making logistics services more accurate, faster and cheaper. The reasons for a higher level of ICT should be the need for accurate information and higher quality customer service levels. Factors contributing to the level of ICT implementation are size of company, technology and policy, and types of logistics services.

ICT enablement may not be the remedy for all supply chain related problems. But, it is a strategic and capital-intensive issue, and its success lies in the readiness of supply chain partners to share information for their mutual benefit. So, mutual trust and confidential information, along with awareness and commitment of top management are considered indispensable for implementation of ICT software systems and tools between supply chain partners. Obviously, ICT tools that enable electronic communication between them have to be compatible, which mostly means another problem arises because of different levels of ICT implementation and use. As previously stated, the remedy for these kinds of problems could be independent third party web service providers that offer the possibility of the use of special services and tools without their internal implementation and the means for interconnection and real-time communication between supply chain participants, the precondition for effective performance of all logistics activities. In this way, just with proper use of right ICT tools and technologies, it is possible to overcome differences between supply chain or logistics partners, which are result of different levels and types of their internal ICT usage.

2.2 An overview of supply chain technologies

An overview of the supply chain ICT includes technologies that primarily deal with managing and controlling supply chain related data and activities, including information exchange within and between companies. They range from mature and widely used technologies to relatively new application systems and services. Some of them are essential for the business - they perform transactional processing and are called core technologies and system, while others represent only an added-value to the core business. Most of described

systems are used steel as monolithic applications, isolated or connected only "point-to-point". Concepts of service oriented architecture (SOA) and cloud computing are rapidly changing the ways these systems are developed and used by supply chain partners, but also the functionalities of these systems are changing. More and more applications are web-based and accessible from anywhere, anytime, not only through computers but also through different mobile devices. Supply chain visibility and collaboration pose new claims on supply chain software that should provide 360 degree view of the supply chain functionalities and establish a network of supply chain partners. Today business intelligence tools and systems are essential for decision making. And there are variety of other simulation and artificial intelligent software we can use to enhance and optimize supply chain functions.
As regards the purpose or usage of a particular technology (Vatovec Krmac, 2005), they can be divided into two main groups--functional technologies and integrative technologies. Functional technologies, which are mostly internally focused, include systems that are used to accomplish a particular function, and also systems that are used in a particular functional area, such as warehouse and transportation management systems. Integrative technologies, which are predominantly externally focused, coordinate and integrate information flow and activities within and/or between companies, such as enterprise resource planning systems (ERP) and supply chain planning systems (SCP).

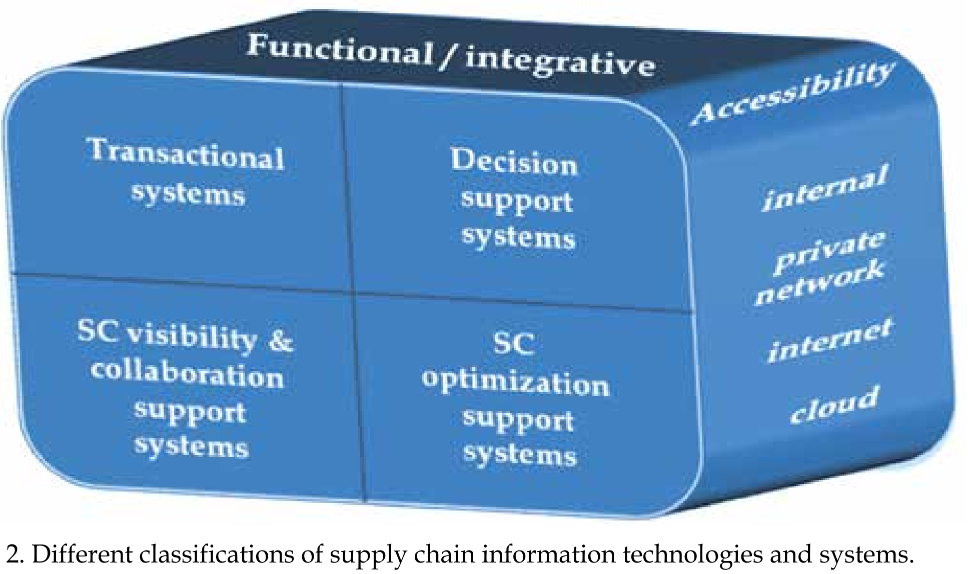

Fig. 2. Different classifications of supply chain information technologies and systems.

2.2.1 Functional technologies

Browsing web sites and studying the literature in the field of transport, logistics, and supply chain management in general we can discover a lot of different functional technologies or systems used to support and manage supply chains. Aside from bar-coding systems, warehouse management systems, computer-aided design, electronic commerce technologies, internet-based logistics systems, radio frequency systems, transportation management systems and geo-coded tracking systems there are also demand forecasting management systems, customer relationships management systems, product data management systems, manufacturing execution systems, automated quality control systems and supply chain event management systems, and many others. They are shortly described bellow in alphabetical order.

Automated quality control systems: Automatic quality monitoring and inspection devices observe the quality of in-process work pieces in automated manufacturing systems, and are essential for effective production. They are used to determine the acceptance or rejection of a work piece or a specific production lot before work pieces are advanced to the next process. They are also used to monitor the calibration of fixtures and the conditions of cutting tools, and can be integrated into a feedback control system to directly influence the manufacturing processes.

Automatic identification technologies (AIT): Is a set of technologies and devices that capture, aggregate, and transfer data to information systems. Using automatic identification technologies significant reduction of administrative and logistics costs is possible. Because of error eliminations the data accuracy is increased, and transmission of data is speedier. Auto- identification technology also increases efficiency through reduction in labor costs, increases inventory accuracy, makes turnaround for delivery of products faster, and eliminates the need for physical inventorying of products.

1. **Bar-coding technology:** Is one of the most commonly used methods of electronic auto-identification. It is a low-risk technology consisting of systems or products that are used in conjunction with many of the other technology systems to produce or use either linear or two-dimensional bar codes.
2. **Radio frequency (RF) technologies:** RFID (Radio Frequency IDentification) has only recently been introduced to the consumer goods supply chain. It requires the creation and adoption of industry-wide standards, integration with internal business systems, and a significant investment in RFID tagging and reading equipment as well as supporting technology infrastructure. Initial costs of RF technologies are significantly higher than bar-coding costs. RF technologies use radio waves to transfer detailed information from tags, programmed with a unique number and attached to items, cases, or pallets, to a company's information system. RF tags are superior to bar-coded labels in that they allow significantly more information to be stored and have the capacity to easily update or alter information at any point along the supply chain without having to change the tag. Another advantage over bar-coded labels is its capacity to reliably operate in harsh and dusty environments; but current RFID tags are not always reliable and will not work with some products or in certain situations. The main advantage and the greater potential of RFID is its possibility to trace products, collect and access the information about products via RFID tags during each step of the logistics chain.
3. **Biometric identification system**: It is a system for uniquely recognizing human beings from momentary information, gained from "scan" of a part of human body (fingerprint scan, hand geometry, palm vein authentication, retina scan, iris scan, face recognition, signature, voice, and DNA analysis) that is compared with the biometrical data stored in a database of biometric data. It is used for human identification and access management and control.
4. **Video and audio identification systems**: These are systems for identification of things (vehicles, objects, etc.) and humans. With analyses of content the system creates a "fingerprint" and it compares with fingerprints in a database to determine if there is a match.

Computer-aided design (CAD) systems: CAD systems are generally stand-alone design tools that are used to design everything from parts to tools and fixtures. With design software company can develop better products that more effectively meet the needs of their customers.

Customer relationships management (CRM) systems: CRM systems are computer-based applications used to manage company's interactions with its customers and therefore to improve the selling and revenue generation process of a company. They provide support for the provision of a service to a customer by collecting customer data and providing information and knowledge about customers and their behavior. They help companies to become more customer-oriented in the face of increased global competition. Their main goals are increasing customer satisfaction, finding new customers, reduction of marketing and client service cost.

Demand forecasting management (DFM) systems: It is an important information system, which represents an integrated part within the framework of enterprise resource planning systems. It is a centralized forecast system capable of satisfying all of a user's information requirements. The DFM system has the ability of providing forecast information for numerous users, improves forecast accuracy and enhances decision-making. Today's demand forecasting management systems are part of collaborative planning, forecasting, and replenishment (CFRP) systems, which are web-based tools for coordinating the various supply chain management activities, including production and purchase planning, demand forecasting, and inventory replenishment between supply chain trading partners.

Electronic commerce technology: Provides the means for more efficient communication between buyer and supplier, and more accurate transmission of orders by enabling computer-based business transactions via private, proprietary networks such as electronic data interchange (EDI) or the publicly accessible internet. Electronic commerce can reduce the costs of closely integrating buyers and suppliers and through electronic networks; companies can achieve an integration effect by tightly coupling processes at the interfaces between stages of the value chain (McIvor & Humphreys, 2004). Electronic commerce technologies include interactive web sites, web portals, electronic mail, extranets (to promote electronic ordering with suppliers), intranets (to facilitate internal knowledge sharing) and EDI systems.

EDI is the most common form of an inter-organizational information system, an electronic commerce technology that improves customer service and lowers costs by facilitating communication and document exchange between supply chain partners, and has a positive impact on inventory levels and inventory management. Local systems linked by EDI support the flexibility of networked companies.

Internet-based logistics systems: They are replacing classical electronic data interchange (EDI) systems. They can handle everything from order management and scheduling to delivery, and are designed to help companies cut costs by automating the processes of booking shipments, keeping customers informed, and making sure that goods arrive on time. Supply chain management has been literally reinvented by the internet and other networked technologies and the practices they facilitate; i.e., e-procurement, e-logistics, collaborative commerce, real-time demand forecasting, inventory management, true just-in-time production, customer interface, web-based package tracking, etc.

Manufacturing execution systems (MES): MES are known also as "shop-floor-control systems". Their aim is to provide a single, flexible platform for managing production, quality, inventory, and process controls. These systems also enable real-time visibility and control of manufacturing operations and help businesses to respond effectively to unexpected customer requirement changes. They are seen as a strategic tool for manufacturers to provide customer-specific, innovative, and cost-effective products in the increasingly competitive environment that is the result of globalization. MES is a dynamic information system that drives effective execution of manufacturing operations. Using current and accurate data, MES guides, triggers, and reports on plant activities as a result of various events. It also manages production operations from point of order release into manufacturing to point of product delivery into finished goods. MES also provides critical information about production activities to others across the company and supply chain via bi-directional communication. (Strategic Direction, 2004) Some of the major benefits of implementing the MES system are higher productivity, higher revenue and sales, higher process capability, reduced manufacturing cycle times and order-to-ship cycle times, stronger agility for handling Just-In-Time deliveries, etc. MES aims to provide an interface between an ERP system and shop floor controllers by supporting various execution activities such as scheduling, order release, quality control, and data acquisition. Adoption costs of manufacturing execution systems are high, and integration with other systems is very complex.

Order management systems (OMS): Companies use OMS to keep track of orders from customers, stock level maintenance, packaging and shipping. OMS are electronic systems developed to execute orders in an efficient and cost-effective manner (filling orders for various types) and to track the progress of each order throughout the system. Modern OMS integrate various orders entry channels, for example e-commerce, phone call center order entry and customer service, Business-to-Business e-commerce, and web sales. Order management encompasses sales functionality, inventory control, payment processing, marketing, and customer relationship management.

Product data management (PDM) systems: PDM serve as the catalyst of a process of re-engineering and optimizing a company's processes, to improve competitiveness through greater speed and responsiveness (Obank et.al., 1995). A major benefit of PDM is the reduction of time to market, as a consequence of control of the product introduction process, which also results in reduction of product introduction costs. Such systems remove barriers to information flow and allow critical information to be accessed by the relevant people. They also improve communication and consistency within companies because everyone has access to the same information. So, PDM systems are important tools for gaining control of information, and consequently obtaining greater control of a business.

Supply chain event management (SCEM) systems: SCEM is a relatively new supply chain application that improves a company's ability to share information across departments or company boundaries and encompasses event management, workflow management, enhanced information capabilities and business analyses. It enables a company to access supply chain information in real time and immediately responds to unplanned events.

Tracking systems:

1. ***Service-tracking system*** provides customers a mean to realize the status of their requests and to anticipate and plan actions. For a manufacturer downstream in a supply chain, this service provides real-time information that enhances the effectiveness of raw material planning and scheduling. Service tracking systems provide the order and delivery status of the products and services; users of the system can make decisions based on the actual status. The internet-based techniques offer users easy access to real-time status information via web-based tracking systems, which have the advantage that information exchange and transmission are not geographically restricted.

2. The ***geo-coded tracking system*** is a technology for tracking transport vehicles, formed of satellite or cellular tracking devices most commonly used in trucks or trailers to ascertain position and feed the information to ancillary systems such as transportation management systems or warehouse management systems and via internet to customers, who can track their goods on-line.

Transportation and warehousing are major logistics activities and major cost factors in logistics services. The primary goal of ICT use in logistics activities is therefore reduction of such logistics costs.

Transportation management systems (TMS): Transportation function is a critical strategic element within the supply chain, and consequently the transportation management system is the key element in a logistics and/or supply chain because it provides links among separated logistics activities. If our aim is to take full advantage of logistics, we have to have also a well developed, efficient and effective transportation system. The influence of the transportation system on the logistics system is the logical consequence of the fact that transportation generates one-third of the amount in the logistics cost. (Tseng et.al., 2005) TMS offer sophisticated algorithms for transport booking, monitoring and planning, and represent one of the primary systems used by logistics service providers, forwarders and carriers. They support information transfer, route and mode planning, choosing and delivering of products, electronic identification, mobile communication, managing claims, and physical automation, tracking and tracing (long distances, multimodal transport). In combination with mobile and wireless technology, communication networks and identification technologies can also help in better fleet visibility, reduction of paper work, and efficient communication with warehouses, providing real time data for the use of management and decision-making. Systems like TMS can enhance the level of customer service, accuracy of all collected data (customers, products, etc.), exploitation of equipment, time and manpower; i.e., all basic preconditions for the effective operation of company.

Warehouse management systems (WMS) or inventory tracking systems: Provide (Kirk …) the software to track and control the movement of inventory, from receiving to shipping, through the warehouse, managing the utilization of warehouse resources such as space, personnel, and material handling equipment to improve productivity and efficiency. They are developed to support decision makers by providing consistent, timely, subject-oriented information at the required level of detail (information on inbound and outbound flows, weight and volume of stored products, type and cost of inventory, information on product design, assembly, packaging, electronic tagging, etc.) (Winter & Strauch, 2004). Three main benefits of these technologies are reduction of shipping errors, increase in productivity, and inventory tracking ability. Logistics service providers and wholesalers are the primary users of these systems. Even better results could be obtained if WMS and inventory management systems would be supplemented by automated guided vehicles, sorting devices and automated storage and retrieval systems. In this way loading and unloading in the warehouse could be much easier and more efficient.

2.2.2 Integrative technologies

Integrative technologies are information systems used to coordinate and integrate information flows and activities within and between company boundaries to allow the company to effectively manage procurement activities to rapidly meet customer needs. These tools provide excellent algorithmic and technological features to support management decisions, allowing customized planning procedures and optimization algorithms. The goal of both types of systems is the same: to be able to enter information from any source into the computer system only once and have the information made available for all. Two widely known supply chain integrative technologies are enterprise resource planning (ERP) systems and supply chain planning (SCP) systems.

Enterprise resource planning (ERP) systems: ERP system represents an information backbone of every business. ERP aims to automate an entire cross-functional business process. It "integrates internal and external management information across an entire company, embracing finance/accounting, manufacturing, sales and service, CRM, etc. Its purpose is to facilitate the flow of information between all business functions inside the boundaries of the company and manage the connections to outside stakeholders." (Bidgoli, 2004) ERP offer a centralized information control system to integrate all company departments and functions and provide integration for supply chain management. It's an integrated set of application software modules or packages (capacity planning, customer service, cost and accounting, sales order processing and distribution, manufacturing, material procurement, production management, quality management, inventory, human resources, distribution, logistics, and finance), which work together as an integrated unit by bringing the visibility of real-time information to all departments and thereby focusing on the business as a whole. ERP software is the dominant strategic platform for supporting enterprise-wide business processes. (Light et. al., 2001) One of the important modules of the ERP system is the inventory management module, which provides functions to calculate safety stock and the reorder point for each item contained in the database based on the item's demand history. Thus, it provides ways to analyze the demand history, make forecasting recommendations, and suggest safety stock levels. (Razi & Tarn, 2003)

The two of the most important parts of typical ERP system are in real-time operating integrated system, and the common integrated transactional database, that supports all applications. With maturity of the Internet and simplification of external communication also functions dealing directly with customers (i.e. front office functions) such as customer/supplier relationship management (CRM/SRM), or all kinds of e–business systems were integrated with all other functions that did not directly affect customers or public (i.e. back office functions).

Advanced ERP systems are integrated also with business intelligence tools and applications and therefore offer management portals or dashboards, scorecards, customizable reporting, searching functions, document and workflow management, and functions that allow external access (web services, wiki, messaging, etc.).

There are a lot of general advantages (regardless the type of the business it supports) of ERP system: integrating a very large number of business processes the company can save time and reduce costs; proper decisions can be made more quickly and easier because real–time information is available to management anywhere, anytime; data becomes visible across the company; multiple (sub)systems are automatically synchronized; integrated database provides a comprehensive view of entire company. Other supply chain management tasks and activities that benefit from the ERP: sales forecasting, resulting in inventory optimization; order tracking (from acceptance through fulfillment); revenue tracking (from invoice through payment); matching orders with inventory receipts, and the vendor invoice.

But there are also disadvantages. The greater of them are very high initial investment, integration of independent businesses results in unnecessary dependencies, problematic customization, re-engineering of business processes that have to fit the ERP system, and others. To overcome all these problems and disadvantages ERP and other software systems should be transferred in the "cloud".

Supply chain planning (SCP) systems: SCP deal with long-term strategic issues between collaborating partners by coordinating material and capacity resources across networks of suppliers, customers, facilities, and trading partners. These systems integrate diverse applications and functions such as planning (demand, sales, operations, supply, and forecast planning), scheduling, distribution, and transportation. One of these systems is the CPFR system, which is used to replace the approach of electronic data interchange (EDI). The objective of the CPFR system is to exchange selected internal information on a shared web server in order to provide for reliable, longer term future views of demand in the supply chain. (Fliedner, 2003) This leads to benefits such as increased sales, faster order response times, lower product inventories, higher order fill rates, direct material flows, improved forecast accuracy and lower systems expenses.

As stated in (Vatovec Krmac, 2005) the distinction between ERP and SCP systems is somewhat blurry. ERP generally covers the full range of manufacturing, sales and accounting software, sufficient to perform virtually all of the information technology transactions required by a company, and provides information and decision support for most of the core processes as well. SCP, on the other hand, is more oriented toward specific logistics functions with specialized systems devoted to demand forecasting, production, transportation, delivery and distribution.

The integrative technologies provide extra intelligence for coordination between partners and greater flexibility, which is needed for this cooperation between networked companies. They have to provide basic communication between the systems and users in the supply chain (data communication, message conversion, flow control, etc.), transparent information (stock visibility, track and trace and report), and advanced management throughout the systems and among the users in the supply chain (inventory management, production management and distribution management). (Verwijmeren, 2004)

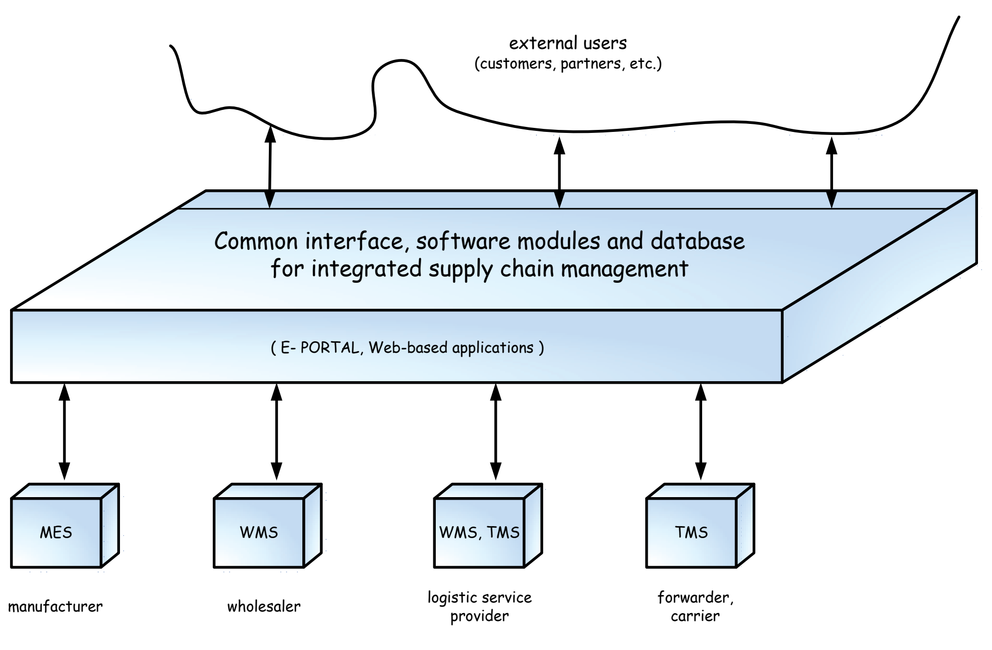

Fig. 3. Modern integrated supply chain management. (Vatovec Krmac, 2005).

Yet there remains one non-technical condition that must be fulfilled in order to achieve all the benefits that modern tools for management of intelligent supply chain actors offer; this is the need for sharing common databases with partners, or the so called "trust factor", which could be the primary factor delineating failure or success. Shared information is the key to assuring that decisions can be made as soon as demand is realized. And this is the first step toward achieving the global goal of modern supply chain management tools and systems, which is improved customer service.

2.3 Internet or web-based applications and strategies

The internet (Lancioni et. al, 2003) provides a low cost network for business-to-business commerce transactions, so can be successfully employed to improve management of supply chain systems. The main benefit of the internet is its capacity to facilitate or speed up the integration of business processes along the supply chain by facilitating the information flows that are necessary to coordinate business activities. It also allows companies to customize service solutions for their customers, which enhances the overall value and competitive position throughout the supply chain network. It allows real-time communication and interoperability between supply chain participants. Inter-company information transfer via the internet can reduce the costs of order tracking and logistics as shipments can be located *en route.*

The internet is seen as a business resource and network technology for the integration of technology at all levels of business practice. (Daniel et. al., 2004) Applications of the internet; i.e., e-procurement, e-logistics, collaborative commerce, real-time demand forecasting, inventory management, true just-in-time production, customer interface, web-based package tracking, etc., can greatly impact business practices in supply chain management.

Internet and web services promise also the ability to reduce time and costs involved in developing, supporting and integrating the internal information systems within a single company and to quickly and effectively integrate information systems with those of customers, suppliers and other business partners, the primary need for cooperation between supply chain participants. As companies linked together are numerous, the connections become many-to-many, so facilitations and services of independent third parties are required (security applications, performance measurement applications, billing and payment applications). But there are some special conditions third party web service providers have to fulfill: they must be industry based (logistics service providers), providing specialized software and services, trusted by users, and offer their services at reasonable prices.

2.3.1 SOA (Service-Oriented Architecture) services/systems

SOA is an architectural approach that "facilitate the creation of loosely coupled, interoperable business services (Web services), that are easily shared within and among enterprises" (Oracle, 2008), and it is a set of design principles for systems development and integration in computing, based on reuse of applications and services, and agility that is the consequence of the loosely-coupled approach. SOA offers business processes and location-independent interoperable services across multiple, separate systems and platforms from several business domains. Its benefits lay in ability to quickly meet customer demands, in lowering of technology costs, in reduction of expensive custom development costs, and in making business rules more visible and easier to transform.

SOA separates functions into services (each service implements one action), accessible over a network. Users can combine these services and reuse them in the proper development of applications. The communication between services and consumers is realized by "passing data in a well-defined, shared format or by coordinating an activity between two or more services" (Bell, 2010).

In many decision-making processes or reporting tasks we need integration of data and information from disparate data sources what SOA makes possible. SOA also facilitates cooperation among different companies, and therefore represents an important feature for supply chain partners' interoperability. It enables networked data-sharing and analysis tools sharing and so makes the analyzed data available to multiple users in real time. As stated in (Epicor, 2009), "SOA provides a modern model of application support across an enterprise without regard to who, what, where or when."

Many companies still rely on batch or background processing (processing is shifted to times when computing resources are less utilized) to support their existing applications. This kind of processing is appropriate for very large amounts of data or transactions where small delays in delivery of information are acceptable. Traditional background processing has changed and evolved in the so called Just-in-Time processing, appropriate for data that does not have real-time requirements. If companies want to move to SOA architecture or to combine Just-in-Time processing with SOA transactional processing they need to overcome the dependency on batch processing. This is possible with implementation of *intelligent service automation* which provides a necessary bridge between SOA and legacy applications, allowing for the inclusion of batch processes into the SOA business processes which requires initiation on time, calendar, and events. Intelligent service automation therefore provides web services to initiate, monitor, and manage background processes. So, the main purpose of the intelligence service automation is to provide an automation engine that supports SOA processing initiation in the background and can be seen as an integral technology in business process execution. (Oracle, 2008)

2.3.2 Web 2.0 / Web 3.0 tools and services

The web is a "tool for improving customer service, decreasing the time to market, and accelerating every kind of interaction" (Epicor, 1999). Combined with concepts of SOA, A^3, mobile computing, and cloud computing it represents an infrastructure for information transfer and collaboration between partners.

Web 2.0 is an extensive set of web tools and applications (so called web-based applications) that improve and enrich the user experience of the Web ("information sharing, interoperability, user-centered design, and collaboration on the World Wide Web" (Shelly & Frydenberg, 2010)). It encompasses social networking sites and social bookmarking, blogs, wikis, podcasts, RRS (Really Simple Syndication) feeds, various forms of publishing, video sharing sites, mushups (process of integration of data from independent applications to produce new information), folksonomies, web applications, searching capabilities, and many others that facilitate creativity, collaboration, and sharing among users.

The main difference between websites (Web 1.0) and Web 2.0 sites lays in the fact that websites limit the user on passive viewing of the content that was prepared for him while Web 2.0 sites allow user to interact and create the content of the site. Web 2.0 is somehow a new form, a new version of World Wide Web because redefines the ways that end-users and also software developers use the Web (the inventor of the World Wide Web, Tim Berners-Lee, call it "Read/Write Web" (Wikipedia, 2011c)).

This set of tools is not yet widely used to support the business, but the promises are very good, because these tools implement new ways of providing information to decision makers. The social computing/networking and Web 2.0 have already resulted in new forms of online collaborative work and information sharing in various companies. Through social networking persons can easily connect and do business, they can use these opportunities for marketing and advertising of proper products and/or services, or only for communication and coordination of business activities. In Gartner predictions for 2012 (Gartner 2010) Facebook, as already today the biggest social network in the world, is seen "too big for firms not to factor it into their B2C strategies". Gartner group see the Facebook as a huge support for advertising, communication, marketing and client support. Considering the compatibility of Web 2.0 with more and more often used SOA concept and their suitability for the supply chain integration and management of various different, disparate companies that should/have to share real-time data, information, and applications, it is logically to consider these technologies as future infrastructure for all other information technologies used to support business.

Web 3.0 or semantic web will represent the next step of the evolution of Internet and web applications. With regard to the fact that Web 3.0 is still "under construction", we can rely only on to promises like: the main improvements in searching capabilities will be done (social bookmarking as a search engine); all information will be categorized and stored in such a way that a computer could understand its meaning as well as a human (artificial intelligence added to the web); it will increase the popularity of mobile Internet devices. The promises are good also for the use in the future business.

2.3.3 Cloud computing

As Internet has matured it has become a useful infrastructure also in business. Today more and more applications, data and services are transferred from the user's computers to the "cloud". These computational resources (applications, databases, files, file service, emails, storage capacities, processing capacities etc.) are available to the users on demand. They can access these resources via a computer network.

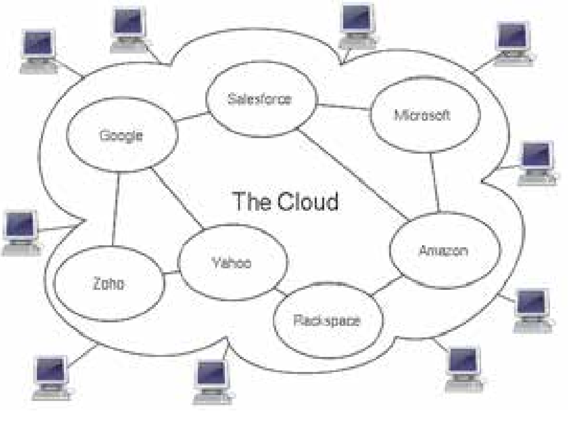

Fig. 4. Cloud computing conceptual diagram. (Wikipedia, 2011b)

The client (an end user) need only operating systems and the applications used to access the cloud via web browser installed on his computer or other mobile device, and it can access

computational resources from anywhere, anytime. For end user there is no need to know the physical locations and configurations of computer systems he uses in the cloud.
Components of the cloud computing are cloud application services or "Software as a Service (SaaS)", cloud platform services or "Platform as a Service (PaaS)", and cloud infrastructure services or "Infrastructure as a Service (IaaS)".

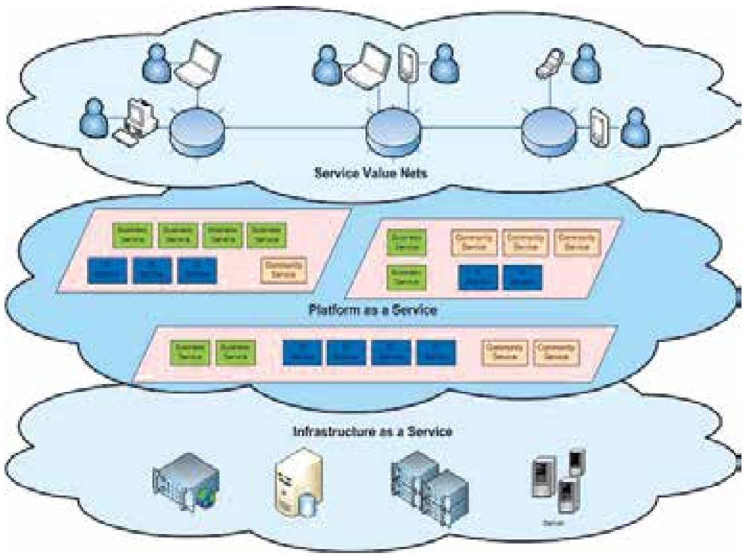

Fig. 5. The structure of the cloud. (Karisruhe Institute of Technology, n.d.)

SaaS (Software-as-a-Service): is often called also on-demand software. Software as a service is a software model. Associated data are hosted centrally, very often in the Internet or cloud. Users can access these software and data via web browser. In the business the term SaaS is used for business applications that are installed in businesses' computer networks (applications including accounting, collaboration, customer relationship management (CRM), enterprise resource planning (ERP), invoicing, human resource management (HRM), content management (CM) and service desk management) (Shally & Frydenberg, 2010).
Software as a service solutions normally utilize a multi-tenant architecture (single version of the application with single configuration is used for all customers), in which the application is designed to serve multiple businesses and users, and partitions its data accordingly. Saas applications therefore not support an application customization like traditional enterprise software. Normally the SaaS applications are updated more frequently. Many SaaS applications offer features that let its users collaborate and share information (like Web 2.0 tools).
Infrastructure-as-a-Service (IaaS): are cloud infrastructure services. IaaS deliver computer infrastructure (platform virtualization environment) as a service. Instead of purchasing all hardware and software equipment (servers, software, data-center space or network equipment), users can fully outsourcing these services. Suppliers typically bill such services on basis of usage (amount of resources consumed).
Platform-as-a-service (PaaS): cloud platform deliver a computing platform as a service, using cloud infrastructure and sustaining cloud applications. It forms a web-based development environment. It consists of computer hardware, including multi-core

processors, and computer software products designed for the delivery of cloud services, including cloud-specific operating systems.

Regarding privacy, security and financial concerns, company's needs, the organization of cloud services etc. various types of clouds are possible (public, private, community, combined cloud). A type of cloud that could be very useful and appropriate for supply chain users is a community cloud. This type of cloud represents an opportunity in the case where several companies have similar requirements and seek to share infrastructure so as to realize some of the benefits of cloud computing.

To support supply chain visibility and collaboration integration of supply chain partners' software is needed. Linking up all ERP and supply chain systems from different supply chain companies is rather impossible. So called "point-to-point" integrations between different enterprise systems are very difficult and time consuming. Therefore, cloud is a good solution in the case where information sharing, orders, goods, and payments tracking along the supply chain are essential. One possible use of a cloud is that all partners simply upload their reports into the cloud and in this way availability of real-time information is reached. Other, much better solution is sharing the same applications and/or databases installed in the cloud.

More and more applications used by supply chain partners is becoming cloud-oriented. Two good examples of the cloud computing in supply chain management are SaaS transportation management systems (TMS) and SaaS warehouse and inventory management systems (WMS).

The opportunity for **SaaS TMS** (Gonzales, 2009) comes from one of the most critical aspects of TMS, the need for communication, collaboration, and information exchange with a network of other partners (carriers, suppliers, customers, logistics service providers, and other trading partners). In the Saas TMS there is only one software and hardware setup of TMS for different users. The network provides shippers with access to relevant carriers to satisfy their transportation needs in less time and with lower costs. There is no need to establish and test all classical EDI and other types of electronic communications anymore, because all trading partners are already part of the network. The costs, efforts, and time for frequent updates of TMS are minimal, because there is only one application to upgrade and is available to everyone. SaaS TMS also facilitates benchmarking and inter-enterprise collaboration, because the data about performance of all companies of the network are available to everyone, so an external benchmark can be done easily and quickly. Regarding payment of use of the application there is only a monthly subscription fee to pay.

Saas WMS (Business Software, 2011) and inventory systems empowers companies to gain real-time visibility into warehouse operations ensuring greater customer satisfaction, improved productivity, and better inventory accuracy. They offer all needed key features like inventory tracking, that offer real-time visibility into supply chain operations, checking goods into inventory and establishing real-time inventory accuracy, streamlining the receiving, put-away, and picking process for optimal operational efficiency, easily locating and picking orders in sequence to improve employee productivity, automating the shipping process to decrease shipping costs and reduce order fulfillment time, and integrating into companies ERP systems. In this way all trading partners can share timely information about inventory levels, orders statuses, payments, and other important information. Warehouse systems are increasingly expected to perform more and more functions—assembly, manufacturing, repair. These capabilities are part of extended value chain processes that include transportation management, procurement, manufacturing, order management, spare parts and repair operations, asset management, and maintenance, so the collaborations between partners and supply chain visibility are the demands.

2.3.4 A3 (Anytime, Anywhere Availability) and mobile devices

In today business there are really great claims on access of data and information at anytime from anywhere in the world, regardless the used device. A framework that provides anytime, anywhere availability means that "any user can gain access to a consistent set of accurate, up-to-date information in their native language from applications and servers spread around the world." (Epicor, 2009) To realize a framework for A^3, SOA environment is needed, because it provides the capability of editing and examining for errors the captured information, and allows a user interface to handle the language aspects. The concept of A^3 leans on conviction that "everyone should be able to deal with the data in the way that is easiest for them." (Epicor, 2009)

The phenomenon A^3 means "the universal connectivity" (Gates, 1999), i.e. bringing together all needed information and services and make them available regardless of where you are, what you are doing, or the kind of device you are using. Gates (Gates, 1999) called this concept the concept of convergence - "convergence of the computer, consumer electronics, and telecommunications industries and the merging of gadgets such as the PC, TV, telephone, and smart devices".

Maybe the most critical aspect of the A^3 environment is the security. The fact that service or software is available anywhere means that there are many points of entry, that must be controlled and supervised. To increase the security of A^3 methods like "Single Sign On" (allows persons to access multiple, independent applications with the same username and password) and "Role Based Access" (access rights are associated immediately based on the individual's role in the company) were developed.

The access should be available only for employees or maybe also for supply chain partners, or even customers. They can access from remote desktops, or mobile devices like laptops, tablets, iPads, handhelds, mobile phones, or other smart and wireless devices. The collaboration of these devices is possible only if they are able to communicate effectively with each other, and this is possible through the use of open internet protocols and standards.

Anytime, anywhere access allows employees to be efficient and effective from virtually anywhere, whether they are working from home or on the road. This convergence is very important also for the supply chain partners, who have great opportunities of communication between them and to gather needed business data and information (like data regarding orders, processing of orders, inventory statuses, shipments, payments, etc.) anywhere and anytime, and have therefore the possibility to react more rapidly and shorter delivering times and consequently reduce overall costs.

2.4 Supply chain visibility and agility

One of the important goals of supply chain management we can also obtain via technology is the improvement of supply chain visibility and its flexibility or agility.

Supply chain visibility or end-to-end visibility, called also 360-degree view of company means that company is able to have a clear view of everything that happens across the entire supply chain and also how well this happens. The meaning of the supply chain visibility (Stackpole, 2011) depends on what kind of manufacturer the company is, on the companies' role in the supply chain, on industry that company serves, and on that where the need for visibility is most serious. For a manufacturer this can be a visibility from supply-side perspective (rapid planning, control of contract partners – contract outsourcing, having a real-time visibility into interruptions, managing customer expectations, reduce returns, improve overall services, etc.), for the consumer products manufacturer this is a visibility from a demand-side (optimization of inventory and sales, better forecasting, improvement of order fill rates, etc.), furthermore it can be seen from logistics point-of-view (tracking a product and a transportation mean, tracing issues, etc.).

The most commonly cited business pressures driving visibility adoption include the need to improve on-time performance, the need to proactively alert customers of late shipments, and the desire to reduce lead times and lead-time variability. Visibility into the supply chain is primarily based on "snapshots in time" rather than "real-time" information. Therefore, tools or solutions that support and enable the supply chain visibility have to provide a company with consistent, reliable and timely information and offer sophisticated reporting tools to help the company make better strategic decisions.

Choosing or developing a solution for supply chain visibility should start by defining the business needs, problems and the kind of required visibility. Strictly speaking, it is not a matter of one, "one-size-fits-all" (Tohamy, as cited in Stackpole, 2011) solution but rather a set of various solutions – product categories that should be connected and interrelated (integrated).

Traditional enterprise software systems like ERP or SCP are not adapted end equipped to provide this end-to-end visibility on the whole. ERP systems are very good tools to give us a good visibility into everything inside our company, but not outside the company. Starting outsourcing and establishing network connection with various partners companies don't need only internal processes visibility but also the access to information outside the company. Modern SCP and ERP systems already address features for demand planning and forecasting with retail partners and also for planning and collaboration across supplier networks, but they lack the ability to give a visibility of how company is executing against its plans.

Business intelligence (BI) tools offer a sophisticated set of reporting tools, but also a possibility to establish an adequate level of supply chain intelligence, which is indispensable for improving overall operational performance. BI tools allow monitoring all processes and provide alarms and notification before the potential problems evolves in troubles or even disasters.

Network solutions, which offer services for connection of supply chain partners, should also be adapted for the supply chain visibility need. Traditional value added networks (VAN), electronic data interchange (EDI) tools and business-to-business e-commerce platforms are experiencing changes in the direction of developing capabilities that let companies track everything from order to payments.

In last few years we are facing with a growing number of new, web-based, software-as-a-service (SaaS) products that offer services of connection of a supply chain network and provide capabilities for supply-side and demand-side collaborative order management, inventory planning and logistics planning. In addition they serve up integrated business intelligence, business process management and real time exception management. (Stackpole, 2011) Tools like SaaS offer also the possibility of synchronization of multiple enterprises connected in the supply chain network.

There are also many applications that focus on particular supply chain visibility problem. The global trade management solution is one of them. Its purpose is delivering of view into

international inventory and shipment status. The purchase/use of these applications is reasonable only in case the manufacturers have a well defined visibility problem.
Another possibility to solve the visibility problem is the development of custom integration between multiple software packages and legacy enterprise systems. But to gain end-to-end visibility this integration has to be connected with external systems (systems used outside company) what is very difficult, time consuming and costly task.

2.5 Supply chain collaboration

One of the prerequisites for the effective and optimized supply chain management is the supply chain cooperation - cooperation and information exchange among supply chain partners. Collaboration requires adequate infrastructure. Therefore, individual partners should adopt software solutions "based on common architectures and data models" (Horvath, 2001), or based on opened architectures like SOA. Anyway, the infrastructure should acts as an intelligent network that enables e-business transactions.
Collaboration among supply chain partners requires access to networked supply chain management application (via internet or virtual private network), large and flexible database, capable to store large amounts of data from different sources, integration of systems and access applications, improved business intelligence, value-added, and e-commerce capabilities (analyzing capabilities, supply and demand chain planning, electronic billing and payment, digital certification, etc.) (Horvath, 2001).
Business Process Management (BMP) is a strategy that forms a necessary collaborative environment for the efficient execution of complex business interactions and activities among supply chain partners. It "represents a strategy of managing and improving business performance by continuously optimizing business processes in a closed-loop cycle of modeling, execution, and measurement" (Oracle, 2008), "is a holistic management approach focused on aligning all aspects of an company with the wants and needs of clients" (Brocke & Rosemann, 2010). Its aim is to enable a company/business process to be more effective, efficient, flexible, and agile, therefore to optimize its business process continuously. The main benefits of BPM are higher customer satisfaction, product quality, delivery speed and time-to-market speed, what are also the main challenges in supply chain management.
BMP per se is a result of convergence of various technologies and strategies and represents an integrated solution that satisfies a company's lifecycle of achieving proper business goals providing knowledge workers with easy access to information, improved communication, and greater collaboration technologies. (Oracle, 2008) BMP life-cycle consists of various activities: vision (design of functions and their processes aligned with strategy and business goals of the company), design (identification and design of existing processes), modeling (what-if analyses on the processes), execution (automation of business processes through software applications and business rules), monitoring (tracking, evaluation and analyze of individual processes), and optimization (retrieving and identifying of eventual problems, finding possible improvements and applying them in the design).
We can say that establishing a strategy for BMP is the first and basic step on the way to realize an effective and efficient information and decision support of the core business functions (internal) and also the prerequisite for establishment of the information chain that underlies the global supply chain of which our company is a part (belongs). Before choosing of the right technology well understanding of the business is necessary and well defined business models are needed. Obviously, the chosen technology should well fit company's business needs and objectives.

Good BPM toolset therefore supports transactional business processes incorporating business intelligence features and allows the monitoring of business performance and its real-time measurement, discovering possible problem solutions and optimizations answering what-if questions based on real data or simulations, and consequently find the points (bottlenecks) in our business where we should invest more.

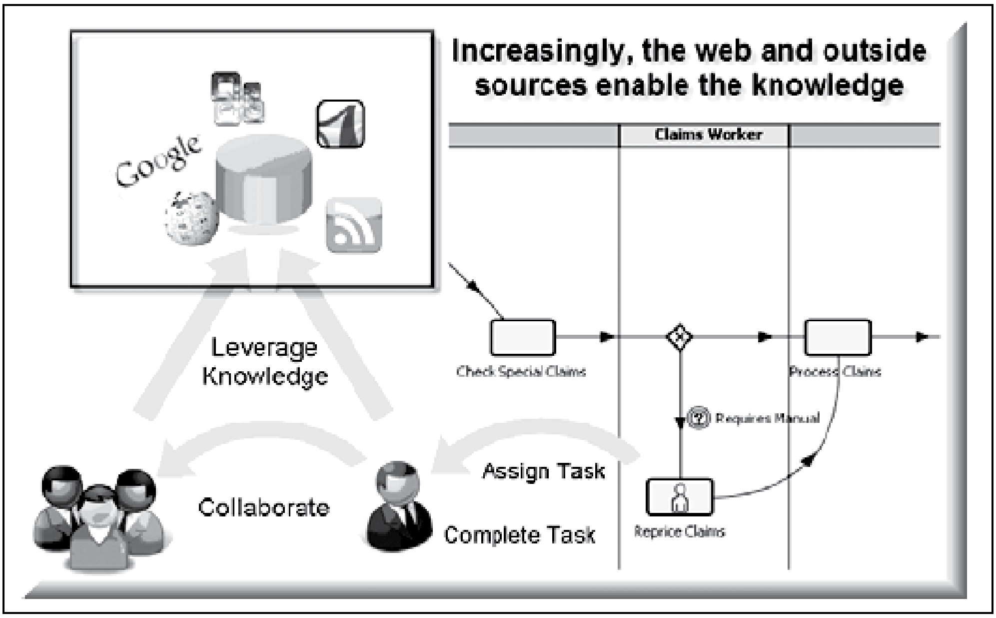

Fig. 6. "BPM is applied to the complex interactions and unstructured activities within knowledge worker collaborative environments." (Oracle, 2008)

BPM not only facilitates discovering of existing information and decision making but, using a variety of tools and resources within and outside the company often also creates new information. Besides of managing complex tasks and unstructured activities in harmony with business processes, it offers a set of well orchestrated tools (templates, portals, collaboration, Web 2.0, SOA services and technologies) that form a necessary collaborative environment for the efficient execution of complex business interactions and activities.

2.6 Supply chain intelligence (Business intelligence - BI)

Today's demands in doing business are increasing every day, regardless of what kind of business a company is involved in. Companies are facing with keen competition, with the need for reducing operational, product and service costs, the need for increasing functionality, flexibility and the ability to take (make) right decisions, based on information gained from operational and historic data, in right time. To take right decisions we need timely and accurate information and reporting environments. We have to cope with a vast amount of business data (from disparate operating systems and applications), rapidly changing customer needs and market conditions, but also with a vast amount of hidden information (documents, e-mails, know-how, voice records, external sources etc.). ERP systems have also been designed to capture all these data, but their grater limitation lays in the fact that ERP do not support ad hoc querying and reporting, and simulations on data. Therefore, we need integration of our core business information system with a set of intelligent tools, intelligent information systems and modern analytical and artificial intelligence tools to discover relevant knowledge from all of these sources, to manage uncertainty, and to create and reach our business intelligence as our main competitive advantage.

It is very important that users are able to explore and analyze data, and make different reports, but it is also important they can predict the behavior of customers, products and processes. Business intelligence tools are tools that can help users to reach all these goals – via querying, reporting, analyzing, visualization, uncovering patterns and correlations and relationships hidden in data. But, the real future of the business intelligence is in right use of these tools. They have to be guided and used by users who understand the business, the data, and the general nature of the analytical methods involved and are familiar with the software environments.

One of the most significant factors influencing the realization of these goals (Vatovec Krmac, 2009) and way of doing business and collaborating with trading partners effectively is information and communication technology, which enables fast and reliable internal and external communication, permanent storing of business data and activities needed for current business and planning future business activities. In uncertain environments, where data from external sources are needed for strategic planning, it is even more important that we know to explore all these data, process them in the way to produce knowledge and find hidden patterns, relationships and correlations that help us in strategic decision making, forecasting trends and possibilities.

These capabilities, related technologies and tools are seen as promising future technologies (Gartner, 2009) and prerequisites to survive or beat the recession (Pincher, 2009). Business intelligence, data content, and data knowledge are emerging technologies that are expected to have innovative potential in the next years.

2.6.1 Definition of business intelligence

Summarizing numerous definitions of business intelligence we can say that business intelligence is a set of intelligent (software) tools and systems that help (facilitate) a company to better understand, analyze, explore and predict what is occurring in the company and also in the broader environment. These tools and systems help the company to turn data, usually collected and saved in databases, into useful and meaningful information, which is then distributed to those who need it, when they need it, wherever they need it for improved and timely decision making. Business intelligence tools also allow a company to see, use and combine large amounts of complex data from different sources - internal and external, normalized or denormalized, structured and unstructured, and to represent the integration of these data in various reports and graphical 3D views. (Schiff, 2010)

Business intelligence helps a company not only to monitor its operations by querying, analyzing, reporting, performing in-depth analyses of what is going on, what helps find and resolve potential problems, identify and leverage new opportunities, predict and plan for the future, align the operations with strategic goals. Indeed, "Business intelligence usually refers to the information that is available for the enterprise to make decisions on". (1keydata, 2011) Because of this it has become a synonym for decision support. In addition, because of the fact that business intelligence is often (but not obligatorily) used with data warehousing it has also become a synonym for this term. However, data warehousing only is a component for achieving business intelligence.

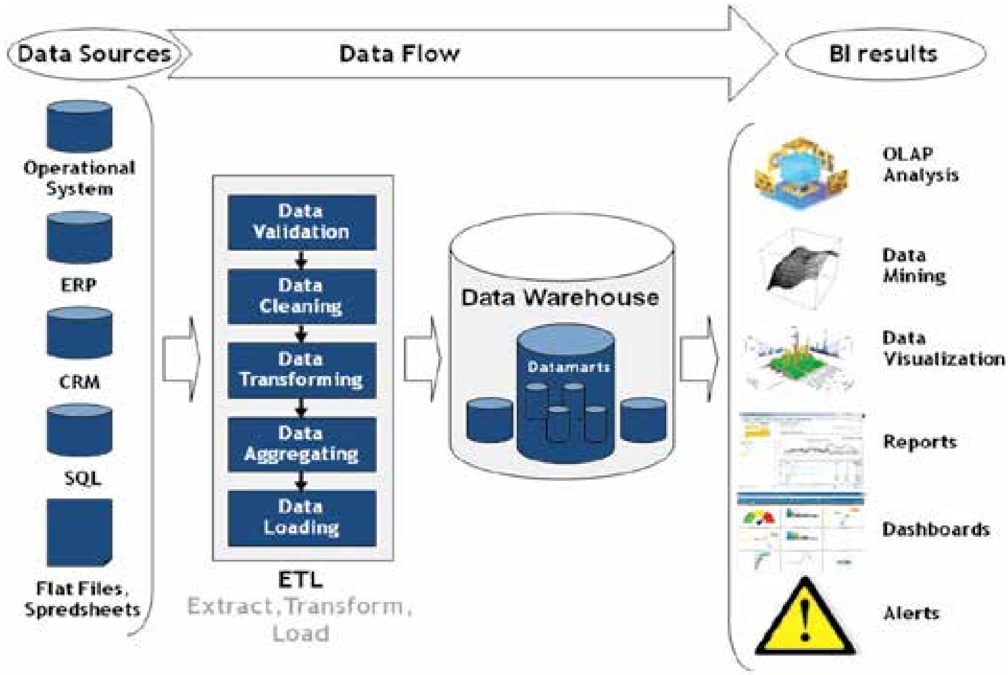

Fig. 7. Through ETL - Extraction, Transformation, and Loading processes, data from various sources are validated, cleaned, transformed, aggregated and loaded into data warehouse, special sort of database system, optimized for reporting. And through use of special software tools we can produce various dynamic analyses of data, known as BI results.

2.6.2 Business intelligence tools and technologies

Business intelligence tools are tools commonly used for implementing business intelligence. This does not mean that business intelligence tools are making non-trivial decision by themselves. "Decisions are made only and business intelligence is garnered only with the combination of the output of the business intelligence tools, human judgment and intuition, and the ability to put the information spit out by tools into a context of information that is much wider than any data warehouse, transaction processing system, knowledge repository can handle. (SDG Computing Inc., n.d.) The term business intelligence tool represents software that enables business users to see and use large amounts of complex data. (Schiff, 2010)

The spectrum of business intelligence tools and functionalities is very broad. They differ significantly regarding their cost, functionality, business intelligence complexity and number of total users. The most common business intelligence tools are as follows.

Spreadsheets

The most common, popular and used business intelligent tools are spreadsheets (or we can say Microsoft Excel files). The reasons for this are numerous: it is relatively cheap, easy to use, well known in the business area, it has/includes almost all functionalities that users need to display data, and quite all other reporting tools have export to Excel and Import from Excel. The most common use of Excel is reporting and goals tracking.

Query, reporting and data visualization tools

Answering predefined questions, a query tool offers to users a static view of information to be analyzed, combined with information from other sources or exported for use with other tools. The next group of tools are reporting tools that are either custom-built or commercial (the determination whether to buy or build a reporting tool has to based on a number of reports, the desired report distribution mode, and the need for ad hoc report creation). Reporting tools are more flexible compared to spreadsheets, and enable each user to create, schedule and run their own reports. This is the software that allows the user to ask (ad hoc) questions about patterns or details in the data. Visualization tools include a set of graphical tools, dashboards and scoreboards. The most common application of visualization tools is the visual interpretation of complex data relationships that facilitate decision making.

OLAP tools

OLAP (On-Line Analytical Processing) tools are used for multidimensional analysis ("slicing and dicing" of the data). They provide users with the ability to look at the data from a variety of different dimensions. OLAP means also "the use of computers to run the on-going operation of a business" (Schiff, 2010).

Data mining tools

"Data mining tools predict future trends and behaviors, allowing business to make proactive, knowledge-driven decisions." (LGI Systems Incorporated, n.d.) A data mining tool is the software that automatically searches for significant patterns or correlations among different factors in the data using sophisticated statistical and other techniques. It comprises various artificial intelligence tools and techniques like neural networks, machine learning, genetic algorithms, decision trees, knowledge management, rule induction, information extraction and information retrieval systems and other.

Fig. 8. The various BI solutions allow users to create reports, dashboards and web portals that visually displays the corporate data the user need to monitor in order to get quick understanding of the health of the business.

Core business intelligence technology (query, reporting, interactive analysis) is used to view or analyze what is occurring or has already occurred (business operations reporting – weekly or monthly reports), while data mining and predictive analysis allow users to predict what may occur in the future (this ability can be a competitive advantage in today's uncertain economy and global crisis) (Schiff, 2010).

2.6.3 The selection of appropriate business intelligence tools

Before we select an appropriate set of business intelligence tools for our business we have to know our business intelligence needs. We have to decide what types of business intelligence tools we would like to have, than choose a right vendor, and finally implement these tools in our business in the right way.

When selecting a business intelligence product we have to consider a lot of important factors. Among them (Schiff, 2010) are specific product features, ease of use, ease of implementation and administration, scalability, user-interface options, the ability to access and integrate a wide variety of disparate data sources, strong search functionality, and how well it integrates into existing and future platform environment (integration with desktop software, operating system). (Sheriff, 2006)

When implementing business intelligence we can choose to do it gradually or "all at once". Gradual implementation means that we first implement tools for operational purposes like databases, reporting and analyzing tools, and when business users have become familiar with them and our business has grown up and expanded, in the second step we implement business intelligence tools for deeper analysis, such as data warehousing and data mining. The strategy of implementation of business intelligence tools depends primarily on the funds at our disposal and also on the expertise or familiarity of business users with different software systems. (Schiff, 2010)

Before choosing a set of business intelligence tools that are most appropriate for our company we have to decide whether to buy or build them from scratch. According to various sources of business intelligence knowledge (1keydata, 2011; Sheriff, 2006; Shiff, 2010) when making the decision of building or purchasing a reporting tool we have to consider our requirements regarding the reports we need, the distribution mode of reports, and the need for ad hoc report creation. If there is a need for a high number of reports, then it is better to buy a reporting tool because it already has a report management system which makes maintenance and support functions easier. If users will access reports through a variety of different channels (not only email or using a browser), then buying a reporting tool, that comes packaged with these distribution modes, is probably the right decision. If we have users that are able to create their own ad hoc reports, then purchasing a reporting tool is a better decision.

2.6.4 Applications of business intelligence in supply chain

The implementation or use of business intelligence tools can help in various ways to achieve goals of every supply chain partner and supply chain as a whole. Some of the applications of business intelligence in supply chain activities (predominantly in transportation and warehousing, and order management as a key activities of supply chain and the activities where most savings can be obtain), are listed below (Chatterjee & Tsai, 2006; Sheriff, 2006; SDG Computing Inc., n.d.; LGI Systems Incorporated., n.d.; Tseng et.al, 2005):

- Achieving a cost-effective means of transport. (Business intelligence software can facilitate a fast and easy selection of the best means of transport considering a vast number of factors (the key factors to consider in selecting the means of transport are physical characteristics of the load, the number of loads to be moved, the distance to be covered, the required speed of movement, the required proof of delivery, cost of building/dismantling loads, packaging costs, space requirements, interface with other storage, transport and handling systems and housekeeping issues) and considering also historic data and past experience.)

- Reducing transportation costs, increasing efficiencies, and improving customer service with route optimization – routing and scheduling. (Route optimization software helps us route multiple vehicles (means of transport) simultaneously considering business rules regarding vehicle capacities, customer-committed time windows, and vehicle costs, work day rules, pre-assignment of orders to vehicles and other.)
- Cargo load optimization software helps us find the best loading patterns for the same shipments, select the best vehicle to match a given shipment, determine how many vehicles are needed for large shipments, determine the exact costs of shipments.
- Analyzing transport operations - routes can help us identify potential problems or inconsistencies in daily operations (or some departments), and compare costs of same shipments on different routes to establish the best one.
- Managing inventory efficiently and effectively by determining of the inventory level of a product or part.
- Managing orders efficiently and effectively to increase customer satisfaction.
- Recognizing trends and understanding how they affect the business.
- Evaluating the operations performed in the company (generating reports), evaluating strategic factors (internal and external) and identifying patterns of business and operational behavior (using data mining techniques).
- Identifying customers that are cutting back on their purchases so that special inducements can be offered to retain them.
- Implement dashboards and scoreboards so that executives and supervisors can quickly recognize operational exceptions or key performance indicators (KPI) that fall outside of accepted ranges. Some of the important KPIs could be planning accuracy, capacity utilization, resource utilization, load balancing, route utilization, scheduling accuracy, vehicle availability, vehicle loading time, average transit time, cost of transportation per ton, on time vehicle arrival, vehicle unloading time, order receipt accuracy, percentage of goods damaged, total order delivery time, on time deliveries, goods delivery rate, transportation costs and other. (Gartner, 2009; Pincher, 2009)
- Establishing and monitoring performance metrics and taking corrective actions if we see they will not be met.
- Comparing year-to-date sales for this year with last year and forecast sales for the entire year.
- Tracking customer orders.
- Integrating operational, spreadsheet, and historic data for analysis purposes to provide consistency for the company.
- Providing business users with the ability to perform their own ad hoc analysis and reports.
- Aligning daily operations with strategic objectives and quickly recognizing when they are not in agreement.
- Analyzing transportation means to verify cost-effectiveness.

- Making independent analyses of marketplace transportation costs to determine if our freight rates are competitive and to negotiate lower transportation costs if we are outsourcing transportation services.
- Forecasting economic and service impacts as consequences of changes in our transportation model, which permits us to find the optimal operating strategy.

2.7 Optimization and decision-support tools and techniques in supply chain

The broad set of tools and techniques, used for decision-support, fall in artificial intelligence domain. The scope of artificial methods, tools, and systems is to create intelligent machines (agents), develop methods and systems that are able to simulate human intelligence in problem solving, living organism, and human brain. Intelligence (Kasabov, 1998) "is the ability to learn effectively, to react adaptively, to make proper decisions, to communicate in language or images in a sophisticated way, and to understand." The central problems of AI include are reasoning, knowledge, planning, learning, communication, perception and the ability to move and manipulate objects. (Russell & Norvig 2003, Luger & Stubblefield 2004, Poole, Mackworth & Goebel 1998, Nilsson 1998, as cited in Wikipedia, 2011a). Typical examples of AI methods are image and voice recognition, language and speech processing, planning, and predictions. Typical approaches used in AI are symbolic computation, artificial neural networks, fuzzy systems, knowledge engineering, genetic computation, game playing, robotics, and experts systems. All these methods and approaches can be successfully used also in improvement of supply chain activities.

Symbolic computation includes techniques as propositional logic, predicate logic, and production systems. This approach is suitable for exact and complete representations. Neural networks and fuzzy systems are paradigms for processing of inexact, incomplete, corrupted and uncertain data and information, frequently present also in supply chain management. Knowledge engineering is a combination of symbolic, neural, and fuzzy computation. Its main purpose is producing of knowledge (a kind of very condensed information) from large amount of data from disparate data sources, using data mining and ETL processes (see Figure).

Neural networks are used for processing very large amounts of data using rules and logical inference, and for making new rules, based on preliminary results and decisions. They are used for learning from these data, make predictions, and find possible correlations or patterns among data. An artificial neural network is composed of interconnecting artificial neurons - programming constructs that simulate the properties of biological neurons. Artificial neural networks are usually used to gain an understanding of biological neural networks. It is complex computer software that provides very good facilities for approximating data, learning knowledge from data, approximate reasoning, and parallel processing. It is used for function approximation, regression analysis, pattern recognition, predictions, discovering potential problems, data mining, system identification and control (vehicle control, process control), customer requirements and habits etc.

Fuzzy logic systems are also rule-based systems, but they are based on fuzzy rules (rules that represent knowledge that is ambiguous, vague, or even contradictory) and fuzzy inference ("fuzzy inference is a method that interprets the values in the input vector and assigns values to the output by means of some set of fuzzy" (Olugu & Wong, 2009)). Fuzzy logic variables, in contrast with conventional Boolean logic, may have values that range between 0 and 1 (variables can be also linguistic; in this case they are managed with special functions). Fuzzy logic is successfully used in predictions, analysis and measurement of performance of a supply chain.

Genetic algorithms perform evolutionary computation; they solve complex combinatorial and organizational problems by employing analogy with nature's evolution (Kasabov, 1998). These algorithms can be part of an expert system or of other information-processing systems.

Expert systems are knowledge-based systems that contain expert knowledge, gathered in the knowledge base, and act in the way the (human) experts do. The knowledge is represented by production rules (if-then). Experts systems are decision-support systems - they provide expertise for solving problems using machine-learning methods and artificial neural networks. They can be used for problem diagnosing, interpretations, monitoring, predictions, etc.

Computer simulation tools: are very powerful computer based systems that represent the real world and offer the opportunity to practice various situations and scenarios which are part of this real world, or are planned to be part of the real world. Simulation tools are used also for training and optimization of various processes, analytical and design processes, forecasting and modeling. Good examples of simulation tools in supply chain management optimization are cargo simulating software and route planning software.

Cargo simulation software is a cargo loading optimization software that allows creation of compact graphical load plans, selection of the optimal truck/container for transportation of the specified cargo, and maximizes truck/container utilization.

Route planning software: is a route optimization software programme, which allows the routing of multiple vehicles simultaneously, honoring various business rules (vehicle capacities and costs, work day rules, specialty pre-assignment of orders to vehicles, customer-committed time windows, etc.). It is designed to plan an optimal route between two geographical locations and to provide a list of places a vehicle will pass by, with crossroads and directions that must be followed, road numbers, distances, etc. (Vatovec Krmac, 2010) It usually provides also an interactive map with a suggested route(s) marked on it. It could be a separate application or integrated part of TMS (track and tracing software).

3. Barriers to the full implementation of ICT in supply chains

During the past two decades, supply chain management has received increased attention among industries because it helps achieve a competitive advantage. Information sharing between supply chain partners is one of the most important enablers for effective supply chain management, and greater supply chain collaboration and visibility. Recent advances in ICT and deployment of ICT tools in supply chains have significantly facilitate the information sharing. Despite the important advantages of ICT usage in the supply chain there are (still) some significant barriers in the process of establishing ICT. The fact is that a large number of manufacturers is still performing a lot of manual retrieving and management data processes using spreadsheets, self-made databases, etc., or maybe neither these tools. The barriers always influence one another and together have a negative impact on ICT capability or enablement of a supply chain, because they slow down this process. I in order to find or develop modes or strategies to tackle these barriers it is important to determine their nature.

The level of ICT implementation depends mostly on the size of the logistics company and types of logistics services this company performs. Regardless of the type of company, we can easily conclude that barriers to ICT implementation are common to all. They are differing only slightly in relation to company size.

Various studies (Harland et. al, 2007) indicate that lack of awareness, support and commitment of top management about use or implementation of ICT could be the most formidable barrier to its implementation. If implementation and continuous development and improvement of ICT (internally and externally) are not strategic goals of the logistics company, it is unrealistic to expect any drastic improvements in efficiency and performance. But there are also many other barriers:

- disparities of supply chain companies,
- resistance of personnel to change to ICT supply chain management (changes in work culture and nature of work),
- integration problems in supply chain (IT infrastructure disagreement regarding the adoption and specification of the technical systems to be used, etc.),
- doubt about security and access privileges to information sources (important barrier in implementing internet and extranet technologies in the supply chain),
- costly, time consuming and "risky implementation of cross-organizational information systems" (Dvorak et. al., 2009),
- luck of trust in mutual connections between supply chain companies,
- fear of information systems breakdown,
- fear of supply chain breakdown,
- lack of funds,
- insufficient or poor ICT infrastructure and resources,
- lack of qualified personnel,
- unfamiliarity of personnel with ICT software systems and tools,
- incompatibility of company with customers and suppliers,
- organizational barriers (changed roles),
- rapid obsolescence of technology, etc.

Barriers can be also grouped by different criteria. One of them could be the source of barrier. In this case we differentiate internal and external barriers. *External barriers* interfere with the capability of establishing information flows among customers and/or trading partners and logistics companies. Clear information flows are necessary for undisturbed cooperation between supply chain partners and a primary precondition for effective supply chain management. Some frequent problems are disparities of supply chain companies, integration problems along the supply chain, fear of supply chain breakdown, etc. Internal barriers are consequences or results of internal problems, economic or organizational, and exacerbate exploitation of internal resources; they also have a negative impact on external functioning. Typical *internal barriers* are unfamiliarity of personnel with ICT systems and tools, lack of qualified personnel, lack of funds, fear of information system breakdown, doubt about security and access privileges to information sources, resistance of personnel to change to ICT supply chain management and others.

Another possible division of barriers is into groups of human-related and technology-related barriers. *Human-related* are all those barriers related to personnel, its capability to use ICT technology, fears, luck of trust, resistances, etc. On the other hand, *technology-related barriers* are all technical problems regarding integration of new ICT equipment and tools with legacy systems, incompatibility of systems and/or tools, rapid obsolescence of technology, disparities of supply chain companies, etc.

The barriers can also be categorized as economic, organizational or technological, depending on their consequences.
One of the big problems or threats to the most innovative logistics service providers is the speed with which ICT innovations spread and consequent rapid obsolescence of these technologies. Logistics service providers have to develop and adopt different software applications and processes to adequately support their business activities and to gain benefits from technologies. The high speed of diffusion and multiplication of applications by computer suppliers, the need for permanent renewal of existing information systems, demand a lot of their time, money and continuous organizational changes, and lead to the emergence of new activities and the elimination of obsolete activities. So, companies may prefer subcontracting solutions or outsourcing logistics activities rather than internalizing operations that necessitate technological investments that may substantially change their ways of doing business.

4. Conclusion

The primary purposes of adopting and implementing new technologies in any specific functional area have always been and always will be the reduction of overall operational costs, the improvement of operational performance, the improvement of customer satisfaction the reduction of inventory levels, and the reduction of lead-time. With proper information technology use also administrative and purchase order costs can be minimize. The importance of integrative and collaborative technologies, that make feasible improvements in information sharing, coordinating of supply chain activities, improvement of trust between partners, and commitment to supply chain relationships, is on the top of the priorities regarding the ICT technology for next decade.
In the field of information communication technologies every prediction as to how the development of technologies will proceed is tenuous. The main reasons are the velocity of changes in doing business, in information technology development itself, and the impact of globalization and other economic factors that drive or have a direct impact on the development of ICT.
But there are some points we can emphasize with confidence. There is the daily phenomenon of the internet developing a greater and more powerful role in doing business. According to the Gartner's' predictions (Gartner, 2010; Plammer, 2010) for next year's internet marketing will be still very important, but the companies should not focusing primarily only on the Internet for marketing purposes because they could find themselves unable to market effectively to customers. This could be a competitive disadvantage for them. Therefore, new approaches and new applications will probably emerge.
New internet-based software architectural and development approaches are already now making a significant shift of internal, in-house applications to the cloud, and probably this shift will be even more "massive" in next year's. SaaS implementations will be even less complex and even more affordable (Gonzales, 2009), and their number will increase significantly.
Considering that knowledge about customers, suppliers, and market demands still represents the real competitive advantage, the importance and improvements of business intelligence, prediction, optimization techniques and tools, will increase.

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Part 6

A Quantitative Approach

29

Supply Chain System Engineering: Framework Transforming Value Chain in Business Domain into Manageable Virtual Enterprise and Participatory Production

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1. Introduction

After 15 years of evolution of the Internet, the e-commerce in public space is crowded with players from C2C (eBay.com), B2B (Alibaba.com), to B2C (Amazon.com) etc. The infrastructure supports a horizontal supply chain connection such as the Supply Chain Operation Reference (SCOR) model from the supply chain council, RosettaNet protocol, and cloud computing providers compiling those standards like Saleforce.com are quite mature. However, when it comes to the vertical integration in B2B for collaborative operation such as ERP, MES etc., it drops to a single digit in multiple-enterprises connectivity (Viswanathan, 2008). That Aberdeen survey indicates that the Internet revolution has very little effect on the vertical integration surprisingly in Supply Chain Management (SCM), even the Best-In-Class enterprises (Tsai el at, 2009). On the other side of society, at May 10, 2011, Google is confirmed losing its crown to facebook, the largest, single community connecting more than 640 million netizens who has been growing rapidly since 2004, with 7.49% vs. 10.4% in total internet traffic according to Hitwise. What links those two isolated phenomenon together is that they are both about hitting the wall of private space or working around on the wall among them. The requirements of privacy and security of the private space naturally block the accessibility from the public search engine giants like Google and each of connectivity among those private spaces has a unique resolution. This chapter believes that the people-centric facebook, and the newly promoting Participatory Production (PP) in this chapter are the two ends of the full spectrum of those private space solution spaces, where the multiple-enterprises solution is about in the middle. In fact, that is not a finding but rather a necessary condition to the hybrid-connected society of the post-Internet era that connecting public space and private space all together.

1.1 Extreme virtual enterprise application of private space spectrum

The **Participatory Production** represents the most complicated value network in the business domain. The extreme complexity is coming from the purpose of PP model to archive and the goal of covering full spectrium of private space. It comes out the solution to PP is a cross-over point of 4 dimensons:

1. The designed-in backward compatibility to the SCOR model in supply chain dimension
2. Full coverage of the DoD 5000 Acquisition Process in system engineering dimension
3. Being connectable to the social network in the social science dimension to obtain human capital on demand, and,
4. Covering technological segment in process industry

That definition sets the boundary of the PP, and, the requirements. In order to solve the management challenges of such a complicated value network, the traditional SCM is exhausted and has to be modified by adding System Engineering, Technology Management disciplines and so on into a new, redefined discipline: Supply Chain System Engineering (SCSE). Since the objective of SCSE is to serve the entire spectrum of private space, the Information Technology (IT) model it adapts has to be covering both the Enterprise Private Space (EPS) and Personal Private Space (PPS). The former connects between enterprises and the later connects between human capitals in various formats from freelancer, collaborative SME, to form a virtual organization. The PPS is a whole new concept to the people-centric domain, and that model provides a new path of connecting the social network to EPS. That path is one of the major missing puzzles of forming a nested society today. In principle, there is a human-centric PPS for any individual who can reside and accumulate his knowledge, expertise and those personal assets are transferable into career development. Ideally, it is also scalable to be a freelancer, collaborative SME, or even large enterprise. Those new capabilities in PPS enable new human capital policy, knowledge management collaboration, and new enterprise level SCM solution in PP application. In this chapter, the PPS provides a new path for the individual climbing up the social hierarchy and PP architecture allows large enterprise connecting downward to reach an individual in participating manner. That closed-loop pair provides a new dynamic circulation of ecosystem of future nested society to boot the e-society to the next energy level.

The term "Virtual Enterprise (VE)" is a neutral description on asset holding approach with unique signature of orthogonal financial boundary and operation boundary. With the SCSE and feasibility of PP application, 3 more elements are added. First, human capital is also participatory in the entire value chain, independently. That starts to make the line between enterprise and individual fading away. Second, enterprises are participating in a same business objective in a mutual beneficial manner, with a bottom-up feature similar to the social network. Third, the business objective is covering the entire product life cycle in a varied mature level to support product delivery. The last two features are enabling size independent, aggressive enterprises in the PP model. Any enterprise even a freelancer with core value can be master of a value chain with super high leverage level, and, though the long acquisition cycle. The SCSE is lowering the entrance barrier to be PP-capable in two folds: the framework developed in this chapter and the SCSE enable ecosystem empowering the freelancer or SME. For the ultra-competitive business environment in the next decade, being a Triple-A enterprise (Lee, 2004) with adaquate Agility is mandatory. In this chatper, being PP-capable is equvaelnt to be eligible as a Triple A enterprise.

1.2 What this chapter covers

The PP model is connecting virtual enterprise type networked entities to the social network to free up the human capital asset. The infrastructure underneath the PP pulling both individuals and enterprises into one hybrid-connected platform is a revolutionary step of human history to sustain full economic activities inside a connected complex. According to the potential impact scope and complexity, this chapter is taking the onion peeling strategy to strip layer by layer from society, then SCM evolution, then how to apply PP in the enterprise. The peeling process exploring what is behind and explains why the SCSE is set to be the physics of running the nested society. The multiple-layers coverage hierarcy in fig 1 is reflecting the complexity of handling such a networked architecture connecting the 4 dimesions. The right color blocks cover the full introduction of the PP topic where the SCM is the root of SCSE in the coverage hierarchy. The gray color is supporting information of SCSE either its upper level in a nested society, or what is predicted in the future development. The Level one under the SCM root is a requirement engineering process about what is required to build a value chain in SCSE. The level two is an allocation process to transform the requirements into a configuration baseline under the SCSE architecture model. The last level on the right is the realization process to transform the designed value chain topology into the functional organization of each participatory entity among the supply chain.

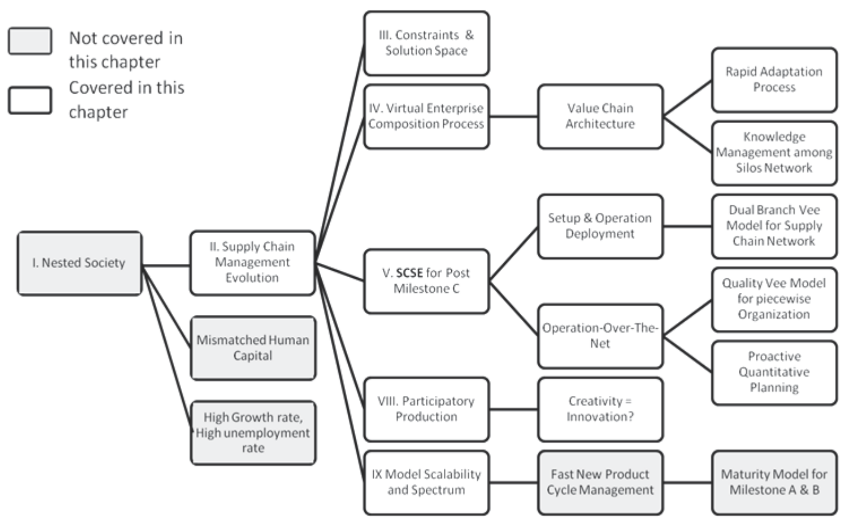

Fig. 0. This Chapter Coverage Hierarchy

Merging the System Engineering into the SCSE has another reason: applies the best practice approach in the management science aspect to solve a complex system that a single discipline cannot resolve. In the value chain domain, the current maturity level is very like the situation of the early 80s' when the acquisition cycle was poorly executed. For PP itself, is to manage science challenges for managing mega, distributed organization problems. The best-practise approach similar to the DoD 4245.7-M standard (Willoughby, 1985) that managing acqusistion cycle for a large project is adapted in this chapter. Reader shall learn how to build a Triple-A enterprise via the adaptation-Alignment process to earn his agility in a participatory manner.

2. Evolution of nested society

The nested society evolution today is like the Solar System five billion years ago when our Sun formed with the Bok globules in the galaxy. The connectivity is the gravity force and

Social Network (SN) is the center of gravity of the digitizing society, or e-society. An Emmentaler-like nested society structure is forming with lots of holes which are either personal private space or enterprise private space as illustrated in fig 0. That hypothesis of putting SN in the center of universe is pulling People back to the center of human history, not Information Technology (IT), where SN is the only native human-centric application not like the others (Dertouzos, 2001)

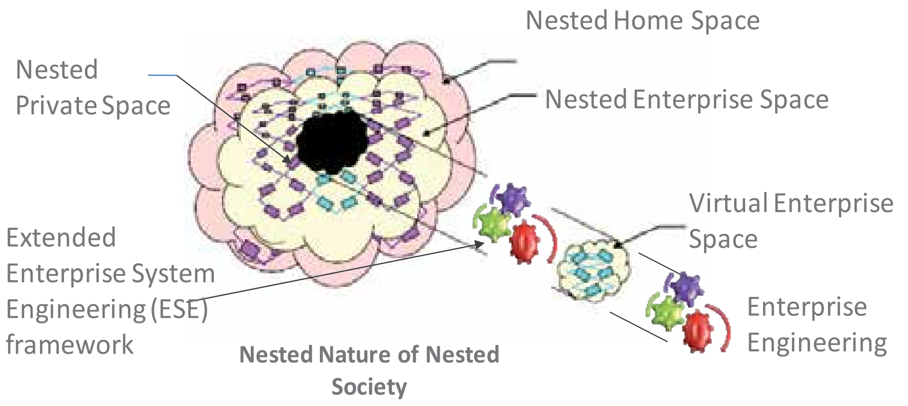

Fig. 1. Emmentaler-like structure for Nested Society

The original concept is from about the business environment, which is a dynamically nested structure. The enterprise is part of such a nested structure and it may contain sub-enterprises, each with its own people, processes, technologies, funding and other resources (Rebovich 2006). That concept was further developed to be connectable to any Supply Chain Network by adding the Extended Enterprise System Engineering layer and the Dual Branch Vee Model in architecture (Tsai et al, 2008). The definition in this chapter to have the PP as the cross-over point of the 4 dimensions completes the implementation gap. The full coverage of the private space and connectable to the SN to the nested society is like a lock-and-key matching. This chapter is taking that nested society as the end point of the IT resolution which covers the full society in a hybrid-connected complex and it can hold all the economic activities the human needs. While pulling in the activities into the complex, it is a digitization process or transformation process which is not necessary a copy-exact but realized by new IT tools. Letter to email, book to e-Book, and department store to Amazon.com, are good examples of replacement. Some are improvement with flow innovation such as Groupon.com. Nothing change in supply and demand but much more efficient than the current practise by employing the internet-enable participatory purchasing power.

2.1 Universe has physics and nested society has it

It is engineering skill to set end point to trigger the continuous, iterating improvement process. Once the end point is set to be the nested society, looking back is possible.

Interestingly, the entire IT evolution process is really like the dust particles in the cloud making up the early solar system. Once the center of gravity was established, it is staring out as an irregular cloud, and many of the dust particles in the cloud have begun to move into more regular orbits, circling the newborn star as a proto-planetary disc. That stage could be analogous to the Google era in public space. Within the cloud, large chunks of rock condensed into the planets, which processed to sweep their orbits clean of material, integrating it into themselves. That portion is not much different from the industrial revolution process such as a new startup, acquisition, merge and consolidation in enterprise, or, forming a cluster community in the social network. Besides the evolution process, there is a mechanism to be borrowed with: the classical physics. It is the science of how the Solar system running and there shall be physics to run the nested society as well. If the PP application and models behind are supporting the full spectrum of the private space, the high density fusion discipline SCSE that brings the 4 dimensions into a single cross-over point to fuel the PP application is nominating SCSE as the best candidate to perform the "physics" position that running the nested society.

The purpose of establishing the nested society model and the physics behind that is to avoid reinventing the wheel. Besides that, knowing the physics is capable to theorize the possible outcome. Taking the Groupon.com as an example, there is no new element in economy sense but a new SN based domain pulling in economic activities from current practice. It is similar with what Dell did to channel business. The physics give precise resolution of the IT evolution process as to calculate what shall be new elements, and exactly where they. With the physics, it will be much easier to know what is needed and how to build the organization to support that "new" business model as well. With that understanding, when Groupon.com localizes in the China market, he must consider the nature of SN in China is different. There are more C-2-B-2-B-C clusters, less real name netizen, less credit system on the back, and tough government control. With all that acknowledgement, the mask of IT is taken out and allow observer seeing through the intrinsic value of digitization to human binges.

2.2 Hyper-connected feature changing paradigm

The IT connectivity changes human history dramatically in two folds: obtaining resources and knowledge management. Before the Internet era, investment was mostly the only way to obtain resources to produce products or services to the end customer. After the network era, however, assets could be "connected" instead of invested and it changed the business landscape dramatically in all dimensions. The hybrid-connected capability in IT or telecom network is fading out the boundary of finance, operation in enterprise, now individual to enterprise. The shifting paradigm is challenging all aspects from the fields to academics all around. Tasks done by grouping talents into a single room before, is now replaced by a cluster of networked resources independent of geography and organization. The first immediate impact is a HIGH economic growing rate and a HIGH unemployment rate together. Going virtual is clearly a significant financial return advantage in the short term to enterprise when taking out resources investment as cost but keep the same revenue in virtual enterprise approach (Tsai et al, 2011). The connectivity enables alternative routes of realizing the same revenue by collaborating with partners and connecting to contractors. Those approaches are allowing enterprise to take out the top two costs from reducing investment in assets and employees in the past. The second is happening slowly but has even more fundamental impact underground: the need for human capital in the job market and the education system which is producing those human capitals. During the transition period of digitization, newly graduated students from school with a single discipline are most likely suffering job hunting difficulty results to a higher unemployment rate. On the other hand, the human capital market is sort of right candidates with cross-field, integrated talent. The former keep the unemployment rate high at nearly 8-10% level and the latter creates a new term "mal-employed" with about 2 million graduated students in 2011. Those are not new in human history during the transition of revolution but this time it is not coming with the classical recession together. The rapidly growing global economy and excellent earning in large enterprises due to newly added connectivity characteristics is a unique signature in the IT revolution.

With the physics in SCSE, those disruptions of society or economy could be easier to calculate and estimate about when the trend could be stopped and the rebalance could be reached. For the new features of virtual enterprise under PP application, a measurement of how well an enterprise is adapting also defined:

Trend, rebalance: theoretically, any balance is breaking and another balance will be reached sooner. The top management trained by manage-by-the number MBA discipline is taking instant advantage of the new outsourcing opportunity driving by excellent ROI of virtual enterprise. However, those optimistic short-term actions will easily be stopped when the cost of quality, lack of capacity for supply continuity, the potential threat of leaking out IP to competitors, broken development cycle or any other cost induced from outsourcing are pushing back when those loses are started appearing on the financial report.

Measurement: There is a "Degree of Freedom (DoF)" of virtual enterprise to measure about how flexible an enterprise to leverage external resources for obtaining the same revenue. For example, a business with 1:3 financial ratios is used to describe a business can only invest 1/3 of the resources it needs and connect to 2/3 of external resources. This definition will be used throughout this chapter. The DoF concept is a straight forward, quantitative measurement of the capitalist competitive 'freedom" concept (Nolan el at, 2007). Traditionally, the complexity of 'cascade effects" make the invisible part of the 'iceberg' to make an enterprise successful is the competitive advantage of unique workflow (Porter, 1998). The hidden cost pushing back from outsourcing is indicating that the 'cascade effect" under the 'iceberg' is not transferable or sustainable easily to the outside when connecting to external resources. That is also a true statement that the size of the enterprise matters when size is representing how well the company is 'cascaded' together in a classical SCM discipline.

2.3 Nested society transformation

In the post-Internet era, virtual enterprise is ideally defined to be with high DoF and size independent in connectivity. That means enterprise has absolute freedom to determine who to collaborate with anytime, anywhere in value chain and only limited to the economic factor, IP protection, and strategic constraints but not quality cost, supply continuity, responsiveness of the supply chain, and the size of suppliers or partners to connect to. If enterprise space and personal space are the "holes" inside the Emmentaler-like structure of the nested society, Fig 2 below is the transformation matrix to serve that objective. The chart illustrates that the networked society having 2 more dimensions in private connectivity within a nested society which is the Product Acquisition path and Career Development path in addition to the public connectivity space in the social network and e-commerce domain. SCSE is in the center of the transformation process and it implies it is a multiple layers architecture connecting entities (Enterprise), human capital (people), resources (assets, material), and, the knowledge associated with those activities among the two paths in the transformation process. More detail will be elaborated in later sections. The others 2 dimensions about backward compatible to SCOR, and including Process Technology are embedded inside the chart. The former is designed-in in the virtual enterprise path, and, the later is embedded inside the product acquisition path.

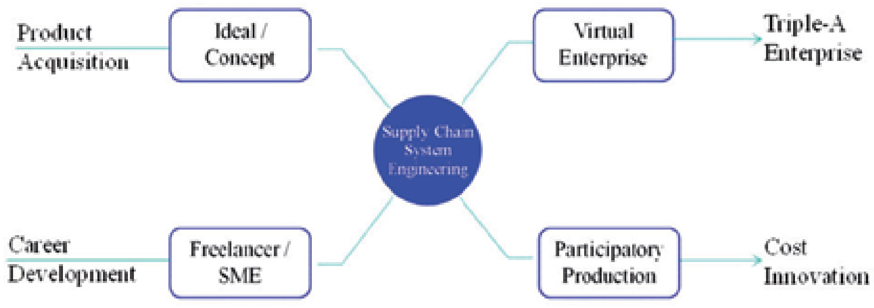

Fig. 2. Transformation Matrix

The transformation matrix is a self-explanatory chart about why it can enable connectivity among private spaces. If e-commerce is the surface of economic activities, Product Acquisition is the engineering cycle to build those products to be traded. What makes the matrix different is the new way to realize the product life cycle from an idea or product concept and how to implement a “triple-A” enterprise (Lee, 2003). The Full concept of Participatory Production is originally from "industrial accumulation", which is accumulation of thousands of small factories in a region of the Suwa-Okaya area of Japan (Kita el at, 2008). That concept is further developed in a more distributed manner with SCSE as the physics to perform the same concept with a much higher DoF regardless of geographical factors and the size of participating enterprises in this chapter. Another path of the transformation matrix is the career path. People, as the center of human beings history, are seeking for life-time, Career Development space to participate in economic activities in varied roles: buyer or service provider, by participating in the virtual enterprise via the Enterprise Life Cycle Management (ELM) concept that will elaborated on later in the chapter.

With the Career Development cycle and ELM coverage, the nested society model in this chapter is a giant, organic system complex to hold economic activities during the evolution process.

3. Evolution of supply chain management

It could it be briefly said that the evolution of the SCM discipline is the history of globalization either academically in school or practice in enterprise to manage the more and more fragmented organization worldwide. SCM has been re-defining itself many times: SCM was logistics focused (Houlihan, 1984) and was further extended to cover the flow of goods from supplier through manufacturing to distribution chains all the way to the end user (Christopher, 1992). That original concentration was for Procurement human capital and shifting to performance optimization later to catch up with the new practice in offshoring. From EDI to Internet, the connectivity cost has dropped sharply and the global competition rose up reversely. The increasing cost pressure driving offshoring to gradually migrate to outsourcing and the scope of SCM is starting to cross the enterprise boundaries when off-loading the financial burden. That new outsourcing capability enables a new focus on "core competencies" to be more lean in production (Lamming, 1993-1996) and to eliminate waste and non-lean elements along the supply chain (slack, 1995). Only those activities adding competitive advantage can be accepted in a general, long-term sense. Since then, SCM has heavily been extended to multiple disciplines since the 1980s. All the evidences above are supporting the statement about "SCM is catching up with globalization revolution" from time to time.

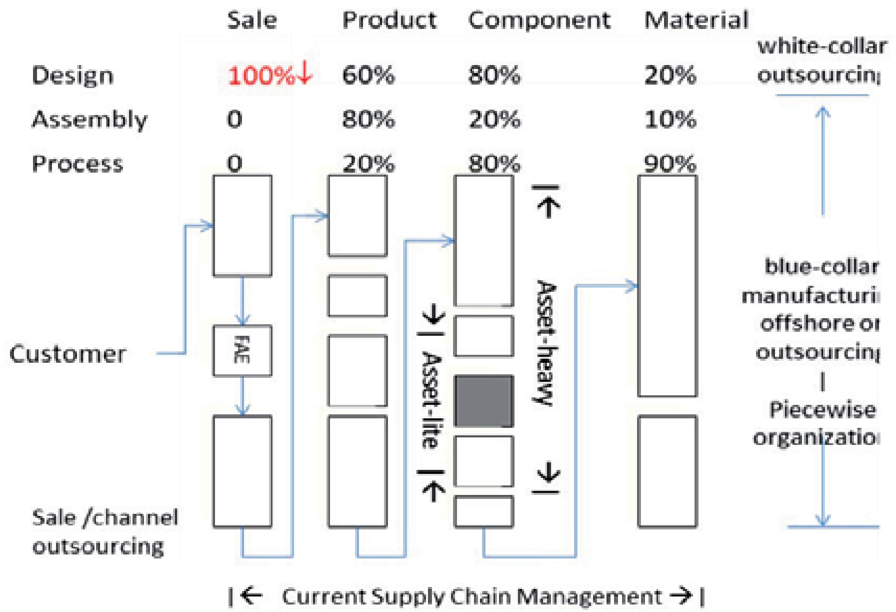

Fig. 3. 3- phases outsourcing toward distributed organization

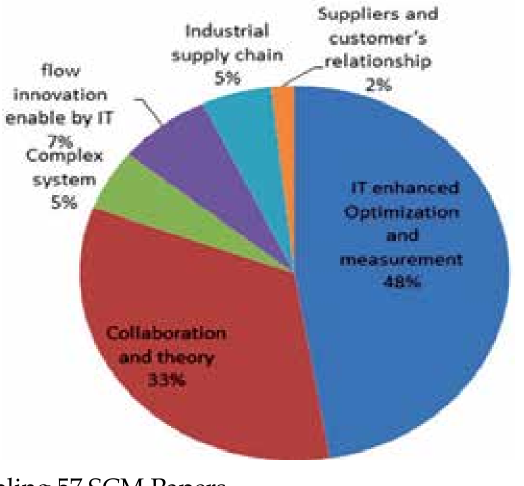

Fig. 4. Statistics of sampling 57 SCM Papers

Fig 3 is a landscape of demonstrating a typical evolution process of an Integrated Device Manufacturing going toward a highly fragmented, distributed organization from one piece. Downsizing or Strategic Outsourcing is the term to describe it in a negative and a positive way. The progress could be divided into 3 typical phases: (1) blue-collar manufacturing offshore or outsourcing from the 80s to the 90s. (2) White-collar outsourcing overlapping from the 90s to the 00s and (3) fully localized Sale and Field Application Engineering (FAE) forces in the multi-poles economy, overlapping from the 00s to the 10s onward. The world is confirmed to be heading into phase 3 by the Economic Policy Institute (EPI) when the statistics said 1.4M jobs were created overseas by U.S. companies, compared to 1M domestically in the year 2010 (Raynor, 2010). More jobs in Sale, FAE, which was treated as "core competencies" in phase 1 and 2, are no longer fully operating in-house but replaced by the localized forces who know the local market better. The new enabler is the fully plannarized channel in e-commerce such as the overcrowded B2B2C market in China (Kai, 2010). In phase 3, both supply and demand are globalized. The "core" of the enterprise is shrinking down to less than 50% in the headquarters where the mother company resides. In the next decade, what is the next SCM evolution step to manage the high N-factor DoF, both ends outside enterprise is a big challenge.

3.1 Academia lagging to respond to a changing SCM

Curiosity keep the cat going, a literature research was conducted by sampling 57 cited papers published since 1996 from the Google Scholar searching engine and the result is summarized in the pie chart in fig 4. The top category is 48%, all regarding to the traditional SCM care about with the objectives of eliminating waste and improving efficiency by adapting IT tools (K.C. Tan, 2001). The 2nd large category is 33%, for discovering new natures of post-Internet SCM: developing new theories, and exploring collaboration methodologies etc. The result reflects the SCM evolution is responding positively to the changes hardly but there seems to be not much rock solid results coming out on integrating external organization that crosses the enterprise boundary (Croom, 2000). Only two categories were caught by the eyes and dropped into the radar screen of the desired solution space: seeing the Supply Chain Network a complex system connecting enterprises in large-scale industry. They are both 5% with 6 cases in total: 4 from Automotive, 1 from Construction, and 1 from the Chemistry industry. The statistic is so disappointing in percentage and even a declining trend of SCM papers in quantity was observed. If fig 3 represents the trend of business development then fig 4 is what the academic field response to the need from business was in the last decade. For those executives searching for a high N-factor DoF solution, the result is far from satisfactory, however, it does have a very good, high-level abstract description to the ultimate goal of SCM in layman words: to be a Triple-A enterprise: Agility, Adaptability, and Alignment (Lee, 2004). Unfortunately, it still lacks the implementation detail to reach that goal. In order to make that high-level "Triple-A" business concept be more practically adaptable, the requirements in fig 3 are therefore fatherly transformed into a mechanical 3D model for the value chain integration in fig 5 below. In the research result, Enterprise wants to be "Triple-A" with a high-N factor DoF and size independent on connectivity with partners have to overcome those challenges.

The 3D model reveals that horizontal, vertical, and human capital integration are three orthogonal dimensions, those used to be handled by independent disciplines. The 1st dimension vertically integrated workflow among functions is what the "cascade effects"

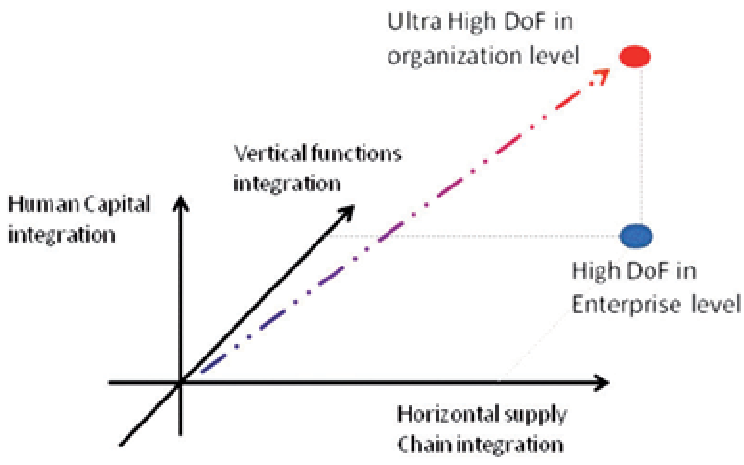

Fig. 5. Simple 3D Model of SCM mechanics for Nested Society

storing in IDM. The 2nd dimension is to make that "cascade efforts" transferrable to a nested enterprises structure. The enterprise archives both dimensions are reaching the high N-Factor virtual enterprise maturity but not in the human capital level. If enterprise can reach the 3rd dimension it reaches another level of DoF taking advantage from the nature of knowledge economy: independent contributor in the form of freelancer or contractor in an on-demand basis. From the asset management point of view, the first 2 dimensions represent more DoF of managing fixed assets and turn fixed assets into a variable cost in the economic sense. The last dimension is representing DoF of flexible organization over flexible business architecture to deal with the business dynamic.

3.2 Best-in-class enterprises are poor in SCM integration

Curiosity keeps the cat going continuously. A survey from Aberdeen Research over Process Collaboration in Multi-Enterprise Supply Chains was conducted recently to see what is happening inside the enterprises in the revolution process (Tsai et al, 2009). The result is summarized into the Table 1 below in the "Enterprise" section on the left. The data clearly answer the question why the SCM evolution hit the wall after the decade development in the post Internet era. It has only two "100%" appeared which is PLM and ERP in Best-In-Class (BIC) enterprise. They are also representing the best practice within the first dimension. However, even in the BIC category, the intra-operation is also suffering difficulty and dropping to 45%- 75% when it comes to integrating Engineering activities in MES and Quality engineering activities in the Quality System. The bottom of the table shows those "cascade efforts" under the competitive workflow are not easy to be transferrable when it comes to the 2nd dimension to integrate the functional integration deeply in-house to be horizontally integrated with external resources. It drops dramatically into a single digit from about 8% and not more than 28% even in the Best-In-Class enterprise category.

The right side of the Table 1 is further examination the availability and readiness from the first dimension going forward to the 2nd dimension then to the 3rd dimension that a virtual enterprise needed for a nested society. The poor result on the right side is making sense when the minimum level of DoF is not reached yet on the left even in the BIG category.

	Enterprise						Virtual Enterprise		
	BIC	AVG	LAG	BIC	AVG	LAG	Enterprise Level Supply Chain Solution		
(Intra)	Quality System (%)			MES (%)			Value Added 3PL (%)	VHRO (%)	ESE (%)
PLM	75	22	0	100	50	33	Operation-Over-The-Net (OOTN) is Operation Management Methodology for Supply Chain Network needs intensive care on Engineering and Quality collaboration		
ISCM	45	43	0	71	65	25			
ERP	64	38	25	100	74	75			
(Inter)	Large Suppliers (%)			Customers (%)			SME suppliers/partners		
Internal Process	17	13	8	28	16	8	Don't know	0%	0%

BIC = Best-in-Class, AVG = Industrial average, LAG =Laggard; MES = Manufacturing Execution System, PLM= Product Life Cycle Management, ISCM = Internal Supply Chain Management, ERP =Enterprise Resource Planning; Inter = Inter-operability, Intra =intra-operability. ELM="Enterprise Lifecycle Management", VHRO=Virtual Human Resource Organization, ESE="Extended Enterprise System Engineering", "SME=Small and Medium Size Enterprise"

Table 1. System to System Integration: Enterprise vs. Virtual Enterprise

3.3 Further evolution: Massive convergence

"Connectivity" is the nature of the Internet and it is a new element to human beings' evolution. The literature research and survey have confirmed the evolution both in academia and enterprise are showing disappointed result after 15 years of post-internet evolution in SCM integration. From the result, this chapter is suggested the current IT-centric approach is not working when it is crossing private space boundaries. From the 2 paths in the transformation matrix, in private domain it has to be user-centric and any connectivity between space owners is unique. Therefore, there are three new constraints have to be considered:

- Hybrid-connected as norm for heterogeneous supply network, no one-system-for-all system like Service Oriented Architecture that again basic principle of competitiveness (Porter, 1998).
- User-centric language when implement workflow automation coming to connection oriented application. IT model needs to express in business language, operation languages, and personal development languages that private space owner understand
- Nested social complex must contain all economic activities at the end of digitization process.

Traditional SCM has a much smaller application scope but it has to compile those higher level constraints when SCM is taking more contribution to connect the private spaces within the nested society. The SCSE in this chapter satisfying the PP application requirements is the first set of solution in human history can fulfil all those constraints. The 4 dimensions fusion process inside the SCSE has achieved zero disruption operation excellence and evolves since then 2000. It took 7 years to transform the IT-centric languages into operation languages in the 3D model that merge technology management and engineering management with SCM. It works but not well consolidated due to too much disciplines included. In 2007, the system engineering and acquisition cycle was added into the SCM project and it was renamed into SCSE. In about 2009, the project was started confirming the SCSE cannot resolve the SME or freelancer issue and it is not satisfied to be an Enterprise level solution. The research team in Flow Fusion Research Lab (here after as "research team") decided to extend the coverage of the private space from virtual enterprise space only to cover the private personal space as well. After the end point has been fixed, massive convergence around the SCSE model is expected via the iterating process. In the literature research, only 10% of the statistic is taking similar approach with SCSE approach. When the 10% minority touchdown first it might or might not trigger immediate massive convergence due to expected high resistance from majority, in reality.

4. Management constraints and solution space

The previous section transforms the IT connectivity domain into the 3D intra-operation domain where there is a language that the management can understand and measure. The 3D model reveals managerial requirements and the solution availability from academics and enterprises from consultant or IT service providers are also explored. This section is to dig out what constraints and decision-making process among executives lead to the gap of the poor SCM integration in Table 1. A pair of bidirectional development paths induced from the 3D model is developed for an ecosystem type of participatory production. That kind of model is suggested to be the solution space for next decade for higher DoF virtual enterprise with a feedback loop.

4.1 Dark side of top-down decision-making flow

Executives are normally the core team who are holding the steering wheel to navigate though the challenges from the changing business environments. However, when there is a revolutionary level change and happens so quickly the experiences of the executives might lead the ship to somewhere unknown based on their successful experiences in the past. After reviewing with hundreds of executives, 3 major types of assumptions were commonly found during the decision-making process of dealing with the value chain management.

(1). "Do Best, IT does the Rest": an executive who over simplifies value chain management as a Procurement function in the traditional SCM. To them, anything outside of the enterprise boundary is a purchasing activity and IT tools for productivity to help Procurement process is where they spend the money. That mentality would never consider engineering and quality activities as possibly part of the value chain operation regardless of the complexity of the collaboration in the 3D intra-operation requirements. In general, the over-simplified SCM leads to high quality cost, low responsiveness, and IT gets all the blame as illustrated in the top-right corner in fig 6. On the other hand, IT can easily find excuses to get out such as "just too expensive to implement" or "the IT consultant does not do the job". That 'musical chair' scenario makes no accountability in the entire organization is the most common lesson learned leads to the poor SCM result. In this case, no organization is required to change.

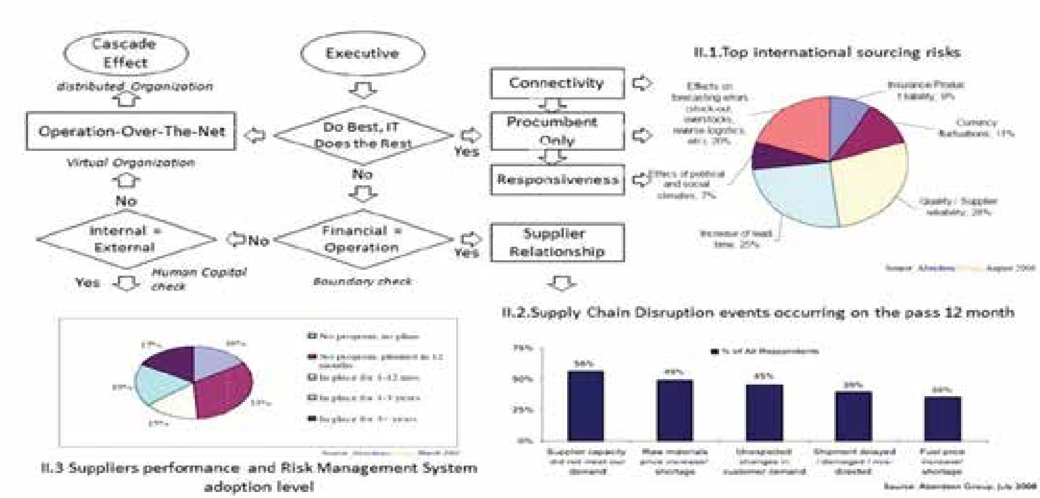

Fig. 6. Mind map of Executive Decision

(2). “Financial Boundary Equal Operation Boundary”: There are another group of executives who think there should be organizational change: when anything comes across the company boundary it is business. Therefore the Customer Relationship function and supporting function such as the legal department are needed to support the Procurement closely. In our research, the Customer Relationship organization approach is a great improvement compared to the Procurement mentality. Actually, the concept of putting SCM in the business level is extremely important. For example, asset-heavy industry to adapt the “SWING” model in the enterprise level to optimize asset utilization in the pharmaceutical industry (Pisani, 2006) and semiconductor (Tsai el at, 2008-2009) are very common. Similarly in the LCD-TV industry, leading brand names were increasing outsourcing production to reduce the risk and gain asset flexibility from 28.2% in 2007 to 41.1% in 2012, especially in hard economic times reported by iSuppli (Wu, 2008). Another advantage of pulling the SCM up into a business, strategic level activity is staying alert when a businessman is supervising the Procurement. Unfortunately, it still cannot handle engineering and quality disruption events as is indicated on the bottom-right corner of fig 6.

(3). “Human Capital is the same in Managing the Internal and the External Organization”: There are some executives who knows either going to the Procurement approach or Customer Relationship approach would not resolve the SCM issue in a complicated industry. However, many of them fall into the 3rd common challenge: difficult to find right human capital to manage tasks for an external, distributed organization. Table 2 below summarizes the major discrepancy between human capital for managing the internal and the external organization. The acronym, RAA, standing for Responsibility, Accountability, and Authority is one of the critical setups in SCM similar to the Project Management requirements in System Engineering.

Human capital strategy is an increasing challenge to most executives for managing virtual enterprise. For example, from table 2, the multiple-disciplines integrator who is covering business, engineering, and IT all together, it is almost impossible to find qualified candidates in the job market. Furthermore, the positive overlap culture that most innovative companies embrace internally is also questionable when applying to the supply chain due to the possible business interest conflicts or IP protection concerns under the over-the-distance

Positive Overlap	authority	Talents	Knowledge	Shared	IT systems	IP Sharing	Teamwork
Internal	inhibit	If due diligence required	Better communication	Mental	homogeneous	Free & legal	Face-2-face
External	inhibit	Back-up contact	Multi-disciplines Integrator	Profits	heterogeneous	Need-to-know	Over distance

Table 2. Requirements of human capital requires in Distributed Organization: Internal vs. External

working environment. For the Human Resource department, there are challenges too. For example, in an extreme case, a company in phase 3 is having more than 50% of its original business outside of its current enterprise boundary. The CEO is now managing less functional departments compared to the executive who is covering SCM function but no employee reports to him. The embarrassing situation is similar for those supply chain integrators. If the human resource is still measuring the pay check, or job grade by head counts under the manager, what salary should the Human Resources pay the super integrator in the supply chain operation that manages 50% plus of the revenue for the company with no one reporting to him?

4.2 Paired, bidirectional decision-making flow

Enterprise pays big dollars to the executive with broad enough knowledge, deep enough insight and knows how to make the right decision. However, those experiences are an advantage but constrains as well when it comes to cutting-edge technology or in a dynamic business environment like today. Sun, CISCO, and Blackberry were great companies and their CEO show incapability to deal with challenges. The research team re-think how to avoid those dark sides of the top-down decision flow to be a real “Triple A” enterprise. The solution here is to borrow a similar approach from the Department of Defense (DoD) back in 1985 while DoD issuing the DoD 4245.7-M standard with lots of templates with best practices for governing the process quality of “TRANSITION FROM DEVELOPMENT TO PRODUCTION”. The 3D model is self-explanatory when comes across to multiple-enterprises, multiple disciplines but those kind of complicated systems we need a “help

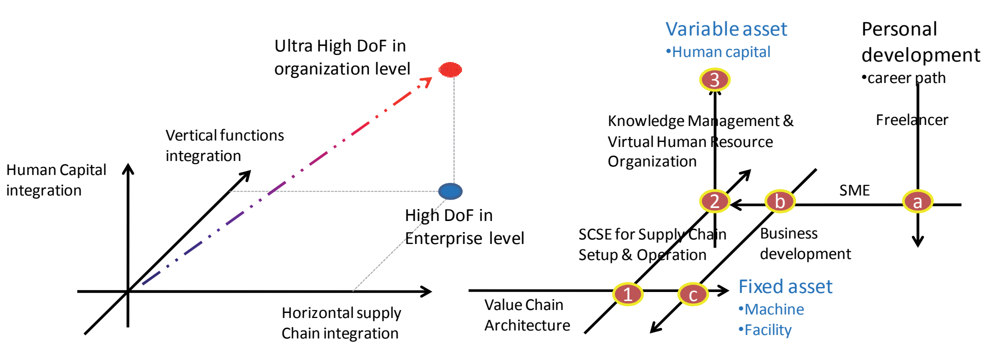

Fig. 7. Bidirectional paths to Enterprise Development and Personal Development within the 3D Model

menu" to assist. The SCSE itself is adapting the System Engineering framework to carry the best practices in the supply chain and set a boundary of deployment for a new supply chain setup of a new supplier selection and operation onward. The original 3D model on the left in fig 7 is further developed to the right hand side to have paired development paths for a Virtual Enterprise executive.

It is paired paths to form the closed-loop. The top-down path to implement downward and bottom-up path coming backward for the freelancer to participate in the job inside the virtual enterprise activities. For the executive, there are 3 steps to do:

1. Value Chain Architecture: focus on value chain integration for business development to bring in opportunity and revenue. Its focus is on the "Horizontal Supply Chain" dimension to access fixed assets such as machine, facility, and determine the 1: N ratios, where N is the financial leverage ratio of the DoF. The financial reference model for that decision making will be discussed in more detail later.
2. SCSE Supply Chain Setup and Operation: When the executive approaches and closes the deal with the ROI he wants, it has assumption of risk such as quality cost and Probability function of risk level, risk exposure etc for a certain N factor in DoF. An expert of SCSE is helping the executive to negotiating the deal in the business architecture stage and implements the supply Chain setup to mitigate risk and set controls to the risk parameters to be below the assumption in the deal. Otherwise, it is a losing money deal with huge losses since the N factor is amplifying both the profit and loses as well. The SCSE framework here is a one-stop shopping solution that can handle SME as well from the pair of the Personal development route. That makes the virtual Enterprise size independent.
3. Knowledge Management and Virtual Human Resource Organization (VHRO): Enterprise with a High N factor in a high DoF model does not have full chain facility therefore holding knowledge and training human capital is a big challenge. For costs concerns and having a goal of not being limited by the knowledge pool internally are the norm in a Virtual Enterprise practice. The VHRO is such an organization structure to assure accumulation of knowledge management with the right human capital in an on-demand basis regardless of the internal or the external human capital pool. The VHRO is connectable to Personal Private Space.

The role of the top-down business development path is quite straight forward but the reverse side of the personal development path might be quite unique.

a. Powered Freelancer: this implies there is a "Personal Private Space" that is holding the career path of the individual be able to perform personal development, and with embedded VHRO to be connectable to virtual enterprise as accessible human capital to the virtual enterprise human capital pool.
b. Powered SME: this implies the "Personal Private Space" is organic and can "grow up" from the individual freelancer continuously to be a business entity as SME infrastructure wise. This SME is also connectable to the Enterprise as part of the Enterprise level SCM solution to the Virtual Enterprise to be size independent. In today's Supply Chain practice, managing SME is a very challenging task in most companies.
c. Business Development: The "Personal Private Space" is growing from freelancer to SME then upward to the large enterprise. When any freelancer comes to this stage it is Virtual Enterprise and his role is changed. The feature to manage the organic growth of

the freelancer to SME and grow as a virtual enterprise is called Enterprise Life Cycle Management (ELM).

4.3 Constraints and solution space

Identifying the root cause is a necessary condition to separate risk from the worry list. Only seeing IT is very easy to get loss where the mind map picture out why most executives in our research cannot get out of the maze when business environments change so dramatically in the IT revolution process. With those understandings of the failure mechanism, Probability of failure, consequence of failure, people can seek a solution objectively to handle the risk. The first things this chapter does is to transform the IT languages in the The3D model that the executives understand and can find people to talk internally via a right sets of requirements in business and operations. The constraints is somewhat the people put it himself therefore limited the solution space himself. To setup right, the virtual Enterprise already was defined as a multiple-enterprise, multiple disciplines, and strong intra-operation dependent system complex. To do it right, it is very risky to rely on a hero to save the company in such a complex system. That is the reason for borrowing the best practices, DoD 4245.7-M type approach enforces the fusion process reference to assure good quality and the paired path provides feasibility of avoiding the dark side of the top-down hierarchy issue. The research team also believes the SCSE solution is an improvement from the DoD approach since they only issues standard, templates, or sophisticated NAVSOP-6071 standard with "trap". However, SCSE is also providing physics, reference models, methodologies, reference IT models, reference facilities etc that with much more tools than the DoD solution by publishing standard only:

- **Double path, feedback loop**: Not only takes care of the top down process but also the bottom up as well as a pair to assure self-adaptation capacity to dynamic environments.
- **Fully empowered life cycle management from freelancer to scalable virtual enterprise**: there is an imbalance in power between sizeable enterprise and the freelancer in many aspects from IT to resources. In this SCSE framework a lot of setup is designed to break those barriers and that is what the "take out the IT mask" means to the IT revolution.

The pair enables ecosystem from asymmetric supply chain, symmetric, to participatory production: The research indicates taking out the IT constraints, size independent supply chain environments, and feedback loop are basic mechanisms to the live, organic ecosystem. SCSE frameworks does all and those constraints are mostly gone. The back-to-basic, risk management approach is what the SCSE employing to provide a new level of DoF of virtual enterprise. The new improved model to allow SCSE connectable to private personal development space has escalated the solution space of SCSE into the full solution space toward the ultimate goal of the nested society. It will be elaborated more detail in later chapter. Overall, user-centric language and feedback loop is helping out the executive walking out of the mind map without getting lose.

5. Virtual enterprise composition process

The composition process of virtual enterprise is an alignment-adaptation-alignment process from the enterprise level to the individual. The 3 step top-down path for the executives are representing the sequence of setting up a value chain in virtual enterprise form crossing one dimension to the others. The horizontal supply Chain integration sets the network topology, cost structure, and flexibility of the supply chain. The vertical functions integration, both internal and external seamlessly, set the organizational structure and architecture of the distributed operation over the selected topology. Since most of the fixed assets required for the target product such as machine availability, facility, and capability have been configured in the first stage, the second stage is how to make those "cascade efforts" vertically transferrable, or adaptable to the new supply chain configuration horizontally. The last step is how to retain that piecewise knowledge among the distributed organizations into one set of integrated system organically and independent of the changing supply chain network topology later.

Nomenclature

ROI= *Return of Investment*
Asset Ratio = actual assert % invested for 100% revenue
N = N *factor of* DoF, N= 1/*Assert ratio*
S= Sensitivity Function of Value Chain
D= *Delinquency*
Q= Quality function in value chain
T=*Topology of the value chain including how to cut the chain into pieces and where to cut*
Inv_i =*Inventory in Stage i*
Out_i =*Capacity Output in Stage i*
$P_i = Price\ in\ Stage\ i$
$P_{Market} = Price\ in\ Market$

$$\text{ROI} = \text{Max ROI(N, S)-Min (Q, S, D, P)} \quad (1)$$

$$S(T, Inv, Q) = \Delta ROI/\Delta D(\%) \quad (2)$$

$$Inv_i \cap Inv_j \equiv \emptyset, \forall i, j \quad (3)$$

$$\text{Total Investment} = \min \textstyle\sum_i Inv_i = a \quad (4)$$

$$\text{Total Output} = \max \textstyle\sum_i Out_i / a = b \quad (5)$$

$$\text{Price Risk Margin} = \max(P_{market} - \textstyle\sum_i P_i) \quad (6)$$

$$\text{Return Risk Margin} = \max(\textstyle\sum_i P_i - \sum_i Inv_i) \quad (7)$$

5.1 Value chain architecting principle

The first step of the composition process is decomposition of the value chain and pick up partners. The definition of "Value Chain Architecture" in the top-down implementation process can be briefly illustrated by the 2-steps in fig 8 technically.

Step 1: N factor analysis and Sensitivity Check: Enterprise can simply plot the graphic by remodelling the asset ratio against the ROI(N,S) in equation (1) as shown on the graphic plot on the top-left corner. Asset-heavy is used usually to describe a company that has a high asset ratio in a capital intensive industry. In the graphic plot example, an asset-heavy with 100% asset-ratio is losing money anyway. However, in the simulation, if the executive sells off assets to be 50% asset-lite and outsources the rest, it is up from around -10% to +20-30% magically without any real improvement. If it is up to 25% asset-lite (75% outsourced), it is up to 45-75% ROI. The executive also needs to check sensitive S(T,Inv,Q) in the equation (2) of the value chain architecture about the appropriated topology, possible critical paths, right inventory policy, quality strategy, and liability payment terms dependent. An example is illustrated on the top-right corner of fig 8 about how sensitive the ROI is vs. the asset ratio.

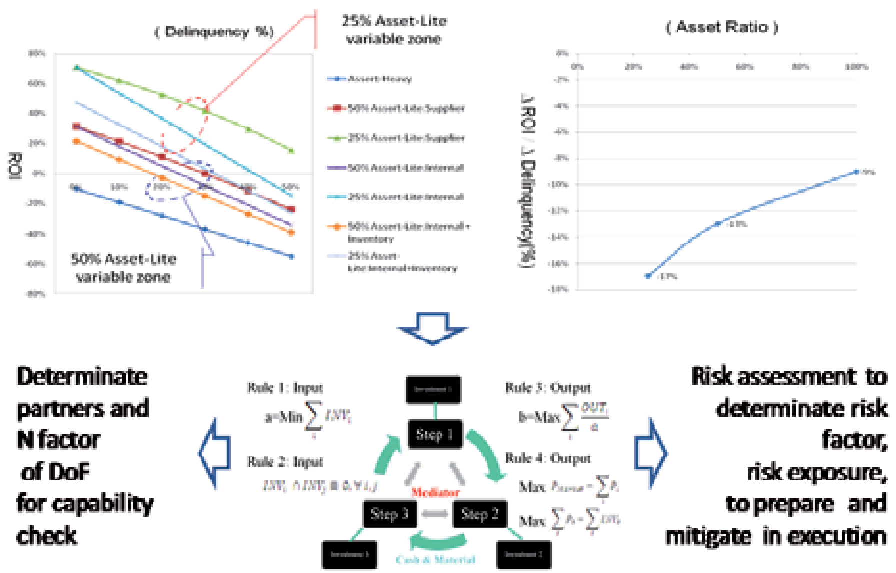

Fig. 8. Value Chain Architecture determination process

This is a first step that the CEO needs to work with the CFO to determine the characteristic of a virtual chain setup with an advantage and a thorough risk assessment. Those are all preparations that any enterprise ought to perform before going to the next step and must be done before making a decision of the next step, making a right decision.

Step 2: Value Partners Alignment: Once the N factor is identified and Sensitive is well understood, the value chain integrator, usually is the product owner, is going to assemble the chain. Before the firmed market opportunity and business model has been verified, there are usually 5 basic rules from equation (3) – (7) to follow as shown in the bottom of fig 8. Equation (3) is to avoid interest conflicts among the chain from the beginning to assure long-term stability. Equation (4) and (5) are straight forward on investment and output capacity. Equation (5) and (6) are risk factors to avoid negative ROI and the year taken to ROI.

The output of step 2 might be varied from step 1 and the chain needs to be recalculated and re-optimized spontaneously. In step 2, the value chain integrator must be a mediator to assure fairness among partners and the Profits and losses are proportionally coming back to each stage of the chain for a long-term relationship.

5.2 Quick adaptation process of supply chain setup

As stated, the minds map of the executive determines the consequence of a supply chain setup: either a trading in procurement route or a contract setup in a business relationship route in general. In this chapter, the SCSE solution with paired paths in the 3D model space cover the engineering route with quickly deploying and handling engineering capability. Since the SCSE is performing based on a unique Business Gateway Model (BGM) architecture, therefore connectivity is assumed (Tsai and Lu, 2011). This chapter is employing a 3C model representing "Connect", "Contain", and "Collaborate" in fig 9 to implement the quick adaptable process.

1. Connect: the Low Level Logistics (LLL) provides superior agility on horizontal connectivity and superior takes ownership later on differentiated workflow automation if necessary. In the experimental data, the connectivity cost is defined in the equation (8) with a great year-on-year cost reduction roadmap
2. Contain: The Virtual Enterprise Space on top of LLL infrastructure is a KNOWLEDGE CONTAINER design which is allows supply chain users to determine what is contained in the supply chain to make it functional (Tsai and Lu, 2011). Inside the container, it has 5 elements (Material, Machine, Methodology, Metrology, and Man) in the terms of a distributed production composition (Tsai and Wang, 2004) and 3 segregated flows (Production, knowledge, human capital) in terms of workflow management in Participatory Production.
3. Collaborate: With basic connectivity and the right container to start with, it can start the Supply Chain Operation, organizational alignment and perform the Operation-Over-The-Net process for continuous improvement in parallel (Tsai and el at, 2009). After positive engagement and up to a certain maturity, the buyer starts to exit and transform ownership to the supplier and focus on activities about supply chain robustness.

Nomenclature

y = the year from project started
CC_i = the Connectivity Cost in Supply Chain node I, in thousand, USD
OE = Organizational Efficiency, multiple factor to productivity for manual operation

$$CC_i(y) = 89.78\ln(y) + 196.52 < 2 \quad (8)$$

$$OE(y) = 2.3811\, e^{0.231y} > 12 \quad (9)$$

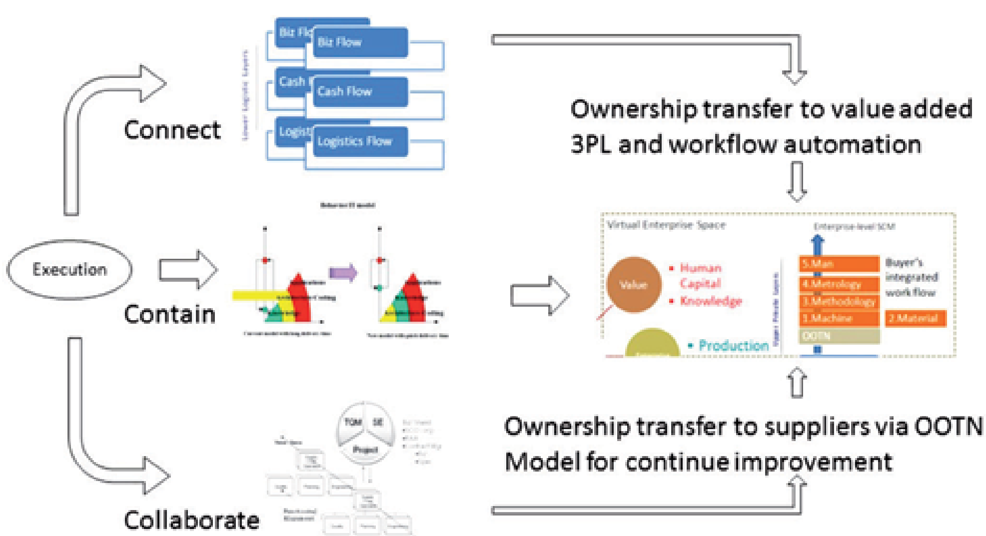

Fig. 9. The 3C QUICK Adaptation process

The 3C adaptation process is the simplest way among today's exiting methodologies available in a complicated supply chain complex market and it has been designed in the possible faults during the execution. For example, the rapid connectivity and the financial services from the LLL service provider is to avoid using IT as an excuse and possible cash flow discontinuity especially in a high N factor value chain. The KNOWLEDGE CONTAINER design is providing complete methodology set and tool set for flexibility and feasibility to cover broad industry applications. The last "C" Collaboration is to avoid another excuse from operation remotely to the distributed organization is not feasible. The 3C adaptation is designed to transfer "cascade efforts" from a competitive, complicated industry from an integrated entity to a fully segmented supply chain such as Participatory Production.

Next section will explore more from "Contain" to "Collaborate" in SCSE to build and manage supply chain for Participatory Production. This is a concurrent, learning organization but the learning curve is expected to be quick. The boundary of the learning organization is set at equation (9) from the experimental data in the past 15 years.

5.3 Management and communication among silos network

All the "Triple-A" setups above are the bright sides and certainly dark side or "weakness" as well in any design:

SCSE is a preventive design, a design for Supply Chain, but still, a passive structure in the implementation level to execute deployment, same as all methodologies

The goal is to transform the central organization from the complicated supply chain complex into a simplified, e-commerce network that has its dark side: a Silos network. SCSE architecture is embedded with aligned, constructed with a feedback loop, and sealed with an ecosystem but that is still a big potential threat to react to changes in a Silos society.

The BGM also has some very unique features in design due to being part of the nested society:

- The BGM is sharing the same skeleton with the Personal Development Space (Tsai and Lu, 2011) in order to cover the full range of partners from freelancer to large enterprises. That provides incentive on being a self-starter for their career goal.
- The Business Gateway is capable of connecting to individual professionals to form a virtual team as external human capital to support business in an on-demand basis

All those factors in pros and cons lead to the same special setup of Self-aligned Knowledge Management (KM) method. To operate a Virtual Enterprise with 50% more assets outside the company boundary is very difficult to communicate, and deploy policy. The boundary for the communication efficiency is set at equation (10).

Nomenclature

IE= number of Incoming Events, per day
CR =Compression Ratio
CE=Communication efficiency, in number of articles, events, or news

$$\mathrm{CE} = \mathrm{IE}/\mathrm{CR} < 20\,/day \tag{10}$$

The excremental KM facility, which is a communality holding freelancer and SME for the nested society, is reported to performing a more than 3x Compression Ratio in articles compression efficiency. The fusion chamber is compressing multiple sources from academic, enterprise presses, and valuable news and all merged under the knowledge model from the book "The world is flat" (Tsai, Lu and el at, 2011). When adapting the similar strategy in the private enterprise network passively the silos are capable of knowing the market changes in real time with less than 10 mins reading time a day for a quick review.

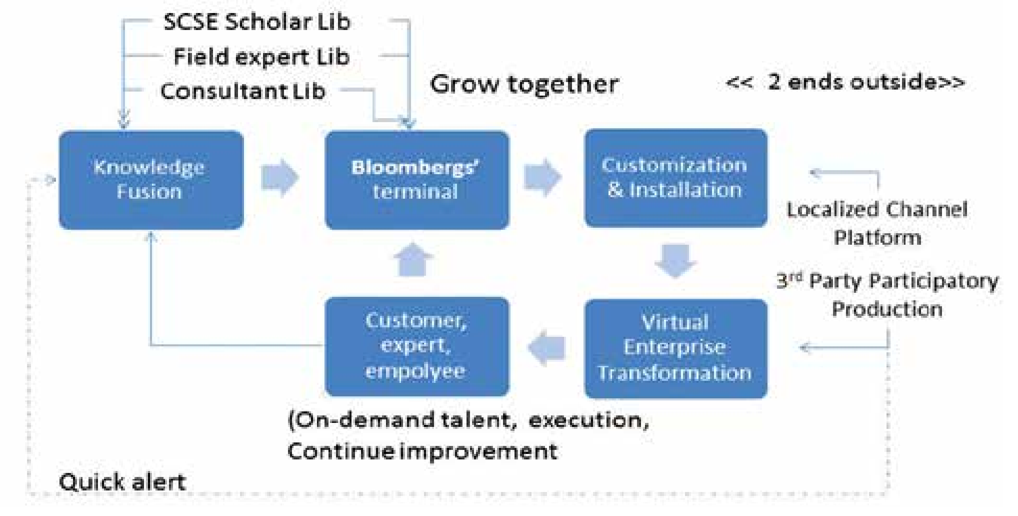

Fig. 10. Self-Aligned Knowledge Management Structure in Virtual Enterprise

With the infrastructure, management is capable of deploying news and deployment to the community for all silos in a segregated supply network actively. If using the article fusion, composition, and automatic dispatch capability further, any member in the private community can actively share an idea of how to improve or react to the changing, dynamic business environments. Reference architecture of adapting such a self-aligned KM features is illustrated in fig 10 below. The uniqueness of this design is that it is including the changing world and dynamic business environment as part of the KM coverage but not limited to the Technology inside the supply chain. It is a full spectrums scan from academic, field expertise, to dynamic news and feedback though a compressed, high-efficient KM network to help communication inside the silos network and align among them. To deal with challenges, knowledge is the first element to have.

The self-aligned architecture in fig 10 is one of the supporting infrastructures of nested society architecture to enable a human capital network outsourcing in BGM by pulling out the human capital as an independent workflow in the virtual enterprise. It is an open structure connecting to the outside community which is designed for the Customer-Centric Organization to busting out silos in the distributed organization for effective collaboration and capability incubation of human capital (Gulati, 2007). The unique design to decouple human capital flow from the production flow in the 3D model is not only to set the KM free from the operational workflow but also to set free the talent management as well. The scope of the paired paths for managing the virtual enterprise dynamics is covering a full acquisition cycle and fragmented value chain, the demand of human capital with appropriated knowledge is varied along the cycle and among the product line as well. It is required to be setup on an on-demand basis and operate like fig 10 to be capable to align with changing, customer-centric business environments.

5.4 Full application scope in acquisition cycle

This section is peeling the onion one more layer down about how to implement SCSE to architecting the value chain, quickly adapt, setup the supply chain, and what KM the silos network is needed to retain competiveness in a dynamic business environments. This section also implies a "Triple-A" enterprise could be an alignment-adaptation-alignment process to reach its Agility in the best practice sense. This composition process is generic to the full acquisition cycle covering all milestones. It is maturity level independent when aligning value chain, performing 3C adaptation process, and conducting KM among the Silos network. The SCSE model has considered the maturity dependency therefore it is a loosely coupled framework in KNOWLEDGE CONTAINER design. The framework is generic to all kinds of engineering activities are contained inside the CONTAINER as long as it is within the design boundary. From next section, it is one more layer down in the headachy and it is more specific to operation setup and operation management required to mass production at post milestone C. For a specific Maturity Model for Milestone A and B will not be covered in this chapter as stated in the earlier section on the coverage hierarchy chart. That will be part of the risk management topic in New Product life Cycle Management.

6. SCSE for supply chain setup and operation for milestone C

The pervious section is generic rules, best practices to covers the full acquisition cycle such that anytime an executive can apply that framework to architecting his value chain in early stage of the acquisition cycle. Once the maturity level is up to be in milestone C, it needs detail, thorough setup of the Production and Sustainment stage of the acquisition cycle. That implies the Product and Process Technology baseline is available for Technology Transfer from the development site into the receive site during the adaptation process. This chapter will assume effective Technology Transfer methodology to cover the availability of the 5M elements (Material, Machine, Methodology, Metrology, and Man) is available. A brief discussion about who needs the SCSE model and following with next 5 big steps sequentially a to build and delivery a SCM solution about the "Contain" and "Collaborate" mentioned in the previous section during the adaptation process.

6.1 Who needs the SCSE model

In early traditional SCM it is mostly single tier operation in term of visibility during the order fulfilment or MRP process. When more and more outsourcing activities in the industry, multiple stages supply chain is not uncommon in end product holding companies such as cell phone giants Nokia, Apple etc. Those are strictly SCM players and they are micro-managing multiple-tiers supply chain. However, it is still retained in procurement level and it is not common to include the engineering in regular practice. Therefore the most popular reference standard SCOR model from Supply Chain Council and protocol RosettaNet are not included that. There are many reasons to keep the Process Technology in-house and most important one is technical challenges about intra-operationability because engineering integration is heavily involved in Process Technology industry such as semiconductor, and chemical process factory. In a raising industry, that barrier is competitive advantage to keep inside but once the industrial cycle is matured. That barrier becomes a major show stopper for who wants to go assert-lite especially to those capital intensive industries.

Therefore for Industry who has complicated collaboration intensive activities in house and consider moving out partial to full production outside but still keeping the core competency inside, they need SCSE. Those engineering intensive activities are not the procurement or customer relationship department can handle. It has complicated Supply Chain Delivery Process in fig 11 in pervious section and coming out with multiple functions organization other than Procurement and Customer Relationship functions. How an enterprise connects the external resources into internal organization is also enterprise dependent. In general, it has a delegated External Manufacturing Organization to handle external activities under the same enterprise umbrella from Quality System, Risk Management, to Product life Cycle management.

6.2 Setup and operation deployment

In SCSE architecture, the process of setting up, deployment, and building operation are very similar with adapting a requirement engineering process in System Engineering. There will be one requirement to all suppliers in abstract level for one supply chain but it will come to different local specification technically and in operation during the allocation process. It has 3 requirement allocation paths in parallel: Technology Transfer, Logistics setup, and the final Operation deployment respectively for any particular supplier as shown on the top portion of fig 11 to establish production baseline and reach operation settlement.

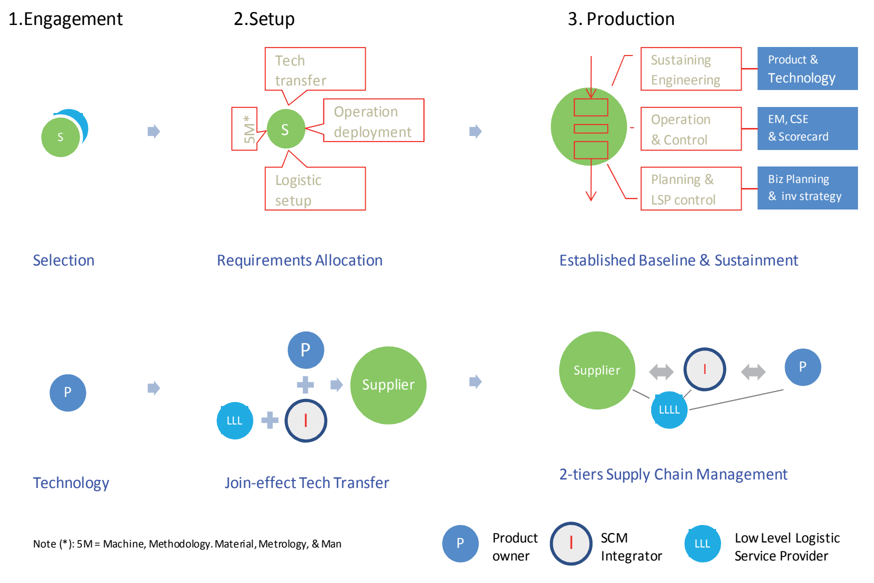

Fig. 11. Supply Chain Delivery Process for Participatory Production

The lower portion of fig 11 is the ownership transformation process among the parties and role changing schema among the Participatory Production setup. The SCM integrator is the "mediator" to put all the puzzles together, balance the interest conflicts according to the boundary conditions set in equation (1)-(7) , and becoming the professional Supply Chain Manager of the newly formed supply chain. The LLL service provider is a new concept in BGM model to pull out Logistic flow, Cash flow, commerce flow from the overall Supply Chain Operation Complex for system complexity reduction purpose (Tsai and Lu, 2011).

The IT model and assumption behind will be briefly covered in the Section: System Scalability and Model Spectrum.

6.3 Dual branch vee model for supply chain network

Network nature is new characters of post-Internet virtual enterprise from traditional SCM. In order to make the enterprise to be connectable to the Emmentaler-like structure for Nested Society complex, there 2 major steps to make it works in our experimental facilities in the last decade.

6.3.1 Be network ready and compatible in term of elements

In this chapter, the Enterprise System Engineering has been modified into a new Enterprise System Engineering (ESE) framework (Tsai, 2008) by adding Strategic outsourcing layer "Value Network" into the four well-known frameworks CIMOSA, PERA, GIM, and GERAM as illustrated in fig 12 below (Tsai, 2008). The model adapts the Classification Schema in ESE framework, which had defined 16 enterprise elements to create "View" of enterprise architecture (Oscar 2004). With that additional strategic outsourcing layer, enterprise is eligible to be network-ready as illustrated in fig 12 how buyer splits the elements categories to form branches in network as part of the nested structure (Rebovich 2006). The new "Value Network" layer under Enterprise element layer has four elements to support architecting value chain: Value Position, Supply Network, Asset Allocation, and Control. With the new layer and elements, activities setting up new supplier in fig 11 can be implemented by cell combination such as Work-Supply-Network-Requirements-Plan-Quality for technology transfer. The cell combination of Resources –Value Position–Strategy-Analysis–Benefit can represent strategic decision.

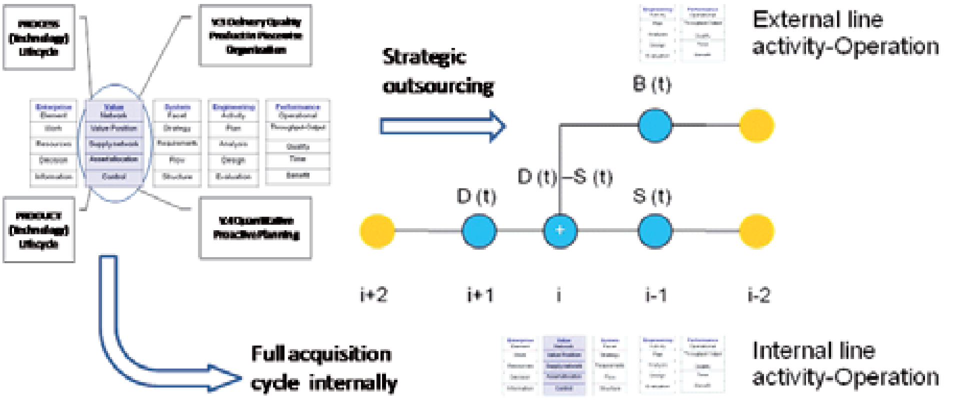

Fig. 12. Network-Ready Enterprise Activities

Figure 12 demonstrates an example of putting the Activity-Operation combination into one internal production line and one external production line on top of the cascaded supply network. That represents the cell combination Work-Supply-Network-Requirements-Activity-Operation of the extended ESE framework, which are now broken down into two segments: "Work-Supply Network-Requirements" and "Activity-Operation." The former is resident in the buyer enterprise and the later is duplicated into multiple copies: one copy stays in internal production line and one copy sends to external production line. Right side of fig 12 is the simple i+2 visibility supply network model for SWING model when applying strategic outsourcing. Equation (11) is the Summation Rule where $B(t)_i$ is the allocation or alternative sources from the mismatch between Supply $S(t)_i$ and Demand $D(t)_i$.

Nomenclature

Node i = *Node i in supply network*
$D(t)_i$ = *Demand time series in node i*
$S(t)_i$ = *Supply time series in node i*
$B(t)_i$ = *Backup Supply time series in node i*
$Output(t)_0$ = *the time series of Product Output at the root, which is the start of the value chain.*
t_f = *forecast visibility up to i+2 nodes*
C_i = *Cycle time in node i*
Y_i = *Process yield of node i*

$$\sum D(t)_i - \sum S(t)_i = \sum B(t)_i \quad , t \leq 0 \tag{11}$$

$$\sum D(t)_i + \sum S(t)_i = 0 \; , t \geq t_f \tag{12}$$

$$Output(t)_0 = \sum_i (Y_i * S(t)_i * \sum_0^i C_i) \tag{13}$$

The ESE structure on the left is enabling the network capability of an enterprise and it is also ready for operation activities including the V.4 "Delivery Quality Production in Piecewise Organization" and V.5 "Quantitative Proactive Planning" that will be discussed in later sections. Equation (12) is the Proactive Planning Rule which is necessary in SCSE setup for better visibility for fast response on sourcing allocation and enabler to cascade the sequential value chain. Therefore all nodes can cascade to a value chain for Value Chain Planning for total output planning in equation (13). The equation (11) – (13) are the basic supply chain network rules for each product in SCSE designed for network-ready enterprise.

6.3.2 Branch Dual Vee (BDVee) model for supply chain network branch building

In this chapter, the master of the value chain has to be network-ready and perform the Branch building from node to node to response to the business demand. There are two basic elements about the BDVee Model: Branch and network. In SCSE, regardless to internal or external resource in value chain, all are stationary node (geographically location), and branch is the line to connect two nodes together. Breaking up the connection between two nodes is removing a branch from the network and the topology of connecting nodes into a network determinate the robustness, surge capability of a supply network. Only when the supply network satisfied equations (1)-(7) to be mutually beneficial that is a value network for long-term supply chain relationship. The BDVee model is focus on managing life cycle of a branch with 2-layer structure as illustrated in fig 13.

6.3.2.1 Build a new branch in network

The top portion of the chart layout is the life cycle of a branch. The down V on the left is evaluating and setting up (or growing) a new branch:

- Evaluation: select target node from resources pool according to availability, technology roadmap, quality system, capacity roadmap, financial stability, business alignment, etc.
- Setup baseline: build setup task team on both sides to transfer process baseline and ownership to target node. Qualify product baseline and build remote operation, etc.

- Ramp preparation: put up ramp-up plan and facilitate resources and activities to support from engineering, manufacturing, logistics, IT, to capacity support, etc. for remote operation.

On the right side of the Vee diagram moving upward, that is simply a realization process of a new, physical branch in supply network. It finally exits when business is misaligned or business value diminished:

- Ramp: deliver the ramp-up plan committed and see whether the smoothness of operation, product yield, and reliability are meeting mass production criteria. Correct all necessaries before going to next mass production stage.
- Mass production: delivery cycle and focus on volume, price reduction, and services.
- Exit: branch disconnection procedure either triggered by business misalignment (price, value chain conflicted, business interests conflicted, etc.) or deliverables misconduct (delivery, quality, service, etc.), or product consolidation due to end of product life cycle.

The 1st layer of the BDVee Model in Fig 13 is also called a network Vee, or Branch Vee to connect nodes into a supply chain network. This layer is focus on the activities when the branch is building.

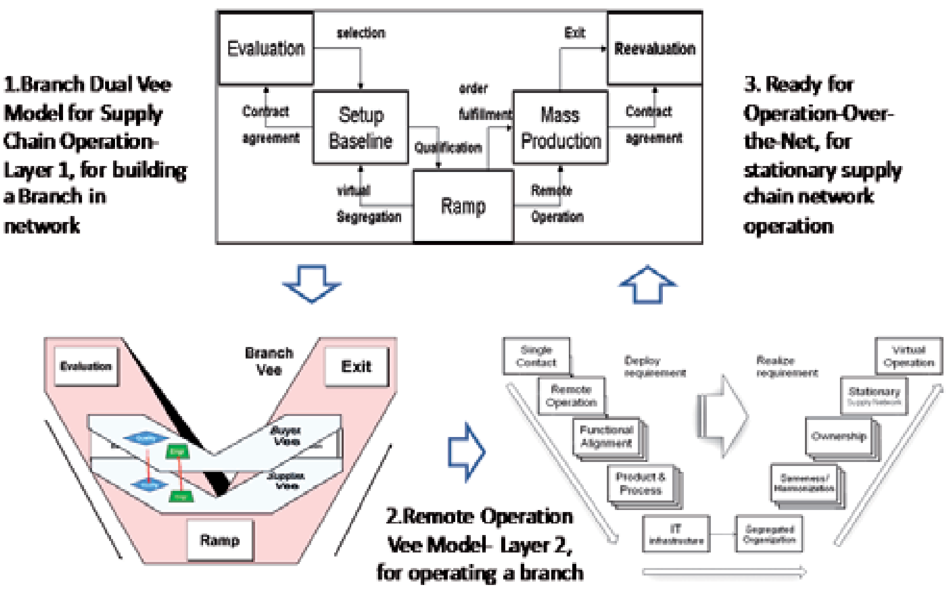

Fig. 13. Building a 2-layers Brach Dual Vee Model for Supply China Network

6.3.2.2 Operating a branch remotely

The 2nd layer is setting up an organization to operate the supplier node remotely and effectively. It crosses over the "Setup Baseline" and "Mass Production" blocks in the 1st level. The "Remote Operation Vee Model (ROVee Model)" conducts all managerial activities to operate appropriately and correctly through the product life cycle.

The ROVee Model has a double-layers structure to connect the two buyer-and-supplier nodes together and it is also a platform to operate remotely after the initial setup. The double layers are identical to connect functional departments of both organizations in two companies. The pair also called "Total Quality Management (TQM) pair" where it states the principle to compile the TQM requirements while setting up a remote operation. The detail of ROVee Model structure is shown as the bottom-right corner in Fig 13. The left hand side of the Vee model is the deploying requirements of building a remote operation.

- Single contact policy: organizational structure required to guarantee 100% information integrity to support Peer-2-Peer operation remotely. The output is "Virtual Operation."
- Remote operation requirements: activities matrix to operate two remote companies seamlessly. The output is "Stationary Supply Network".
- Functional alignment requirements: transfer ownership to at least one functional department (Collaborative Planning). The output is "Ownership" in supplier.
  - Collaborative Quality: quality ownership transfer (Tsai and Wang, 2004).
  - Collaborative Engineering: engineering department ownership transfer.
  - Collaborative Planning: transfer quality and engineering sensitivity to planning department (Tsai et al. 2004-2008).
- Product and process requirements: select one of the options to produce product from supplier. The output is "Sameness / Harmonization" for product/process.
  - Turn-key Solution: product in EDA/DFM tools only and all process technologies are provided by supplier, no inter-stage process dependency among value chain.
  - Technology Transfer: product owner has its own process baseline and transfers to supplier. Buyer only wants capacity from supplier, strong inter-stage process dependency among value chain.
  - Process R &D: buyer working with process technology provides to develop customer specific process for customer. Strong inter-stage process dependency and heavy communication among value chain.
- IT requirements: IT setup to meet fundamental requirement for "segregated organization."

Both "functional alignment" and "product and process" requirements in the deployment cycle have options. This design represents a very important nature of supply network: every branch could be different in term of product, process and therefore difficulty level to build a branch in the supply network. Some of them will require 3rd level Vee model such as the three functional alignments (Tsai et al. 2004-08) and Technology Transfer. The flexible dimension horizontally in department alignment and flexible dimension vertically in difficulty level are critical features of the BDVee Model to be backward compatible to current scientific management practice and widely adaptable to other industries. The Quality Vee Model in section 5 "Delivery Quality Production in Piecewise Organization" is a very common functional Vee that most enterprise will come to implement when building a new branch.

6.4 Quantitative Planning Model for quality

A Quantitative Planning Model was created to support supply network in fig 12 under the BDVee model. Based on that model, here we define the Inventory Time Series$INV_t(i,j)$, Supply Time series$S_t(i,j)$, Return Material Acceptance time series$RMA_t(i,j)$, and Supply Cost time series $SC_t(i,j)$ from supplier j [2],

Nomenclature

i = the current buyer
j = the supplier j

$t_l(j)$ = *remaining available time for supply from supplier j at supply stage l*
l = the supply stage l, including the inventory (stage 0),
$WIP_t(i,j,l)$ = *WIP quantity for buyer i at supplier j at stage l at time t*
$pr(i,j,t_l)$ = *purchasing request function*
$p(i,j,t_l)$ = *probability function of*
$qc(i,j,t_l)$ = *Cost function*
$n_t(j)$ = *number of WIP stages at supplier j at time t*
$m_t(j)$ = *number of planned periods for new start at supplier j at time t*

$$\text{Quality Return} = \sum_l \mathrm{pr_t(i,j,t_l)} \cdot \mathrm{RMA(i,j,t_l)} \quad \text{(p.1)}$$

$$INV_t(i,j) = INV_0(i,j) + \sum_l pr_t(i,j,t_l) \cdot RMA(i,j,t_l) \quad \text{(p.2)}$$

$$S_t(i,j,t_l) = \begin{cases} INV_t(i,j), t_l = t_0 \\ pr(i,j,t_l) \cdot p(i,j,t_l), t_1 \le t_l \le t_{po} \\ S_t(j,j+1,t_l),\ t_l \ \ge t_{po} \end{cases} \quad \text{(p.3)}$$

where $pr(i,j,t_l)$and $p(i,j,t_l)$ are

$$pr(i,j,t_l) = \begin{cases} PO,\ \ t_0 \le t_l \le t_{po} \\ 0,\ elsewhere \end{cases} \quad \text{(p.4)}$$

$$p(i,j,t_l) = \begin{cases} \frac{SH\{i,j,t_l\}}{PO},\ \ t_0 \le t_l \le t_{po} \\ 0,\ elsewhere \end{cases} \quad \text{(p.5)}$$

If a quality event happens at buyer's production line, the Buyer Quality Event should be estimated which is defined as

$$BQEC_t\,(i,j) =$$
$$\sum_{t_l} WIP_t\,(i,i,t_l) \cdot Cost(i,i,t_l)\ + \sum_{t_l=t_0}^{t_{eng}} WIP_t\,(i,i,t_l) \cdot Cost(i,i,t_l)\ + \sum_{t_l=t_0}^{t_{stop}} \{SC_t(i,j,t_l)\} \quad \text{(p.6)}$$

$$t_{ct} + t_{FIFO} = \sum_{all\ stages} ct_i \quad \text{(p.7)}$$

$$\{SC_t(i,j,t_l)\} = \sum_l^{p_t} qc(i,j,t_l) \cdot pr(i,j,t_l) \quad \text{(p.8)}$$

where

$$\mathrm{qc(i,j,t_l)} = \begin{cases} \mathrm{P_j, t_l = t_0} \\ \mathrm{Cost(i,j),\ \ t_l \in T_1} \\ \mathrm{P_0, t_l \in T_2} \\ \mathrm{0, t_l \ge t_{po}} \end{cases} \quad \text{(p.9)}$$

Eq. (p.1)-(p.9) provide basic quantitative model for planning which are related to quality event. Eq. (p.1)-(p.2) are inventory level due to possible quality event and Eq. (p.6) is what the buyer wants to eliminate. How this Quality System Vee Model contributes to the quality cost will be discussed in next section.

6.5 Be a segregated, efficient network organization

In this chapter, building a stationary supply chain needs a very efficient communication system since organization is located worldwide and has to work like under the same roof to claim the "geographically independent advantage". The Segregated Network Organization design is another critical feature besides the single-contact policy mentioned in the BDVee model during the realization process. Fig 14 is showing the major evolution steps to archive that goal to build cascaded, segregated supply chain architecture. In order to build a fast switching, fast response supply network, it has two elements to adjust: the node itself and communication paths between nodes in value chain. This section is to discuss the network aspect of the requirements of building an efficient supply network formation.

First, in regular organization, customer (or sale) department and procurement department are separated as shown on the top-left corner of Figure 14. Between them is Operation. In this study, the structure of the C-O-P has been modified into a new structure to combine "C&P" and put "O" perpendicular to the "C&P". In SCSE architecture, the Business Planning that facing Customer(C) and Procurement(P) Planning that facing Suppliers are combined into a single function unit to reduce system complexity. In network aspect, the supply network is continuing to evolve to a new level of Node structure as shown on the right side of fig 14.

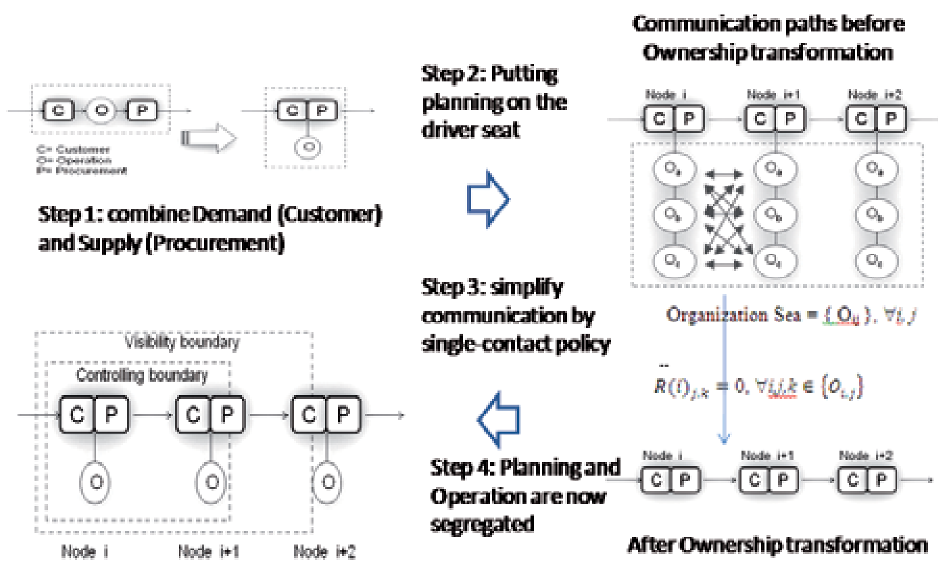

Fig. 14. Planning Driven, high-efficient and segregated network organization

To put planning in the driver seat it has to segregate the operation and planning. Segregation is not equivalent to separation since Segregation is a platform concept. In a Segregated Network Organization actually everything are connected but just deeply buried into the system and not noticeable to every end user. The boundary of segregation is defined in equation (16)-(17) below. In a generic supply network, the communication in the Organization Sea can be expressed by equation (14) and (15).

Nomenclature

$O_{i,j}$ = *Organization j in Node i*

$P(i)_{j,k}$ = *Communication path between organization j and k in node i*

$R(i)_{j,k}$ = *Communication path between organization j in node i and organization k in node i+1*

Organization Sea = { Oij }, $\forall$i, j

$$\text{Communication Set} = \left\{\sum_i P(i)_{j,k}\ ,\ \sum_i R(i)_{j,k}\right\} \quad (14)$$

$$R(i)_{j,k} \gg P(i)_{j,k}\ \forall i,j,k \quad (15)$$

After the segregation step shown on the right side of fig 14, equation (16) becomes the condition below. Subtitle equation (16) into (14) and get (17)

$$R(i)_{j,k} = 0,\ \forall i,j,k \in \{O_{i,j}\} \quad 16)$$

$$\text{Communication Set} = \left\{\sum_i P(i)_{j,k}\right\} \quad (17)$$

After the virtual segregation condition is met. The complicated supply chain complex is now highly simplified into the i+2 network on the left-bottom corner of fig 14. With the segregation and extended visibility, nodes can be cascaded into value chain by the overlapped +2 visibility and perform value chain planning. For Operation, it is working segregated on engineering and quality activities that will be discussed more detail in later section.

6.6 Planning-centric, organic supply chain

This section is layout the 4 important reengineering areas to be a virtual enterprise from our best practice field research: (1) be network-ready intrinsically to add the "Value Network" elements into the ESE framework; (2) know how to build a network branch by applying the 2-layers BDVee model; (3) Build quantitative planning model; and (3) To set up segregated Network Organization to reduce complexity hence high-efficient organization in communication. Thos are major steps to build a fast responds, fast switching, from nodes to branch, and cascades the branches into value chain for stationary supply chain network.
Comparing the decision-making path in the executive mind map in fig 6, this section gives the essential set up methodology and mathematic model to build supply chain in network aspect. The steps here are completed re-organization to simplify the decision making loop must shorter by combining business planning and production planning to make responsive supply chain therefore agility. The mathematic model with right elements connecting to different functional department such as engineering, quality engineering in a segregated network is a very special design to deal with volatile market. The "Planning in the driving seat" concept is very different from the Procurement-Centric or Customer Relationship Centric approach in the executive mind map but customer-centric or demand-centric. The IT therefore connects to all elements in the supply chain from end customer to each level of suppliers to response to volatile market organically. "Organic" is a more advanced and suitable to "Agility" in organization aspect because of the human-centric concept to managing the dynamic market. In a post-milestone C supply chain, Planning is the center with minimum communication path to customer, business decision from executive, suppliers, and now engineering and quality. Since network layer is the e-commence layer in BMG model it is also designed to be backward compatible to SCOR model.

7. Quality vee model for piecewise organization

In SCSE architecture, the BDVee Model is an open architecture for completing Supply Chain Network building in network aspect and this section comes to further functional layer on operation step. Operation is about to mitigate quality risk and compile goal and schedule, it is business specific. Although the BDVee model saying functional level Vee is optional. The Quality is clearly playing a very critical role in the Participatory Production. In SCSE, Quality department in supplier is redefined to replace the on-site representative of buyer. Quality Vee model in this section, is a reference model do that job to eliminate hidden quality cost inside the piecewise organization in supply network. In virtual Enterprise, the N factor of high DoF borrowing from the financial leverage concept is a multiplier factor to profit and it is also a multiplier factor to lose as well. Therefore the quality cost is the number one risk that a virtual enterprise needs to eliminate (Aberdeen, 2006).

7.1 Repairing broken links in piecewise organization

In most virtual enterprise application, when the quality auditor comes to audit the quality system, they often find the process is somewhat broken due to outsourcing. In a piecewise organization, the basic traceability is hard to maintain and the quality deployment is tuned into business alignment which falls into contract management category. What makes it worse is that, when a quality alert is raised by an end customer, it is hard to locate who is responsible for the issue quickly. In fact, such quality control problem has long been there waiting for the right time to emerge. Quality cost or financial punishment is always a lagging indicator to outsourcing. In the past decade, the quality issues were not emphasized enough by customers either because of the overwhelming low price or alternative choices. But once when the price reduction is stall, or the market is dominated by one supplier or single region, the quality issues are escalated. For example, DELL's service quality represents the former and China's toy safety recalls represent the latter case. In most case, buyer sends on-site representative just for “watching”. In SCSE, Quality Vee is a framework to transfer the ownership as shown on the left side of Fig 15 for right accountability. It is a Convergence Cycle of transferring ownership between companies.

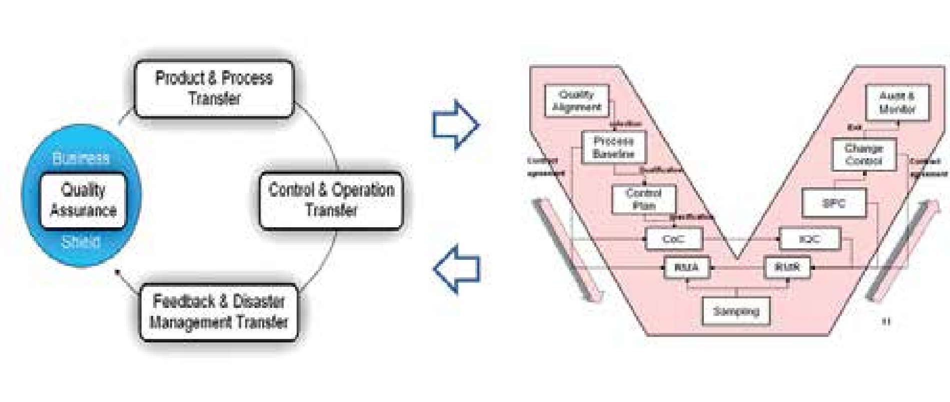

Fig. 15. Quality System Alignment and Quality Vee Model to Transfer ownership to Suppplier

Since SCSE is employing the TQM concept when building the BDVee Model for a new branch. In reality, both buyer and supplier are having complete, efficient and functional organization and they do not need a new organization to supervise them but a way to distribute ownership thoroughly and a way to collaborate seamlessly, just like in TQM. In fig 15, is showing the Quality Vee Model is a tool to perform functional alignment in Quality

System of both ends. In quality control, proactive approach is the best practice to eliminate quality disruption event before it actually happens:

- Product and Process Transfer: install proactive quality indicators in production line at supplier side by applying product sameness and process harmonization principles among suppliers.
- Control and Operation Transfer: install effective control plan in supplier with pre-installed lesson learned; activate effective remote operation.
- Feedback and disaster management transfer: install mini Business Management System (BMS) as virtual Operation core and integrate supplier's BMS to buyer's overall disaster management.
- Business shield: engineers working with colleagues internally now has methodology and principle references working with counterpart externally to compile the ownership transformation

After the ownership transfer, the external supplier became an extended organization of the buyer but works as if an integrated, internal organization with no additional overhead. If taking semiconductor industry as a worst scenario in supply chain operation, this system engineering approach model can be simplified to apply to many industries.

7.2 Quality Vee (QSVee) model

The detail of the QSVee model is shown on the right side of fig 15 with three major parts: (a) deployment cycle on the left, (b) realization cycle on the right, and (c) planning involvement cycle at the bottom. The deployment cycle down the Vee is breaking down into four blocks:

- Quality Alignment: quality manual, coverage, and beyond.
- Process Baseline: how the product is being made (process) and what is going to residue (product).
- Control Plan: what defect level and process capability are allowed during the fabrication process.
- Quality of Compliance (CoC): specification to outgoing product quality attached to supply contract.

After the deployment cycle there is a realization cycle up the Vee on the other side of the QSVee:

- Incoming Quality Control (IQC): counterpart of CoC in buyer as double gate, lagging index.
- Static Process Control (SPC): critical portion of control plan review by virtual BMS, concurrent quality index.
- Change Control: governing change process by constitutional "Baseline Document", also control virtual BMS.
- Audit & Monitor: internal and external audit to assure QSVee is compiling Quality System of buyer and supplier, a connection window to existing Quality System and organization.

Parts (a) and (b) manage the Quality System rebuild process to connect two entities and to transfer responsibility from buyer to supplier. Applying those two parts into a piecewise organization can get the same quality result as if working with internal organization (Tsai and Wang, 2004). If considering parts (a) and (b) only, QSVee is a result of modeling the Collaborative Quality Protocol in a system engineering approach. Part (c), however, is a further improvement by connecting Quality system to the Planning system:

- Return Material Request (RMR) / Return Material Acceptance (RMA): RMA is part of the SCOR model but a lagging step. To include Planning in QSVee is to improve planning sensitivity and to transfer ownership in mass production.
- Sampling: a sampling plan to control inventory quality is essential to reduce overall risk and quality cost.

The "Planning Involvement cycle" enables the planning to become the center of quality activity in a matured production line as illustrated in fig 14. This new findings in our case study makes the supply chain operation model more effective and efficient. More explanation will be illustrated after the quantitative model.

7.3 Prevent quality disruption

The pervious section explains structure of QSVee and alignment steps to install the Quality System that repairs the piecewise organization. This section is presenting how to measure the quality performance of this model and how to validate the QSVee model to assure it is a right setup. The effectiveness of the model will be demonstrated following the sequence in the "Convergence Cycle"

7.3.1 Product and process transfer

The deployment V of the QSVee Model is to assure the product sameness by transferring process baseline to the supplier, implementing effective control plan, and governing process harmonization. Taking a process specification with LSL, USL, σ, T, μ, and the process capability C_{pm} as below (Chan el at, 1988),

Nomenclature

LSL = *Lower Specification Limit*
USL = *Upper Specification Limit*
σ = *sigma of distribution*
μ = *X bar of distribution*
T = *Target of process specification*

$$C_{pm} = \frac{|USL-LSL|}{6\{\sigma^2+(\mu-)^2\}^{1/2}} \quad \text{(p.10)}$$

Eq. (10) is for a single product line. For multiple production lines,

$$\sigma' = \sqrt{\sigma_1{}^2 + \sigma_2{}^2 + \cdots . \sigma_n{}^2} \quad \text{(p.11)}$$

where $\sigma_1, \sigma_2, .. \sigma_n$are sigmaare from different lines. If $\sigma_1, \sigma_2, .. \sigma_n$are equal, Eq. (p.11) can be rewritten as for any σ_x

$$\sigma_x = \sqrt{\frac{\sigma^2}{n}} \quad \text{(p.11.1)}$$

While adapting the "copy-exactly technology" transfer methodology in setup stage [3], the newly added production line is independent of internal or external suppliers if and only if Eq. (p.11.1) is hold for all suppliers in order to hold the same process capability in Eq. (p.10). The continuous driving on process capability improvement by transferring ownership to supplier production line can drive Eq. (p.1) to

$$\text{Quality Return} =$$

$$\sum_l pr_t(i,j,t_l) \cdot RMA(i,j,t_l) \cong 0 \qquad (p.1.1)$$

The item $RMA(i,j,t_l) \cong 0$ is coming from outliner of single event. Eq. (p.2) can also be rewritten as

$$INV_t(i,j) \cong INV_0(i,j) \qquad (p.2.1)$$

Eq. (p.2.1) is equivalent to assuming that the production line is zero quality risk or the external line is equivalent to the internal line in terms of quality. The challenge is the $1/\sqrt{n}$ factor in Eq. (p.11.1). It implies that a supply array is not easy to maintain the capability.

7.3.2 Control and operation transfer

Eq. (p.10)-(p.11.1) and (p.2.1) would not hold long if Control and driving forces are not consistently in place and driving. In the realization Vee of the QSVeel, IQC, SPC, Change Control are all control systems installed to remotely control the supplier line to assure that the quality will be hold. Be more aggressively to protect buyer, those control systems are all designed to eliminate the possibility of receiving defected products from supplier, so that Eq. (p.6) can be rewritten as

$$BQEC_t\,(i,j) = INV_t(i,j) \cdot P_j + \sum_{t_l=t_0}^{t_{stop}} \{SC_t(i,j,t_l)\} \qquad (p.6.1)$$

Eq. (p.6.1) demonstrates that an effective realization V can quarantine that the defected material from defected supplier line will not affect buyer's production line and the defect problem can be detected at early time such that planner can react proactively. The quality cost is on the supplier side and the supply disruption is covered by the tolerance design of the supply network at no cost (Tsai and Yun, 2008). In our case study, supplier loves buyer to deploy QSVee since it minimizes overall quality cost and it sustains supply continuity.

7.3.3 Planning as quality gate keeper

The Planning involvement cycle at the bottom of the Quality System Vee Model that put planning in the driver seat is a very neat design found in this case study. In a piecewise organization like supply chain, engineering and quality engineering are only involved during the supplier setup and disappear after qualification. However, in B2B activity, Planning and logistics operations are the real and first-hand operations to compile quantity moving along the supply network.

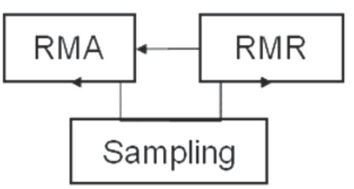

Fig. 16. Planning activities in Functional Vee Model

Fig. 16 is the bottom portion of the Functional Vee Model in Fig 15. The RMR and RMA involvement is to enforce planning has same sensitivity with engineering and quality engineering. For an unexpected quality event, if Eq. (p.2.1) cannot hold and Eq. (p.6.1) also cannot quarantine the infected material, infection starts in buyer's production line, and the quality cost will dramatically shot up to Eq. (p.6) with longer quality discovery time in Eq. (p.7). While Planning takes ownership in inventory management and requires supplier to perform sampling by using material start time at supplier, planner can load those sampling material onto the production line sweeping through buyer's line instead of FIFO strategy. The action assures infected line can be detected in minimum cycle time. The ownership also enhances planning to take immediate action to enforce $t_{eng} = 0$ such that $\sum_{t_l=t_0}^{t_{eng}} WIP_t\,(i,j,t_l) \cdot P_j \cong 0$ and Eq. (p.6) can be reduced to

$$BQEC_t\,(i,j) = \sum_{t_l} WIP_t\,(i,i,t_l) \cdot P_j + \sum_{t_l=t_0}^{t_{stop}} \{SC_t(i,j,t_l)\} \qquad (p.6.2)$$

The quick action from planning reduces the maximum quality cost in buyer product line to $\sum_{t_l} WIP_t\,(i,i,t_l) \cdot P_j$. Planning in this quality event also takes immediate action to minimize quality cost $\sum_{t_l=t_0}^{t_{stop}} \{SC_t(i,j,t_l)\}$ on supplier side and inventory cost $INV_t(i,j) \cdot P_j$ on buyer side as well. Since planning is in driver seat, immediate action also takes place to fill the customer's demand using alternative supply sources to satisfy customer. In supply chain management, planning should be always the one in the driver seat even in terms of quality control.

7.3.4 Change control and baseline control

Fig. 17 is the state diagram of a change control process before and after applying QSVee between two companies.

Let's define process time of an engineering change t_{engr},

$$t_{engr} = \sum_i \sum_j \left(S_{ij} + R_{ij}\right) + \sum_i \sum_j \left(BS_{ij} + BR_{ij}\right) \qquad (p.13)$$

where S, and R are time of status change internally, and BS and BR are time of status change externally by going through buyer's review and approval. If the external routing BS and RS in Fig. 17 are long due to lack of IT connection between two change approval systems from two companies, such that,

$$S_{ij} \ll BS_{ij} \text{ and } R_{ij} \ll BR_{ij}, \forall i,j \qquad (p.14)$$

The Eq. (p.13) can be rewritten as

$$t_{engr} \cong \sum_i \sum_j \left(BS_{ij} + BR_{ij}\right) \qquad (p.13.1)$$

Eq. (p.13.1) is one of the reasons why Eq. (p.2.1) cannot be hold and it is degenerated to Eq. (p.6.1) and (p.6.2) due to inefficient piecewise organization. In this case study, the path in Fig. 17 is changed with a new document "Baseline Document" and a new operation meeting "Weekly Meeting", as our virtual BMS, are introduced to the remote operation.

Eq. (p.13.2) shows the same organizational efficiency as internal operation. The after-QSVee path in Fig 17 is an example of installing a "Business Shield" to an internal organization among value chain while setting up supply chain. With an effective piecewise organization, Eq. (p.2.1) can hold longer and can be pulled back more easily before drifting to Eq. (p.6.1) and (p.6.2) by a much effective organization.

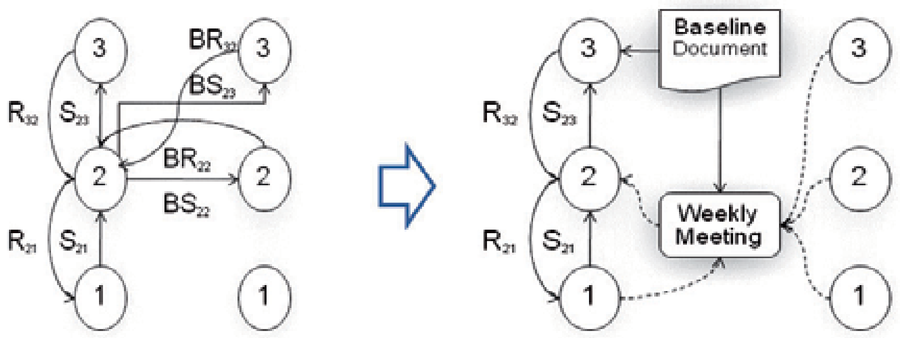

Fig. 17. State diagram of change control path before and after the Quality System Vee Model

The "Baseline Document" and "Weekly Meeting" in Fig. 6 enforce $BS_{ij} = 0$ and $BR_{ij} = 0$. Eq. (p.13) therefore can be rewritten as

$$t_{engr} = \sum_i \sum_j (S_{ij} + R_{ij}) \qquad \text{(p.13.2)}$$

In our case study, after the three steps: Vee Model setup, virtualization and elimination, people in piecewise organization hardly aware any behaviour is required to change to deal with supply chain network. The piecewise origination operates seamlessly as if a single organization within the same enterprise.

7.3.5 Rebuild the ownership

There are four major steps to repair the broken links of a piecewise organization. First, the convergence Cycle is to governing the ownership transferring process. Second, QSVee is the architecture or framework to perform that task. Third, there are also outline special setup and activities from technology transfer to change control in order to assure QSVee Model is a preventive system on quality events. After all those infrastructure are set. The last step is to redefine Responsibility, Authority, and Accountability (RAA) across the piecewise organization in the supply network. RAA is a critical System Engineering approach, especially in Supply Chain Operation. The accountability is normally overlapped with responsibility within a company but that assumption is not holding up while across the company boundary. Since every enterprise with his unique culture and acronym, carrying assumption within enterprise crossing the enterprise boundary is a very common mistake. QSVee model is also part of the system simplification process to create Segregated Network Organization.

The QSVee Model is a default setting in our Operation-Over-The-Net framework in later section. The Operation will cover the rest of the RAA during the Operation Deployment stage for new Supply Chain Network setup.

7.4 Planning-centric, proactive quantitative planning

The BDVee model section mentioned SCSE is Planning-Centric instead of either Procurement-Centric or Customer Relationship dominated. After the QSVee Model implemented, the ownership transferred and quality cost is expected to be segregated under the organization seal and Planning is on the driving seat of the supply chain as fig 18.

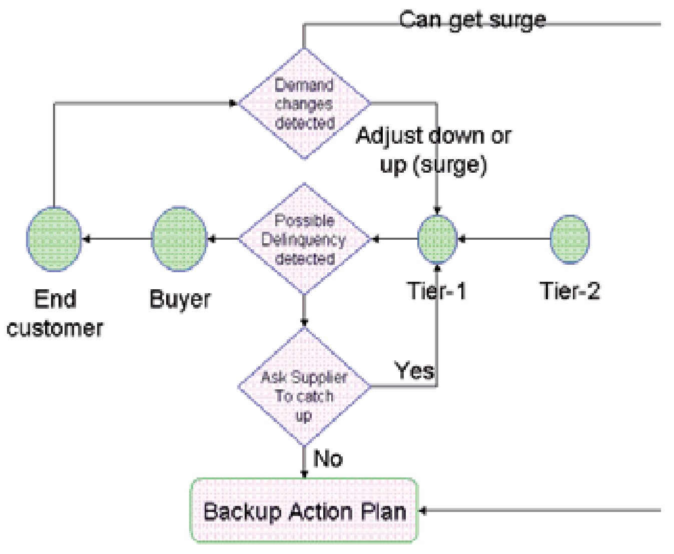

Fig. 18. Allocation flow of detecting a possible delinquency or possible change from customer

Combing business planning and production planning and special design in QSVee as shown in fig 14 and 16 are the two major structure changes to promote planning to be largely extended to be more operation capable in next section. Planning is not only doing the planning job but also working as the first line defender of the supply chain operation such as sampling for quality (Tsai and Yun, 2008). In SCSE, planning is the only organization who is working in daily basis and it is the only resource to perform that daily routine job when most of the engineering are on and off under an on-demand basis. Because of the fast i+2 visibility and fast switching capability, planning here is more powerful to perform the allocation process as show in fig 18 to challenge the high volatile market.

Volatile demand from static supply: Long supply visibility not only enables the supplier switching possibility but also opens a new door of supply network design. Given the Variances from supply and demand,

$$\mathrm{Var}(D_t) \geq \sqrt{{S_1}^2 + S_2^2 + \cdots S_j^2} \tag{18}$$

$$S_j^2 = \mathrm{Var}\big(S_t(i,j)\big)^2 + \mathrm{Surge}_j \tag{19}$$

$$P_j / S_j = \mathrm{constant} \tag{20}$$

Equations (18) - (20) enable a new approach of supply network design: the volatile, customer-driven demand in consumer market can be satisfied by a static supply array.

Equation (18) is the boundary of the supply array and Equation (19) is the source of variation where $\mathrm{Var}\big(S_t(i,j)\big)^2$is from bad performance and Surge_j is the surge capability that supplier committed to the buyer. Equation (20) is the allocation priority factor which implies higher flexibility means higher price. Volume, flexibility, contract length, performance are all planning factors that will affect cost and supply capability in a dynamic supply network.

Fig 18 demonstrates changes could be from supplier due to delinquency or from customer. Either change will break the demand supply balance. So the supply network should accommodate whatever change at the customer end and keep supplier as static as possible in the "long lead time and cycle time" semiconductor industry. The Equation (11) can be rewritten as

$$\sum D(t)_i - \sum S(t)_i = \sum B(t)_i\,,\ \sum B(t)_i < S_j^2\ ,t\ \leq 0 \tag{11.1}$$

In the Participatory Production, the planning taking more responsibility to check CoC with the LLL service provider in the production stage of fig 11. It has partial function on manufacturing, quality control and production control functions in a regular enterprise as well. In some extreme setup with a right candidate, Leader in Planning is uplift as Virtual Manufacturing Manager to manage most of the post-milestone C activities in the acquisition cycle.

8. Operation-Over-The-Net (OOTN)

After building up the branch of the supply network via the BDVee Model, transferring ownership to supplier and rebuild the piecewise organization via the QSVee Model, an Operation management to sustain the supply chain is next challenge to perform in a post-milestone C production. Since the architecture, organization, activities are all set up to this stage, this section is to elaborate the principle to setup OOTN and how those elements in pervious sections putting together and run it. The OONT must overcome the four natural barriers: (1) enterprise is built to be differentiable, (2) business relationship is dynamic, (3) trade secrecy is need-to-know, and (4) each enterprise has unique culture. In term of SCSE uniqueness, the OOTN also demonstrates how the Planning-Centric architecture is scalable to deal with all kind of supply chain network from simply backward compatible to SCOR, to be the virtual manufacturing manager role in large, complicated application. In "connectivity", OOTN will show its capability to deal with heterogeneity of supply chain network.

8.1 OOTN is a back-to-basic approach

This solution assumes the multiple-enterprises operation environment today is like the Operation Management (OM) among internal organizations 20 years ago: immature in IT automation, but full of possibility (Tsai et al, 2009). The back-to-basic principle results a top-down approach: copying functional requirements from internal OM organization to OOTN organization is the less resistant path on behavior change in order to treat OOTN as an extended OM to managing external resources. For example, a planning function in internal OM needs a peer in OOTN to response timely and accurately. Fig 19 below is the 4-steps OOTN implementation process that compiling the 3D model in a closed-loop manner.

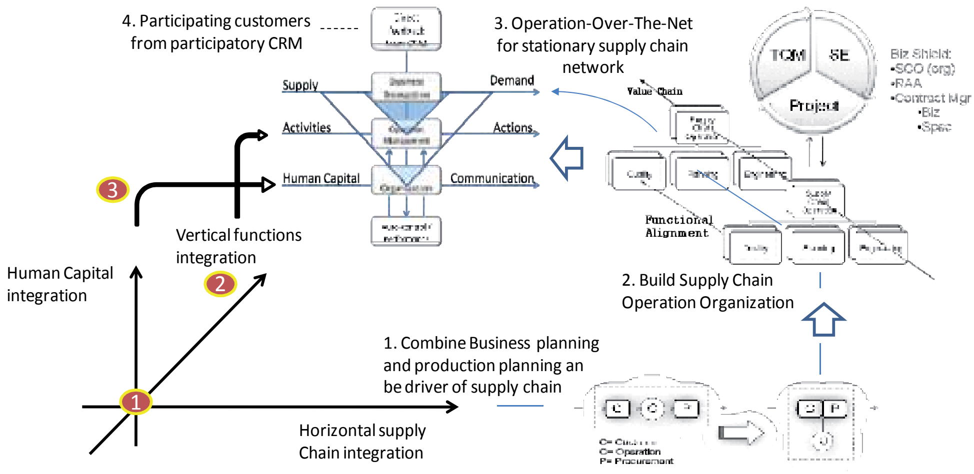

Fig. 19. A closed-loop, 4-steps OOTN implementation process

1. To reform the organization to be network-ready by implementing the ESE elements and combining the business planning and procurement.
2. To form the virtual organization chart for operating the internet based OM System. The Supply Chain Operation (SCO) is the core of OM which acts as an integrator of SCM to optimize the existing resources, enforce the existing operation disciplines or adapt new disciplines, and etc. Its ultimate goal is to assure smooth operations throughout the supply chain. That is equivalent to an Operation Manager or Fab Manager role in internal OM. Three basic disciplines are required to perform the job smoothly are Total Quality Management (TQM), System Engineering (SE) , and Project Management (PM) in additional to the domain professional.
3. There are three basic functions connecting to the SCO integrator: Planning, Quality, and Engineering. Both the Quality and Planning functions detail have been covered by the pervious section "Quality Vee Model for Piecewise Organization" and "Planning-Centric, Proactive Quantitative Planning". For engineering, this chapter is intend to leave it opened since it is totally enterprise and even product dependent even within a enterprise. As mentioned in the section "Virtual Enterprise Composition Process", this chapter is to provide a quick adaptation with "container" in the 3C adaptation process. The engineering potion part of the "Operation Deployment" step during the setup stage and supported within the Quality System procedure when it settle in "Operation and Control' during the QSVee realization process for transferring the ownership. That "Operation and Control" is the charter of SCO organization for the OOTN. The Virtual Organization is a peer-to-peer structure that requires coordination from supplier or customer to perform perfect functional alignment. The aligned virtual organization is an organic complex which fully meets the integration requirements, both internally and externally, to overcome the four barriers of implementing Supply Chain Collaboration (SCC).
4. Inside the OOTN Architecture, there are 3 horizontal workflows and 1 vertical workflow. Beside the 3 horizontal flows that operating with the SCO along the supply chain. However, that is too long for a supply chain to react with the end customer. The vertical flow is a very unique design to connect the OOTN to the end customer or the collaborative, common pool that connectable to end customers. That turn the topology

of the chain structure into a start topology where the customer in the center in other dimension. That is a very important design for customer-centric supply network.

Different problem statement leads to different solution. The back-to-basic OM approach is heading different direction of the "Do best, IT does the rest" mentality that trap the executive in the decision mind map and cannot escape from the maze. OOTN is a very simple architecture where IT tools are evaluated based on their cost, time-to-market, and being human-centric to meet the dynamic life cycle of a branch in supply chain network. OOTN and SCO organizational development is compiling the basic continuous improvement approach that aligning with the three-stage organization theory that can be used to improve operations throughout the supply chain: (1) efficiency, (2) effectiveness, and (3) began to incorporate the ideas and expertise of their suppliers and partners into the management of the supply chain, from within industry to crossing industry boundary (Melisa and Snow, 2007).

8.2 The OOTN architecture in business level

The OOTN architecture is a top-down design using system engineering approach. It views system as a whole and conducts SCC via the periodic OM over the stationary supply chain. The traditional on-site management is easy to start but very costly to operate, which is often ineffective, and lack of right ownership after all. That on-site concept is replaced by the online collaboration OOTN in our best practice. In fact, OOTN is the answer to the executive to help him getting out of the mind map maze since it is an extended organization from the internal OM organization that the executive know how to approach without putting an IT up front such that he can talk the language he understand, and the people he knows. The scope of OOTN in business level is defined in Table 3 which states a process to support operation level management.

Functional level	Application Level in Management	
	Operation over Supply Chain Network	Business over Value Chain Network
Decision	Compliance	Strategy
Process	OOTN	Allocation
Activity	Responsive	Re-structure

Table 3. OOTN Integration within Enterprise

Table 3 defines scope therefore identifies the system requirements as what is needed to operate it and result in the SCO. This requires interdisciplinary efforts from Planning, Quality, and Engineering as a team at functional level to response to activities across the Supply Chain Network to assure the compliance from business level deployment. Table 3 also indicates that any possible failure to compliance will alert to higher level which might trigger business level allocation process and back to planning execution in fig 18 from business decision over the value chain network. That is another reason why SCSE architecture is putting Proactive Planning in such a fusion role between business, production, and front line defender or engineering for fast switching capability in volatile market. From the definition in Table 3, OOTN is also an infrastructure connecting e-Service on frontend and MES on the backend. In step 3, the OOTN is operating over the System Architecture of OOTN which has direct interface to end customer to have them directly interactive with the OOTN on the back office to enhance responsiveness of the entire supply chain, hence customer experience to the service provided.

8.3 System architecture of OOTN

In terms of architecture, OOTN is derived from ISO 7 layers protocol, as a multi-dimensional gateway that transmits events therefore actions along the supply chain horizon. OMS, in this analogy, is equivalent to the network layer in level 3 where the OOTN receive event alert from one spot, move upward to higher level to process, make decision, move back to OM, and route activities to the right spot in SCN. The simplified form of system architecture of OOTN is presented in step 3 of Fig 19. The OM is in the centre of vertical and horizontal workflows. In the OOTN architecture, only the Supply-Demand workflow in horizontal direction is covered by current Supply Chain Operation Reference (SCOR) model that makes the OOTN model backward compatible to SCOR standard from supply chain council. The other two workflows "Activities" to take actions and "Human Capital" to communicate are additional to SCOR. The workflow in vertical direction is a very unique design that allows CRM of the entire supply chain on the front end to feedback directly to the Operation Management over-the-net to make the supply chain more responsive. Here are the other key features of each block:

- Activities-Actions path: in additional to the transactional path, engineering activities in complicated supply chain is not covered by SCOR, the core of OOTN to route activities.
- Human capital-communication path: another element in addition to the transactional path in order to communicate and collaborate activities or transaction over-the-net crossing enterprise boundary, which is different from working internally and requiring different kind of human capital. It is equivalent to Data Link or Physical layers of ISO model.
- Direct Feedback from front end or CRM: OOTN architecture is a customer-centric structure built for networked enterprise and with direct feedback algorithm and workflow setup that create a new, fastest path of reacting to end customer.
- Auto-control / Performance unit: monitoring unit to assure all components of the system are well-connected and well-measured to provide fast feedback to OM in a positive loop.

The 4-steps OOTN implementation in fig 19 is a closed-loop process to response to the original requirements of the "Simple 3D Model of SCM mechanics for Nested Society" and the proposing solution of the Enterprise Development path in "Bidirectional paths to Enterprise Development and Personal Development within the 3D Model". The closed loop in macro view starts from the horizontal supply chain integration, then perform the veridical functions integration via the SCSE implementation to setup the value chain, and finally complete the Human Capital integration. There are also micro views for each individual dimension in the system architecture of OOTN: horizontal supply chain vs. the Supply-Demand pair; Vertical functions integration vs. the Activities-Actions pair; and Human Capital Integration vs. the Human Capital-Communication pair. All the 3 loops are fused together in the OOTN architecture in fusion chamber aspect including the direct feedback loop e-CRM with the end customer. That unique design allows SCSE

to connect private space in enterprise along the chain and directly to end customer in public space.
VI.4 Operating the OOTN Backbone: OOTN is a backbone of SCN in network and telecommunication sense because it routes activities via the IT network. Therefore it is also backbone of organization and operation in management sense. It is designed to be backward compatible to SCOR model in business transaction. Furthermore, it is backbone of Peer-to-Peer computing in terms of protocol, architecture and business algorithm that support stationary enterprise. With all those compatibility, managing SCC by employing OOTN can take a lot of advantages:

- Only few specific IT setup is required to add a supplier or customer to an existing SCN or form a new SCN
- High degree of freedom to plug in differentiable workflow, adapt different cultures, and seal trade secrecy through human interface to OOTN
- Fast ramping up and switching supplier to coup with dynamic business relationship
- Not constrained by IT connectivity, internal pre-programmed complex procedure, or those external consultant told to do, therefore be able to deal with business dynamics. The success of SCC result in good quality, efficiency, and effectiveness is mostly credited to the fact that stake holders can focus on business process, procedure, engineering innovation, and commitment of continuous improvement in periodic OM.
- Good scalability: If business relationship is long-term or the business scale is justifiable to build multiple enterprises workflow or application. Invest the workflow permanently with no regard.
- Fully customized in each branch of the heterogeneity of supply chain network since OOTN is KNOWLEDGE CONTAINER design.

The highly scalable, flexible OOTN which disjoints IT and SCC make big differences comparing with current IT approach. The OOTN architecture is compiling differential competition principle (Porter, 1998) and Service Oriented Architecture or E2OPEN are not. Business owner can therefore perform business architecture design freely to optimize value network and position such as resources allocation, asset ratio decision etc then do IT consideration later. Those flexibilities are critical to capital intensive, complicated industries such as aerospace, semiconductor. In our study, scalability provides stable structure, and that enable knowledge management. Stationary provides another dimension of scalability by making business architecture geographically independent. Those are key elements of virtual enterprise to keep their differentiable workflow as the core competency under the nested society. The OOTN or equivalent capacity is a must-have ability today as the right hand of the CEO to manage external resources.

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8.5 Assure supply continuity

Having multi-tier supply visibility and being able to quickly respond are not enough to assure supply continuity. The total supply and demand must satisfy Equation (21) below in order to maintain supply continuity, which is a business requirement, not a solution. Any interruption caused by quality problem or up-sized demand from end customer can break the condition in Equation (21).

$$\sum_{j_i=1}^{J_i} \sum_{l_{j_i}=1}^{n_{j_i t}+m_{j_i t}} S_t(i, j_i, l_{j_i}) \geq D_t(i) \tag{21}$$

The fast supplier switching capability in OOTN provides a new flexibility to deal with the volatile demand or unstable supply, thus is capable of assuring supply continuity in all economical cycle. We have adapted the concept of Process Capability Index CPU as the method of handling demand or supply volatility, which is estimated as

$$\mathrm{CPU} = \frac{\mathrm{USL} - \bar{\mu}}{3\sigma} \tag{22}$$

If only considering the variation of supply and demand, i.e. $\mu = 0$, then USL ≈ 3σd. Therefore, if ignoring μ, which means all suppliers commit total quantity but may not satisfy individual shipment, the supply continuity can be satisfied if and only if, either Equation (23) or Equation (24) can be satisfied as shown in Fig 20.

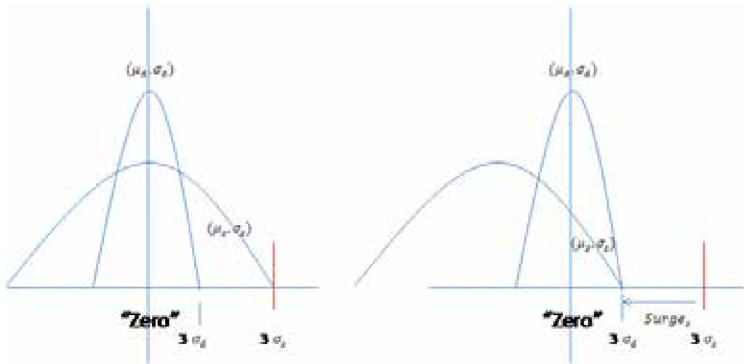

Fig. 20. Surge capability

$$\sigma_s \leq \sigma_{d,\text{ or}} \tag{23}$$

$$3\sigma_s - \text{Surge}_s \leq 3\sigma_d \tag{24}$$

Both Equations (23) and (24) are derived based on the assumption of normal distribution to simplify the demonstration. The surge capacity Surge_s is the extra reserved supply capacity collected from all suppliers as shown in Fig 21.

Equations (22) – (24) enable a new approach of supply network design: the volatile and customer-driven demand in consumer market can be satisfied by a static supply array. Equation (23) is most likely not feasible therefore Equation (25) is a more practical solution in designing supply network. In some industries, if the qualification time or setup time for a new supplier takes too long, fewer suppliers will be added into the supply network. In this case, using the surge capacity Surge_s is the only way to deal with the demand or supply volatility. However, this may not be feasible as well in a hot season and it can be quite costly. Usually price for surge capacity is proportional to its volume. Higher surge capacity implies higher flexibility which also means higher price. Volume, flexibility, contract length, performance are all planning factors that will affect cost and supply capability in a dynamic supply network.

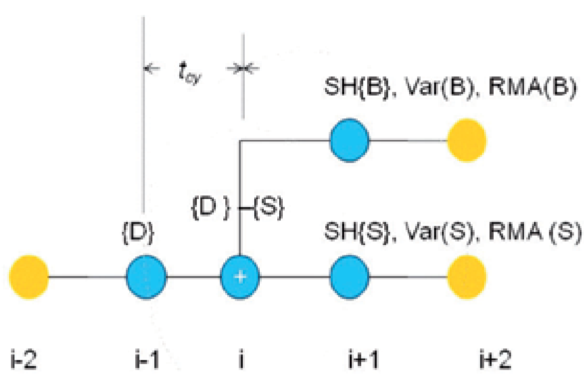

Fig. 21. Multi-tier supply collaboration

Having planning on the driver seat will ensure fast responsiveness therefore minimize cost and assure supply continuity. However solving and preventing quality problem, and qualifying quality suppliers and surge capability are still engineer or SCO integrator's job. Optimization is not considered in OOTN as it is either applied to internal resource optimization or value network optimization at the business levels defined in Table 3.

8.6 Minimize bullwhip effect

OOTN is designed to enforce supply continuity collaboratively therefore minimizes bullwhip effect as well. The demand variation from customer $\mathrm{Var(D)}$ is not controllable but order variance $\mathrm{Var(Q)}$ can be manageable. Equation (25) quantifies bullwhip effect and Equation (26) shows how the variance is amplified along a decentralized supply chain.

$$\frac{\mathrm{Var(Q)}}{\mathrm{Var(D)}} \geq 1 + \frac{2L}{p} + \frac{2L^2}{p^2} \tag{25}$$

$$\frac{\mathrm{Var(Q^k)}}{\mathrm{Var(D)}} \geq \prod_{i=1}^{k-1}\left[1 + \frac{2L_i}{p} + \frac{2L_i^2}{p^2}\right] \tag{26}$$

Our proactive planning unit is a highly collaborated but centralized SC control unit that has the best potential of eliminating or minimizing the Bullwhip effect. If the $t_{\mathrm{avaliability}} > L$ condition can be met, supplier can back fill or refill the order to absorb the variation $\mathrm{Var(D_t)}$ from buyer, or buyer can reallocate the variation to other suppliers following the disciplines described in Equations (21) – (26). The multi-tier supply visibility and control schema enables a new way to manage collaborative supply chain network and gives a new boundary. In OOTN, Planner who is responsible for Master planning is also responsible for Supply Planning and Production Planning. Thus the lead time or response time can be eliminated. Therefore Equation (25) can be simplified as,

$$\mathrm{Var(D_t)} \equiv \mathrm{Var(Q)} \tag{25.1}$$

If Equation (3) is met, which means the supply continuity is achieved, by applying Equation (25.1) repeatedly for all supply chain stages, Equation (26) can be extended to:

$$\mathrm{Var(D_t)} \equiv \mathrm{Var}\left(\mathrm{Q^k}\right) \tag{26.1}$$

The bullwhip effect is based on the fact that there are delays from one stage of supply chain to the next. The OOTN structure is to enforce the quick responsiveness to demand variation $\mathrm{Var(D_t)}$at every stage of supply chain. With the multi-tier supply visibility, planner can proactively make planning decision before supply disruption can take place.

8.7 Human capital in OOTN:

The word "Virtual" and the complexity of workflow in Fig 19 have briefly defined the human capital requirements in OOTN architecture. The highly integrated activities to be conducted requires a single man who is capable of executing and driving TQM, SE, PM, and even PLM during the product lifecycle, or, an equivalent organization who can conduct those communication and execution effectiveness and efficiency. That is a capability issue where a simple production line only needs one but a complicated production line have to be multiple tasks. The "virtual" implies that particular integrator must be capable of working with Planning, Quality, and Engineering as well in terms of organizational structure on both supply and demand ends, to be the Operation Manger over-the-net covering functions required in Fig 19. OOTN is architecture to "Connect" buyer and supplier that means to utilize all existing resources on both sides is design principle. Therefore, SCO is virtual and do does OOTN. The primary human resource to run the OOTN has to be very experienced to have full picture of how organization is working internally and externally otherwise it will be very easy to get lost in the piecewise organization. There are lots of dark sides:

- Those kinds of human capital are very difficult to find
- Executives does not know exactly what human capital he wants when he is still trapped in the executive mind map
- No such job grade in most human resources category. A human resource finding a candidate for procurement will not fit that needs.
- No exiting payment schema to justify those jobs managing high percentage of revenues or cost outside of enterprise but with no employee inside reporting to him. There will be more challenges when the world is confirmed to heading phase 3 by Economic Policy Institute (EPI): the statistic said 1.4M jobs were created overseas by U.S. companies, compared to 1M domestically in year 2010 (Raynor, 2010).

There are two ways to solve those challenges in human resource. The executives and human resources need to adjust and school needs to "produce" right human capital to reduce barrier. SCSE discipline is designed for that purpose with framework includes all those material and condiments from system engineering to IT. To be familiar with SCSE will help a right human capital to perform the job right with less efforts and risk.

8.8 Best practice applying OOTN

There are two major dimensions in improvement by adapting the OOTN architecture: the supply continuity and customer-centric organization even it is piecewise, and "temporary" in term of the full acquisition cycle. The former is for delivery and the later is for sustainment independent of the length of the acquisition cycle. The direct linkage to end customer allow the players of the chain decouple from the acquisition cycle regardless to while milestone or how long a supplier stay in the value chain. The table 4 below is one of the best practices that the research team sees how well the OOTN can last with no major interruption and continue to roll even in the sustainment cycle. That is the longer data the team can see for a product in consumer market when the design team wants to challenge how good the Supply Network Reliability in SCSE design. It has been way past 3 years requirements and 10 years for automotive. For the 15-25 years for military industry, does not have one product to prove that yet. The table 4 below is the result from the experimental facilities that executing this model for more than 10 years with zero disruption since it started. It has been delivered more than a Billon chips to end customer from the supply network and become sole supplier of the customer due to his superior deliverability on performance from Quality, Service, Delivery, and Price over the time. The suppliers are switching on and off dynamically and network level allocation are working normally as expected to archive the 400% volatility in historical record.

The back-to-basic approach in the best practice reveals one very important signal. The triple-A enterprise requirement is a rapidly adaptable infrastructure in all level with fast switching capability to suppliers.The back-to-basic approach is saying the engagement, disengagement processes of one supplier is to leverage the experience of IT evolution of the past 20 years but not the continuity of anyhow. Every branch is different therefore the supply chain heterogeneity is norm. Therefore back-to-basic approach is an effective strategy that quickly repeats the learning from 20 years IT evolutions in the past, "make it works" first then "make it productive". This research result explains why the poor B2B system integration result in Table 1 and where the executives mind map coming from. Accenture invented the "Fourth Party Logistics (4PL)" in 1996 but they abundant it for same reason. That is a right concept but the physics they embrace is wrong, and, it failed. SCSE try to define the physics right for the virtual enterprise but it needs IT facilities, right IT consultant players to accelerate the IT evolution to a right direction.

Year since started	Yr-1	Yr-2	Yr-3	Yr-4	Yr-5	Yr-6	Yr-7	Yr-8
Device.Supplier	4	8	10	10	8	14	14	17
Family-A Yield Inc.		10%	0%	2%	1%	3%	0%	0%
Family-A >3% event	0	1	2	0	1	0	0	0
Disruption(Family-A)	0	0	0	0	0	0	0	0
Family-B Yield Inc.			165%	6%	1%	4%	0%	-1%
Family-B >3% event			0	0	0	1	0	2
Disruption(Family-B)			0	0	0	0	0	0
Total >3% event	0	1	2	0	1	1	0	2
Total Disruption	0	0	0	0	0	0	0	0

Table 4. 10 years Zero Interruption since Started

9. Participatory production

The beauty of physics is capable to theorize the possible outcome of future evolution of nested society if this is right hypothesis. The solar system took tens or hundreds of millions of years to have the most of the debris either removed by the planets or moved into stable orbits resonant with those in the planets. Same as the nested society, the IT evolution will take time whether it is the public space, private space in personal development, or private space in virtual enterprise. The research team visioning the hypothesis therefore it has the result as SCSE from the efforts in last decade. This section is continued to extend that hypothesis after the 10 years success to the next decade. The SCSE is now in high maturity level on the virtual enterprise part that is covering well in the 1st dimension and 2nd dimension of the 3D model. It means the Enterprise Private Space (EPS) is matured both in physics and real practice in industries but the 3rd dimension to be connectable to the Private Personal Private Space (PPS) still weak and lack of sufficient volume data to fully validate the detail of the equation although the experimental facilities are working grate as expected.

The continue trend of the SCSE in virtual enterprise that foreseeable to the "Paired, Bidirectional decision-making flow" is Participatory Production. It has two levels as well in term of complexity. The level on is only cover the 1st and 2nd dimensions which is already validated in a very complicated supply chain that applying the process in this chapter. This section is to visioning the coming decade is the decade to fully validating the "Paired, Bidirectional decision-making flow" in both ways. The Social Network just starts to mature. It will take time for the large chunks of rock to condense into planets.

9.1 "Creativity" =" Innovation" if "R&D = [R@a] ∪ [D@b]"

The current Participatory Production evolution is just about to give high DoF for Integrated Device Manufacturing (IDM), which integrates resource vertically for effective innovation in the horizontal dimension. In this chapter, the SCSE is very solid in post-milestone C production; however, it is still lack of volume data in early milestone in low technology maturity stages. Fortunately, the physics tells us the "Virtual Enterprise Composition Process" is generic and applicable to full acquisition cycle. Hypothetically, the Research and Development in early stage could be a collaborative effort which is what the DoD already does for many years. Those are not common in commercial environments but the research team already sees more and more cases are observed although the result are not traceable or available yet to public. This section is assuming the equation of "R&D = [R@a] ∪ [D@b]" and the availability of the "Paired, Bidirectional decision-making flow" are both valid. Those assumptions will come to next level of Participatory Production in ecosystem as illustrated in fig 22. In the chart, there are couples of new elements that is not common in today practices,

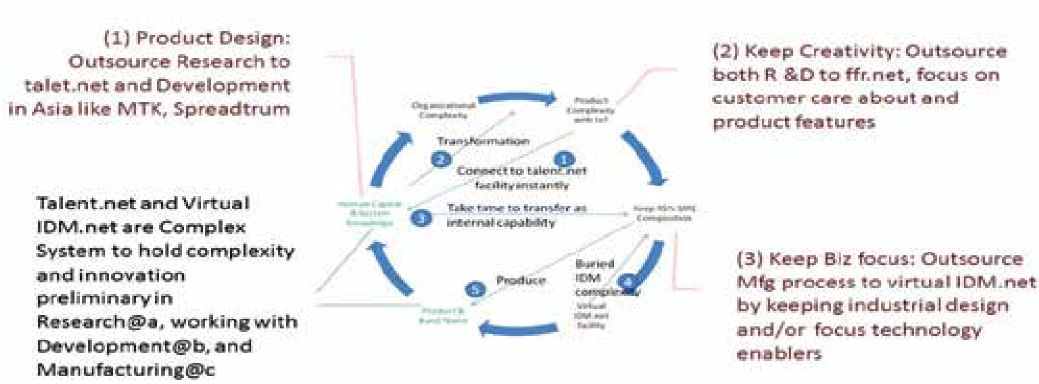

Fig. 22. Decentralization Invocation Cycle of Multi-tier supply chain collaboration

A virtual IDM facility: A public facilities can execute "R&D = [R@a] ∪ [D@b]" to lower the barrier of innovation cycle

- A Human Capital Pool with System Knowledge: A public facilities that provide PPS which is connectable to EPS to compile the 3rd dimension of the 3D model. The talent is grouped by system level knowledge such that the freelancer or SME is powerful enough to deliver full product therefore capable to earn their living by staying in the facility.
- Product complexity with Internet of Thing (IoT): the sensor network will give more life to the participatory production when sensor is on as an extension of human beings that can reach, see, or feel remotely.
- full Enterprise Life cycle Management available that allow the bottom up path of the "Paired, Bidirectional decision-making flow" actively form ecosystem

Those are new elements that are being theorized to be happened and validated in small volume facilities. Due to the huge complexity of adding those assumptions onto the nested society it has been causing huge challenges on system complexity itself, and computing power to conduct the responsive result back to the other end of the cloud. The research team has been identified at least 3 hardware components to be the hardware accelerator for the nested society infrastructure. The cloud computing, the physics of the nested society and the hardware are going to reform and redistribute the function being performed today in daily activities. Nothing change of the input, output of the production acquisition cycle but just the way of collaboration, and hardware, software to implement it will be very different.

9.2 Maturity and available facilities

The concept of Participatory Production is not new and it is originally from the purpose of the term "industrial accumulation", which is accumulation of thousands of small factories in a region of Suwa-Okaya area of Japan to perform Participatory Production (Kita, 2008). This chapter rename the Suwa-Okaya to "Participating Production" is to capture the nature of IT in connectivity and the bottom-up power of the IT revolution that the original name does not coves. During the revolution process, the power is continuously shifting to individual and barrier of the innovation that the IDM holding will be dramatically reduced.

The concept of about "Creativity" can be equal to "Innovation" is also not new when Mr. Pink, author of "A Whole New Mind: why right-brainers will rule the future" promotes the new paradigm of "Conceptual Age" where jobs are "high concept or high touch" can't be exported. In the increasing global competition in next decade, the research team foresees both ends of the economic forces are converging to the same trend but in the opposition direction. Fig 22 can demonstrates that trend in this way:

- Innovation leader, US represents: The" APPLE STORE" is a leader to demonstrate the power of networked organization and the success of iPhone, IPod, and IPad turns hardware into almost no value in competitive advantage sense. See the elements Apply holds in the fig 22: "Product and Brand Name", "System Knowledge", and key components in IDM such as A4 Processor and touch screen IP. In a iPad sells at $499, the EMS Foxconn only charges $11.2 to Apply, or only 2.2% of the total sale. COE of Acer, Nokia are stepped down. Blackberry, Lenovo are all under challenges. Apply is representing the "Concept Age" in enterprise but once the fig 22 like infrastructure is up to certain stage, SME or freelancer can do it too.
- Manufacturing leader, China represents: That is very interesting finding in our research team: China is going in the opposite direction standing where they are strong. Not mention that China has end 110 year US leadership and become world's top manufacturing nation with 19.8% of the world's manufacturing output vs. 19.4% in US (Merco Press, 2011). SME with less than 300 employees are 91.9% in China (Li and Cheng, 2003) Therefore the largest, fully plannarized channel in e-commerce such as overcrowded B2B2C market is in China (Kai, 2010). China is holding the creativity in a very large pool such as the 80% giant Alibaba (Matthews, 20008), and the clone phone in Shenzhen area. They do not have the system knowledge yet, but the government intends to skip the current generation to jump on the next generation such as clear energy and IoT.

Even though the overall maturity of the "Creativity" = "Innovation" is low but the commercial availability of the infrastructure already in place such as the "talent.net" and "Virtual IDM.net" in our experimental faculties and partners facilities. If the physics is right, the world is converging the way the physics calculates and somebody is picking up the position and become third-party service provider of the industry

10. System scalability and model spectrum

When WalMart is defined it is an IT company, it creates WalMart and sooner he becomes leader in retailer market with his innovative VMS model and efficient SCM. Similar in Amazon.com, when it is also defined Amazon.com an IT company around the end customer sale experience, it becomes the leader on online e-commence with innovative SCM on warehouse, logistics, and cloud computing facilities. Both of them are taking full advantage from IT and become industrial leader on his territory. This section is having the brief description of what kind of IT infrastructure can be the backbone of the SCSE architecture, EPS, and PPS to support the physics of running the nested society.

10.1 Business Gateway Model (BGM)

The rule of "Do Best, Outsource the Rest" has been modified to a new rule: "Cover what you do best, Link to the rest" for superior Agility (Jarvis, 2007). The IT infrastructures to support the virtual enterprise setup mentioned in the "3C Quick Adaptation process "of the PPS is presented in fig 23 below. The advantage of being a virtual enterprise to be on-demand in resources, conceptually, however, the word "ON-DEMAND" has two meaning-- agility and feasibility. Beside the OOTN in operation level in feasibility, the fig 23 below demonstrates the Business Gateway architecture on business level feasibility to deliver AGILITY of Supply Chain Network. The architecture on the right has similar structure to the ISO 7-layers protocol: a public platform in Lower Logistics layer (LLL) and a business domain specific Upper Private Layer (UPL). To put cash flow inside LLL, as one of the services of LLL provider, is an optimal business solution by proven model in Value-Added Logistic (VAL) player for 13 years in this case study. This design is extremely important for the long value chain for Participatory Production with high product value which means high outstanding inventory cost in the supply chain, or, freelancer type of virtual enterprise with super high leverage ratio in finance. The top layer in LLL is Business Layer which is the gateway layer and route operational activities upward to UPL via the OOTN layer above, which acts as a session layer. The gateway layer also route physical goods moving downward in LLL to next step of the chain with financial care option. That design serve the purpose to connection-oriented enterprise to provide the capitalist competitive 'freedom" to any enterprise to cascade resources into piecewise organization in an on-demand basis.

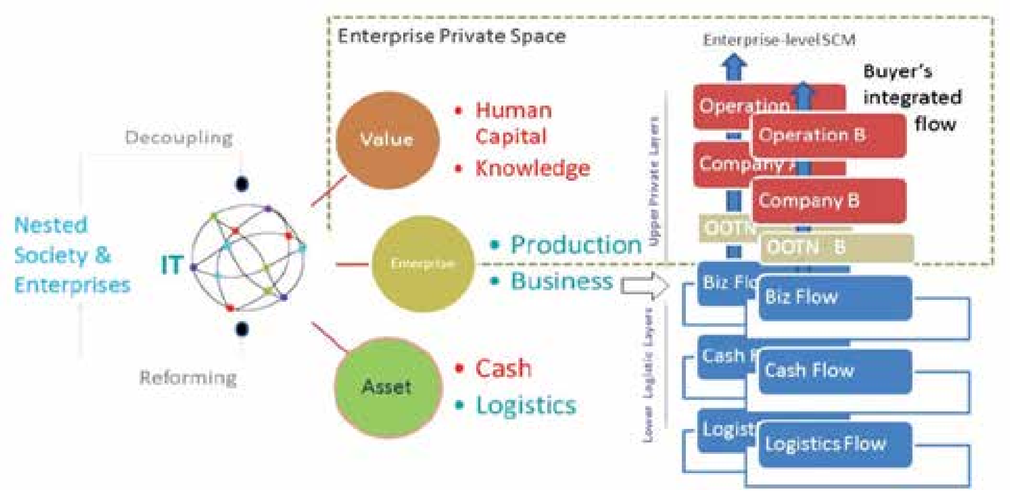

Fig. 23. The 1+6 flow model and its mapping to the ISO 7-layer like Model for Business Gateway

The BGM architecture is sponsored by the 3-tiers 1+6 flow model as showing on the left side of chart. The 3D model is constructing for the needs in the supply chain physics but it is breaking down into a 1+6 flows architecture when it comes to IT implementation. The 6 flows are "Logistics", "Cash", "Business", "Production", "Knowledge", and "Human capital" in the 2nd tier. The IT flow is the root on top. The 6+1 IT architecture is the core of the SCSE model and architecture in our research for the nested society in post-Internet era. The BGM is also modulated and the top UPL is exchangeable.

10.2 Personal Private Space (PPS)

When it comes to the 3rd dimension of the 3D model, the UPL of the BGM is replacing by a PPS module as illustrated in the fig 24 below but sharing the rest of the infrastructure of the BGM. The module design makes the UPL as real connectors between Virtual Enterprise and Freelancer, SME adapting the same model instantly. Small agent fee might apply for out-of-standard participants but it is small money comparing to current cost in connectivity as mentioned in equation (8). By adapting the 1+6 infrastructure any entity in nested society can "park" to any stage of the supply chain freely in value chain and "park" as in freelancer as participant of the virtual organization. Inside the PPS, it contains 4 modules: "Networking", "Personal Center", "Product Manager", and "Article Manager" which any PPS can grouped together to form VHRO, perform knowledge management, and even Production Development. Under the PPS, the knowledge is resident in the PPS and he has options to continue to sharpen his profile or group with others resources to shot for opportunities.

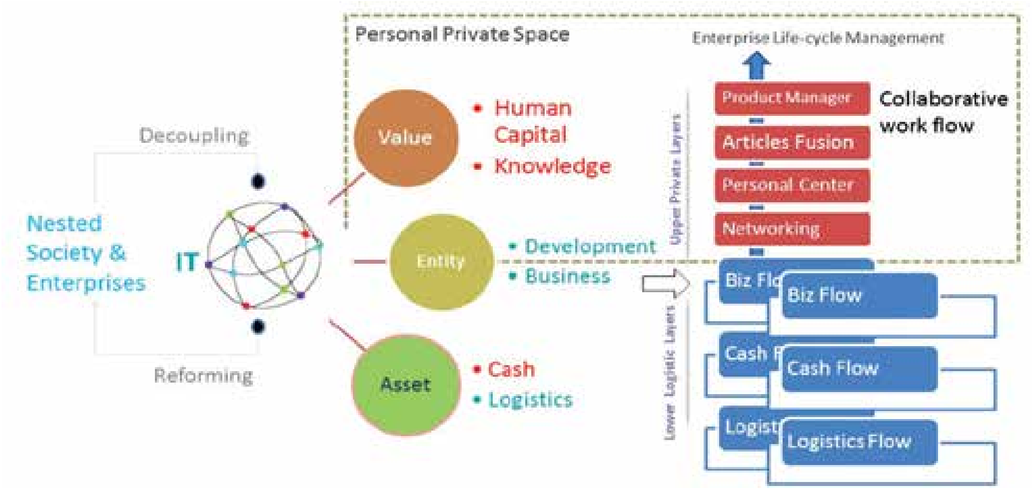

Fig. 24. The "Personal Development Space" over the Business Gateway Model

The rest of the PPS connected to in fig 24 is the reference ecosystem that a group of PPS are parked together as is an example of Talent.net community in fig 22 that provide full Enterprise Life Cycle (ELM) service to grow to conduct career development path. With the features in the reference ecosystem, each individual freelancer or SME is similar staying in a large company supporting departments such as Human Resource (Virtual Human Resource Organization here), Procurement (Supply Chain here), Facility (such as Warehouse here), Collaborative tools (Such as Forum, VoIP, HCT for product project management).etc. Without proper supporting resources, individual with PPS would not be practically having

full coverage in learning cycle to be competitive with the one who claim up the social ladder providing by enterprise.
Beside the administrative support in workflow collaboration, the ecosystem also act as the coordinator to fanning in new technology such as the Dynamic Gateway Group (DGG) for unify communication techniques, Internet of Things (IoT) for next generation sensor network, etc in Fig 24. The ecosystem is also facilitated what the member needs in common such as academic support from School in Supply Chain System Engineering (SCSE), and, bargaining with the 3PL to provide logistics services for lower Logistics Level portion of the PPS model. The distinguished design of this ecosystem is they are all adapting the same under layer IT model and users in the ecosystem are identical in architecture except the differentiable workflow embedded. LLL service provide who is IT compatible to the BGM gateway is connectable between Enterprise and directly to freelancer under BGM and PPS architecture.

10.3 Highly scalable supplier life cycle management

For large enterprise with a school of SME, freelancers they need to manage, it is always a big challenge where it is not big enough in business transaction to justify the cost of IT connectivity for workflow collaboration in current IT connectivity model. That is another main reason of causing that poor result in B2B system integration in Table 1. With the IT model and SCSE architecture in this chapter the problem can be easily resolved with the reference application in fig 25. It is a deal-mode, hybrid structure where the yellow color on the top-right corner is still the IT setup today roughly with 20% of supplier but occupying 80% of the revenue according to the 80/20 rule.

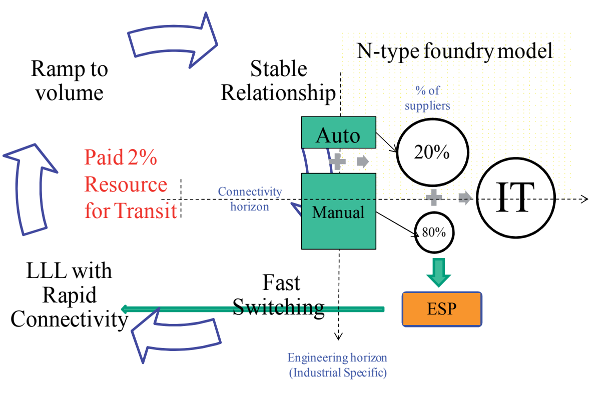

Fig. 25. The Supplier Life Cycle Management with dual routes

In the chart, it provides a cycle to manage the new suppliers. That explains the source of IT connectivity challenges. The 20% suppliers consume 80% of the resources and only leave the 20% for the rest. For company like Texas Instruments, ADI, or Players working in analog industry with thousands of product lines, that is the major bottleneck of business development and scale up when managing SME suppliers manually is an unsolvable solution in productivity.
The left side of fig 25 applying the SCSE architecture is the suggested solution to high product mixes industry with small qty in technological segment. The manually operating production line can adapt the model here with appropriated LLL service provide to kick

start the “Cover what you do best, Link to the rest” cycle in on-demand basis. Once a supplier is growing up in volume as indicated, it reaches the criteria of entering the “N-type” to become N+1 of the matured, IT pool. That completes the cycle seamlessly under the IT and cost constraints. The ESP is an Engineering Service Provider it could be either performing by internal Business Unit who responsible for the product line or hired contractor out of the dual cycle.

10.4 Low maturity level in facility supporting participating production

The IT infrastructure in this section has covered the full spectrum of the SCSE architecture and what it needs to connect to PPS therefore connectable to public space to complete the connectivity all the way to nested society. This is why the research team is “accidentally” find the redefined SCSE is the physics of the nested society when it has to resolve the SME part of the connectivity issue to work with SME especially the world is decoupling into smaller size of enterprise, both dominantly and globally. The IT model also demonstrates the scalability because of the “parking” concept under the same 1+6 flow model with the cost equation (9) and very unique feature such as “pretending” capability to allow dynamic skin to participate virtual enterprise activities via the VHRO model. Covering full ELM cycle and reference design in ecosystem empower individual to have equal power in IT to compete with large enterprise. The unique segregated network design is highly simplified the network size and complexity, hardware accelerated network provide real power of huge network, therefore IoT reference model is doable. The research team suggests the maturity of the current design in participatory Production is moderated after all years test and validation. It is just time to release to “production” to have more field test where the research team the maturity level in the field is low. Unfortunately, the study shows the higher the N-factor of the participatory Production, the stronger dependency of the public facility to make it success. However, it is also a bright side since it implies it is an attractive business to players who wants this market because of the positive loop of business model: High-N factor value chain pair with Participatory Production service provider is the winning pair of the global competition. That is opportunity.

11. Conclusion

The Participatory Production in this chapter representing the most complicated value network on the extreme side of private space and it has been demonstrated by peeling off layer by layer systematically through the document hierarchy. The System Engineering approach to conduct requirements, allocation, and deployment process is a self-explanatory, a best-practice approach like the DoD 4245.7-M standard to delivery framework for implementation. For enterprise, this chapter provides a rock solid path to transform into Triple-A virtual enterprise in an ultra high degree of freedom with on-demand human capital capability. For an individual, this chapter provides a full scalable career path from freelancer, SME to large enterprise in a participatory manner. For SCSE, the bidirectional pair in the 3D model determines its capability of being the physics of running a complicated complex operation. As a solution space including both enterprise and an individual, SCSE is nominated as the best “physics” candidate to running a nested society. On the other hand, the SCSE is the first user-centric framework that transforms the IT-centric languages into the operation domain languages to help an executive walking out of the mind map to make the right decision himself directly not through the IT or a consultant to clear out the accountability. Although the model in this chapter is only covering the detail in the post-milestone C of the acquisition cycle, the maturity of the overall SCSE and the associated IT model is sufficient as the first set of infrastructure to support the nested society to start the iterating process of improvement. This chapter concludes that the nested society as the end point of the IT revolution is set when the SCSE as the physics of running the nested society is confirmed.

Another purpose of this publication is to accelerate the fusion process of the IT revolution since the search team also suggests the review process of the academic system today is one of the barriers that slow the fusion process. If human capital crossing 3 disciplines is a natural barrier of any review board, it implies that any topic, paper, proposal that has more than 3 disciplines will be naturally denied since no eligible referees can be found adequately. Or, the topic like the physics of running the nested society, triple-A enterprise might take decades to bubble up to the top of the hierarchical tree in the current academic structure. That might explain why only 10% of samples in the literature research going the multiple disciplines approach. For a super scale management solution like that, DoD stepped out to carry out the DoD 4245.7-M standard is an good example to accelerate the complex solution. DoD is responsible for tax money therefore accountable to the project management to invent the standard for a defense project. But for the nested society or Participatory Production challenges today, who should be accountable in the government level to lead the way when the competitor of enterprise is an aggressive governor not the war between enterprises? The game rules have changed and a new game plan is required in the “FREE economy” campus.

12. Acknowledgments

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The Research on Stability of Supply Chain under Variable Delay Based on System Dynamics

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1. Introduction

With the swift development of modern science and network technology and fortified trend of economics globalization, the cooperation between supply chain partners is happening with increasing frequency and the cooperation difficulty increased correspondingly. Supply chain is a complex system which involves multiple entities encompassing activities of moving goods and adding value from the raw material stage to the final delivery stage. Feedback, interaction, and time delay are inherent to many processes in a supply chain, making it a dynamics system. Because of the dynamics and complex behaviors in the supply chain, the study on the stability of supply chain has become an independent research field only in last decade. At the same time, the great development of control theory and system dynamics provides an effective way to understand and solve the complexity of evolution in the supply chain system.

The research on stability of supply chain was put forward during the studying of bullwhip effect. According to the paper of Holweg & Disney (2005), the development of the research on stability of supply chain and bullwhip effect can be divided into six stages:

1. Production and Inventory Control (before 1958)

Nobel laureate Herbert Simon (1952) first suggested a PIC model based on Laplace transform methods and differential equations. In the model, Simon used first order lag to describe the delay of stock replenishment. Vassian (1955) built continuous time PIC model using Z transform. Magee (1958) solved the problems of inventory management and control in order-up-to inventory policy. At this stage, early PIC models were built based on control theory and the dynamics characteristics of PIC systems were discussed.

2. Smoothing production (1958-1969)

In the early 1960s, Forrester (1958, 1961) built the original dynamics models of the supply chain using DYNAMO (Dynamic Modeling) language. He revealed the counterintuitive phenomenon of fluctuations in supply chain. The methods Jay Forrester proposed have gradually developed into system dynamics methodology which is used to research on dynamics characteristics of supply chain systems. For the bullwhip effect in discrete-time supply chain systems, analytical expression of the change in inventory under order-up-to policy was presented based on certain demand forecasting method (Deziel&Eilon,1967). At this stage, the problems such as seasonal fluctuations in inventory and demand amplification had gained attention, but the terms "bullwhip effect" and "stability of supply chain" were not formally proposed, the emphasis of the academic research during this time was the traditional production management.

3. The development of control theory (1970-1989)

Towill (1982) built a relatively complete PIC system model without considering the feedback control loop of WIP (work in process). Bertrand (1980) studied the bullwhip effect and inventory change in an actual production system. According to the above researches, customer demand was assumed constant and productivity was random. Bertrand (1986) made further study on the bullwhip effect and inventory change in PIC system with feedback control.

4. Stage of "Beer Game" development (1989-1997)

Sterman (1989) suggested a system dynamics general stock management model after doing experimental study on "beer game" of MIT and analyzing 2000 simulation results based on system dynamics. Using continuous time equation, Naim&Towill (1995) discussed the feedback control and stock replenishment with first order lag in a supply chain model. The "beer game" and the corresponding problems in supply chain have been studied until now, recent research focus on information sharing and bullwhip effect in supply chain (Croson& Donohue, 2005). At this stage, system dynamics methodology has been deeply applied to the field of supply chain (Towill, 1996). Both system dynamics methodology and control theory emphasize the importance of "feedback control" to stability of supply chain, Sterman also considered the effects of decision behavior on fluctuation of inventory and order.

5. The further development of "bullwhip effect" (1997-2000)

Lee et al. (1997a, 1997b) pointed out the clear concept of "bullwhip effect" and identified four major causes of the bullwhip effect(demand forecast updating, order batching, price fluctuation, rationing and shortage gaming).From then on, academic circles set off an enthusiastic discussion centering on bullwhip effect. However, research papers during this period didn't make thorough study of feedback control (Holweg&Disney, 2005).Later studies showed that there were more than four significant bullwhip generators(Geary et al.,2006), but the views of Lee et al. have been widely received and quoted up to the present (Miragliotta, 2006).

6. The stage of avoiding bullwhip effect (after 2000)

The dynamic characteristic of supply chain represented by bullwhip effect had received considerable attention and many researchers shifted the focus of work to prevention of bullwhip effect at this time. Represented by Towill, Dejonckheere and Disney, a number of scholars brought control theory deeply to the research of bullwhip effect and related problems. They proposed APIOBPCS (Automatic Pipeline, Inventory and Order Based Production Control System) on the basis of methods and achievements from system dynamics (Disney&Towill, 2002, 2003a; Dejonckheere et al., 2003; Disney el at., 2004; Disney el at., 2006). The study on stability of supply chain has become an independent research field at this stage and the following studies are mostly done using control theory based on PTD (pure time delay) assumption. Up to now, the research of preventing bullwhip effect in multi-stage supply chain system has breakthrough progress(Daganzo,2004; Ouyang& Daganzo, 2006).

This chapter focuses on the stability of supply chain under variable delay based on System Dynamics methodology. First, we builds a single parameter control model of supply chain, By simulations and related analyses, a quantitative stability criterion of supply chain system based on system dynamics is proposed, this criterion evaluates stability by the undulate phenomenon and convergent speed. Then the stability characteristics in single parameter control model with two different delay structures (first order exponential lag and pure time delay) are discussed and the corresponding stable boundaries of the supply chain model are confirmed. Second, based on "system dynamics general stock management model" and control theory, the general inventory control model is built. Combined with the quantitative stability criterion of supply chain system proposed earlier, we analyze the complexities of the model under different delay modes. Finally we present the stable boundary and feasible region of decision and give our conclusions. This research indicates that delay structure is a key influencing factor of system stability.

2. Stability criterion of supply chain based on system dynamics

The differences of quantitative description of bullwhip effect result in different definitions of stability of supply chain. Lee et al. (1997a, 1997b) described qualitative evidence of demand amplification, or as they called it, the bullwhip effect, in a number of the retailer-distributor-manufacturer chains and claimed that the variance of orders may be larger than that of sales. In order to gain more insight on what is really happening, Taylor (1999) suggested analysis on both demand data (passed from company to company) and activity data (e.g. production orders registered within the company). The variance ratio is by far the most widely used measure to detect the bullwhip effect. It is defined as the ratio between the demand variance at the downstream and at the upstream stages (Miragliotta, 2006). As variance ratio is a static index, it is difficult to describe the complex and dynamic nonlinear system problems. In this section, we will not apply the variance ratio to measure the stability of supply chain system.

The theories and methods in nonlinear dynamics are applied to the studies on stability and bullwhip effect of supply chain and several criterions for describing and judging the stability of supply chain system are formed, such as peak order amplification, peak order rate overshot, noise bandwidth, times of demand amplification (Disney&Towill, 2003b; Jing Wang et al., 2004; Riddalls&Bennett, 2001; Zhang X, 2004;). The above criterions are used on the premise of testing the dynamic behavior of supply chain system. The test function is usually step function, pulse function or pure sine function, not the actual demand function. The purpose is to distinguish the effect of internal and external factors on stability of supply chain system. Some studies based on cybernetics directly adopt the distinguish methods in nonlinear dynamics, several methods are as following: Lyapunov exponent method; critical chaos; state space techniques (see for example Huixin Liu et al., 2004; Lalwani et al., 2006; Riddalls&Bennett, 2001; Xinan Ma et al., 2005). However, these methods are applied under a lot of constraint conditions and some parameters do not have specific economic meaning, sometimes it is difficult to obtain ideal result, but the basic idea of analyzing structure characteristics of the system to measure stability in cybernetics is worthy of learning.

Although the researchers have already pay attention to the problems of stability and complexity in supply chain system, they focus on revealing dynamic characteristic of the system and pay little attention to the problems such as stability criterion, stable boundary, and feasible region of decision of supply chain system. Qifan Wang (1995) measured the stability of system by analyzing open-loop gain, the method required all variables in feedback loop to be continuous and derivable and it is not applicable to high order nonlinear system. Sterman (1989, 2000) adopted the concept of "peak amplification" to describe the dynamic characteristics of system during the research on beer game and general stock management system, but he didn't give a specific stability criterion. Combining system dynamics and chaos theory, Larsen et al. (1999) described the stability of supply chain system from a chaos perspective, but the calculation of the study is a time-consuming and difficult task. Since now, there is no quantitative stability criterion of supply chain systems based on system dynamics, which seriously restrict the application of system dynamics into further research on stability of supply chain.

2.1 Single parameter stock control model of supply chain

2.1.1 Basic assumptions

The stock control model of supply chain in this section can be understood as one node along the chain, the basic assumptions are as following:

i. The downstream demand mode is uncertain, do not make prediction on it.
ii. There is no restriction on inventory capacity.
iii. There exists delay time (DELAY) in the sending of products to downstream and the average delay time is constant. The orders is described as WIP (work in process) before the products arrive.
iv. There is no reverse logistics, products can't be returned to upstream.
v. The supply chain members adjust orders according to demand from downstream and actual storage and maintain the inventory at a desired level.

2.1.2 Structure of the model

Figure 1 presents the single parameter stock control model of supply chain discussing in this section.

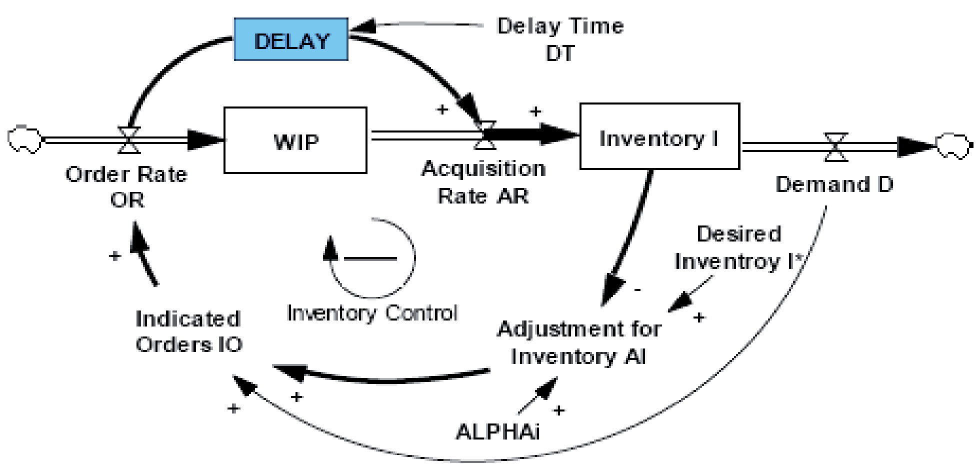

Fig. 1. The single parameter stock control model of supply chain

To facilitate the model description, the following notations are introduced:

OR: the order quantity at time t,

WIP: the orders placed but not yet received at time t,

ALPHAi: the rate at which the discrepancy between actual and desired inventory levels is eliminated, $0 \le \alpha_i \le 1$,

I^*: the desired inventory level,
I: the actual inventory level at time t,
D: the actual demand at time t,
AI: the adjustment for the inventory level at time t.

Figure 1 is built on the basis of the generic stock-management model proposed by Sterman (1989). The adjustments include two aspects: first, there exist two different delay structures (first order exponential lag and pure time delay) in the model; second, without consideration of WIP adjustment, the orders depend on demand and inventory adjustment. The above adjustments simplify the feedback control loop of inventory, making the system affected by just one negative feedback loop. Theoretical basis of the adjustment is the analytic method of "open-loop" in system dynamics methodology (Qifan Wang, 1995; Sterman, 2000).

The above model adopts the experimental methods to describe the individual behavior in a common and important managerial context. It contains multiple actors, feedback, nonlinearities, and time delay. The parameters of the order policy are estimated and the order policy is shown to explain the decision maker's behavior well.

2.1.3 Variable settings

As shown in figure 1, the indicated orders IO depend on demand D and adjustment for inventory AI ，so it can be defined as the sum of D and AI. There exists the transmission delay of orders between two successive levels and the delay mode can be represented by a standard function DELAY of system dynamics, including first order exponential lag and pure time delay. The desired inventory I^* is constant. As products can't be returned to upstream, the order rate OR must be positive. That is:

$$IO = D + AI \tag{1}$$

$$OR = \text{Max}(0, IO) \tag{2}$$

$$AR = \text{DELAY}(OR, DT) \tag{3}$$

Considering the stock and flow structure, the stock of WIP is the accumulation of the order rate OR less the acquisition rate AR. Similarly, the stock of inventory I is the accumulation of the acquisition rate less the demand D.

$$WIP = \int_{t_0}^{t} [OR(t) - AR(t)]dt + WIP_{t_0} \tag{4}$$

$$I = \int_{t_0}^{t} [AR(t) - D(t)]dt + I_{t_0} \tag{5}$$

where WIP_{t_0} and I_{t_0} are the initial values at time t_0, demand D is an external variable that can't be controlled.

The adjustment for the inventory results in the negative feedback mechanism which regulates the inventory. The adjustment is linear in the discrepancy between the desired inventory and the actual inventory. That is:

$$AI = \alpha_i (I^* - I) \tag{6}$$

where α_i is the rate at which the discrepancy between actual and desired inventory levels is eliminated, $0 \le \alpha_i \le 1$. The value of α_i represents the sensitivity of decision-maker to the gap between the desired inventory I* and actual inventory I. So the ordering policy can be described as follows:

$$IO = D + \alpha_i (I^* - I) \tag{7}$$

The ordering policy is based on the anchoring and adjustment heuristic (Tversky & Kahneman, 1974). Anchoring and adjustment heuristic has been widely applied to a wide variety of decision-making tasks in the field of control theory and system dynamics methodology (see for example Sterman, 1989; Riddalls & Bennett, 2002; Larsen et al., 1999; Huixin Liu et al., 2004). From (7) we can see that without demand forecasting, the ordering policy can be described by the single parameter α_i..

2.2 Dynamic characteristics analysis of system

2.2.1 Simulation design

Suppose the system is in a stable state at the initial time without fluctuation of inventory and order rate. When the system is disturbed by a small perturbation on demand, we can study the system behavior from the response curve of inventory or order rate. With reference to Sterman (1989) and Riddalls & Bennett (2002), the initial values (unit) of variables are presented in Table 1.The model is built using well-known system dynamics simulation software, Vensim PLE. The run length for simulation is 60 weeks.

WIP_{t_0}	I^*	I_{t_0}	DT	α_i	D_{t_0}
300	200	200	3	1	100

Table 1. Initial values of variables

The demand pattern is a step function, that is, the demand stays at an original level up to a certain instant and thereafter is increased to a shifted level. In this study, there is a pulse in the demand in week number 5, increasing its value to 120 units/week.

In the simulation, the decision parameter α_i is changed with a small decrement from 1.00 to 0.00 so as to simulate various ordering decisions. We concentrate on illustrating how minor changes in the decision parameter can affect the dynamics and stability of the system. System dynamics and relevant studies show that the size of step input of demand and the desired inventory will not affect the structural stability of the system (Croson & Donohue, 2005; Sterman, 1989, 2000).

2.2.2 Dynamics characteristics of system under first-order lag

If the delay structure of WIP is first-order lag, the (3) can be described as:

$$\frac{dAR(t)}{dt} = \frac{1}{DT}[AR(t) - 0R(t)] \tag{8}$$

When α_i changes continuously, the response curves of inventory I* and desired rate OR can always converge to the stable state, that is, I=I* and OR=D. Figure 2 shows two typical patterns of behavior in the converging process: smooth convergence (α_i=0.1) and fluctuant convergence (α_i=0.8). The simulation indicates that the transition between two patterns of behavior happens when α_i changes gradually, and when $\alpha_i \in [0, 1]$, there are only the above two typical behavior patterns.

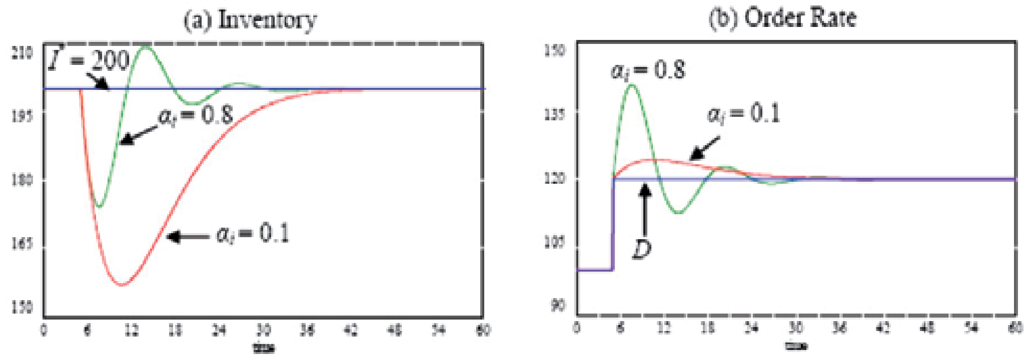

Fig. 2. The response curves of inventory and order rates under first-order lag (DT=3)

2.2.3 Dynamics characteristics of system under pure time delay

If the delay of WIP is pure time delay (PTD), then Eq. (3) can be described as:

$$AR\ (t) = OR\ (t - DT) \tag{9}$$

With a continuous change of α_i, the response curves of inventory and order rate show four kinds of behavior patterns: smooth convergence (α_i=0.1); fluctuant convergence (α_i=0.3); oscillation with equi-amplitude (α_i=0.52); divergent fluctuation (α_i=0.58).It is worthwhile to note that the above response curves appear to be oscillation with equi-amplitude only when α_i takes a special value (e.g. α_i=0.52) and this special value is a critical point at which the system curves begin to divergent. Figure 3 shows the response curves of inventory and order rates under pure time delay.

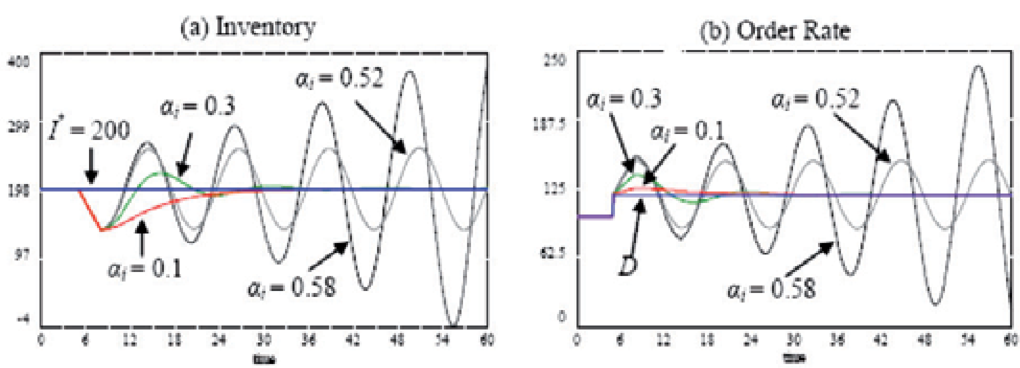

Fig. 3. The response curves of inventory and order rates under pure time delay (DT=3)

2.3 Stability analysis and criteria of supply chain

2.3.1 The definition of stability

There are different definitions of stability of supply chain. The traditional ideas of system dynamics state that only the behavior of smooth convergence is stable while the other fluctuate behaviors are unstable (Forrester, 1958). The main reason is that system dynamics methods focus on systems under first-order lag, and the studies on stability of supply chain emphasize the two above situations as shown in figure 2.

Scholars using control theory stress the importance of pure time delay. It is commonly accepted that fluctuant convergence is a gradual process of system to be stable and oscillation with equi-amplitude is a critical state of stable system. Based on the definition of stability in control theory and the methods applied by system dynamics, we propose the following definition of stability of supply chain system:

Definition 2.1: Suppose the system is stable at the initial time, when imposing a small step disturbance on demand, if the inventory (or order rate) can get stable at a certain equilibrium level after a period of time, then the system is stable.

There are two points to be stressed: first, the disturbance imposed to the system can't be too large, as the large disturbance may destroy the structure of real system and the simulation results can deviate from the actual situation of the system; second, the structure and surroundings of economic system may not always keep in a specific condition, so the system can only keep steady state within a limited period of time. In addition, computer simulation and calculation can't last for an indefinitely long time.

2.3.2 Stability criterion

Simulations show that for both first-order system and PTD system, when the decision parameter α_i change from 0.00 to 1.00, the behavior patterns of response curves of inventory and order rate undergo a gradual change from convergence to fluctuation without any sudden change as shown in figure 4. Therefore, we can test the stability of system from the appearance of response curve of inventory I or order rate OR.

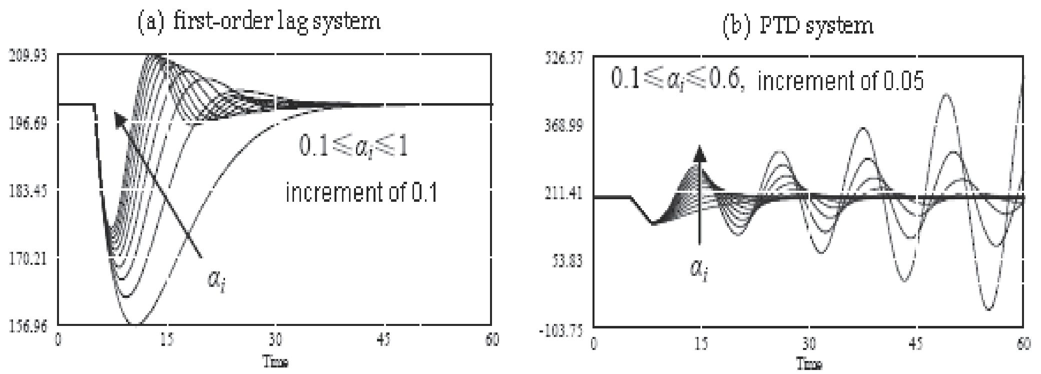

Fig. 4. The gradual change of response curve of inventory in two systems

The response curves shown in figure 4 can be abstracted to the general form of inventory fluctuation as shown in figure 5. As α_i takes different values, it is difficult to obtain the inventory curves changing laws in the stock control model. Therefore, we can't give a unified description on the fluctuating behavior by analytical methods. Although inventory fluctuation curves can well reflect dynamic behaviors of the system, it is difficult to make a horizontal comparison among the above curves.

As the underlying cause of the fluctuation of inventory is the deviation between actual inventory I and desired inventory I*, we use the area between the two curves to describe the fluctuation in supply chain. This practice is similar to the method in cybernetics that use "noise bandwidth" to make quantitative description of bullwhip effect (Dejonckheere et al., 2003).

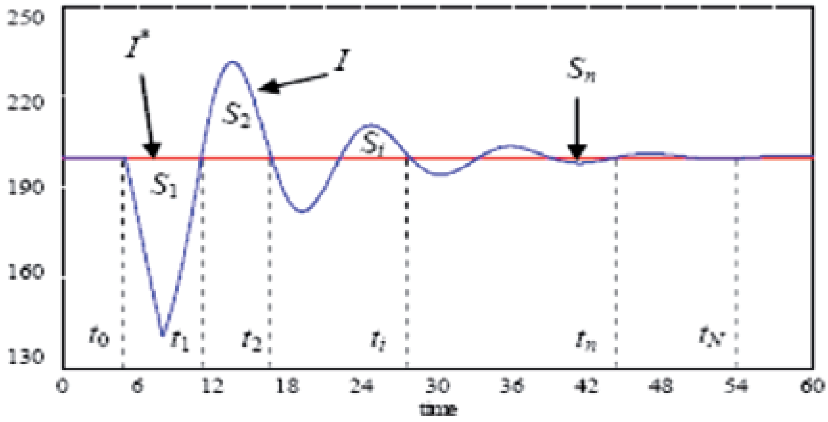

Fig. 5. The general behavior pattern of inventory fluctuation

As shown in figure 5, assuming that the inventory curve begins to fluctuate at time t_0, the inventory curve and desired inventory level intersect at time t_1, $t_2 \ldots t_i \ldots t_n$ in succession, and the area between two curves can be divided into several parts S_1, $S_2 \ldots S_i \ldots S_n$. Let the absolute value of the area between the two curves be s_n, that is:

$$s_n = \sum_{i=1}^{i=n} |S_i| \tag{10}$$

i. If the system is smooth convergence, then there is only one arc between the two curves:

$$s_n = |S_1| \tag{11}$$

ii. If the system is fluctuant convergence, then $|S_i| > |S_{i+1}|$ (i=1,2…n). There exists a natural number N, when $t \geq t_N$, $I \equiv I^*$, $|S_{N+1}| \approx 0$, and:

$$\lim_{n \to +\infty} s_n = s_N = \sum_{i=1}^{n} |S_i| = C \text{ (Constant)} \tag{12}$$

iii. If the system is oscillation with equi-amplitude, then $|S_1| = |S_2| = \ldots = |S_i| = \ldots = |S_n|$, and:

$$s_n = \sum_{i=1}^{n} |S_i| = n|S_1| \tag{13}$$

iv. If the system is divergent fluctuation, then $|S_i| < |S_{i+1}|$ (i=1,2…n) and:

$$\lim_{n \to +\infty} s_n = +\infty \tag{14}$$

To sum up, that is:

$$\int_{t_0}^{t_n} |I(t) - I^*| dt = \sum_{i=1}^{n} |S_i| = s_n \tag{15}$$

$$S(t_n) = \int_{t_0}^{t_n} |I(t) - I^*| dt \tag{16}$$

where S is the inventory integral curve. We can distinguish the behavior of the system according to the form of curve S, that is, S curve can be used as the stability criterion of the system.

The S curve can be obtained by the software, Vensim PLE. As shown in figure 6, we present the S curves of PTD system with different decision parameter α_i corresponding to figure 3(a) and the trend of S curve is the same as stated before. When S curve keeps a horizontal state or small-scope fluctuation around the horizontal line finally (e.g. α_i=0.1; 0.3), the system has returned the stable state. That is, the order meet the demand completely and I=I*.

According to the definition of stability and the above simulation analysis, the sufficient condition of the system to be stable is presented as following:

$$\lim_{t\to\infty} S(t) = C \text{ (Constant)} \tag{17}$$

Eq. (17) can be replaced by the following description:

Definition 2.2: Assuming t_0 is the starting time of simulation and t_F is the end time of simulation, if there exists t_s ($t_0 \le t_s \le t_F$) to make S(t) = C (Constant), then the system is stable.

The constant C can be understood as the system stable level, and the smaller the value of C, the better stability of the system. In the condition of step disturbances on demand and no prediction, C is positive.

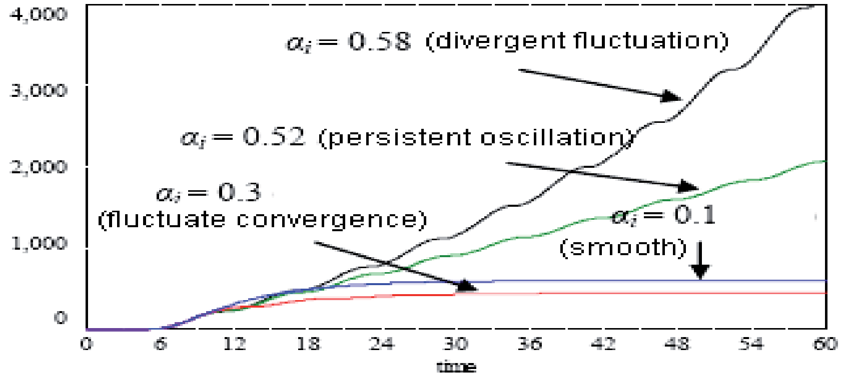

Fig. 6. Inventory integral curve under pure time delay (DT=3)

The value of S (t_n) directly reflects the deviate degree of the actual inventory I from the desired inventory I*. When the inventory is too high or too low, the holding cost and shortage cost will increase accordingly. Therefore, the S curve can intuitively measure the potential cost burden. On the other hand, the S curve reflects not only the general situation of system behavior but also the behavior change with time varying. Compared to stock variance, the S curve can measure the consequences of long time small-scope fluctuation (with small stock variance) of the system.

In conclusion, the S curve is able to reflect different behavior patterns in supply chain system. What's more, it is more convenient and visible to estimate the effect of fluctuation on inventory cost, ordering policy and forecasting. Besides, according to the definition of stability, the two behavior patterns of first-order system reflect that such systems are always stable, and this conclusion is in agreement with the results obtained from cybernetic methods. The relationship between typical behavior patterns and stability criterion is summarized as shown in table 2.

Inventory status	Sharp of S curve	Delay mode	System state
Smooth convergence	Be similar to exponential curve, base number∈(0.-1)	First-order; PTD	Stable
Fluctuant convergence	Be similar to exponential curve, base number∈(0.-1)	First-order; PTD	Stable
Oscillation with equi-amplitude	Be similar to straight line	PTD	Critical stable
Divergent fluctuation	Be similar to exponential curve, Base number∈(1,+∞)	PTD	Unstable

Table 2. Behavior pattern and its stability

3. Study on the stability of general inventory control system

In the last section, the dynamic characteristics of single parameter stock control system were discussed and we adopt the inventory integral curve as the criterion for stability judgment. Based on cybernetic studies, the dynamic behavior patterns of inventory in supply chain system are limited to the four typical behavior patterns shown in table 2 (Lalwani et al., 2006). Therefore, as a result of primary judge, the stability criterion proposed in the previous section is still valid for more complicated systems.

However, the single parameter stock control model has ignored the management of WIP and there is significant difference between theoretical model and managerial practice. Meanwhile, the previous simulation shows that the delay structure of WIP is a key factor of system stability. Therefore, it is of great theoretical and practical importance to study the effect of WIP on stability of supply chain system.

In this section, based on the generic stock-management model (Riddalls＆Bennett, 2002; Sterman, 1989), we add the WIP control loop to the previous model and built a general inventory control system with dual-loop and double decision parameters. Then the applicability of stability criterion is validated and the stability characteristics in double parameters control model with two different delay structures are discussed.

3.1 General inventory control system model

3.1.1 Basic assumptions

The general inventory control system model in this section can be still understood as one node along the chain, the basic assumptions are the same as i-iv described in 2.1.1. Considering the management of WIP, assumption v in 2.1.1 is changed as following:

v.The supply chain members adjust orders according to demand from downstream, actual storage and WIP, and maintain the inventory at a desired level.

3.1.2 Structure of the model

Figure 7 represents the general inventory control model:

Compared to the model in figure 1, there are three increasing variables:

WIP* the desired WIP,

AWIP the adjustment for WIP,

ALPHAwip (a_{WIP}) the rate at which the discrepancy between actual and desired WIP levels is eliminated, $0 \le a_{WIP} \le 1$,

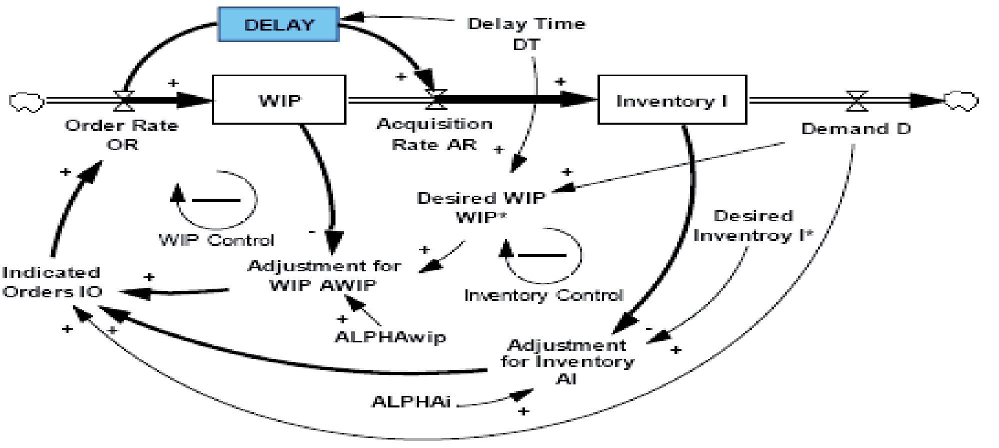

Fig. 7. The general inventory control model

3.1.3 Variable settings

Except the indicated orders, the settings of other variables in inventory control loop are the same as Eq. (2)-(6). To regulate WIP, a negative feedback mechanism is used. Adjustments are then made to correct discrepancies between the desired and actual inventory AI, and between the desired and actual WIP AWIP. Eq. (1) is adjusted as follows:

$$IO = D + AI + AWIP \tag{18}$$

Since WIP* is proportional to the demand as well as the delay time, we define the desired WIP as the delay time multiplied by the demand D. That is

$$WIP^* = D \times DT \tag{19}$$

$$AWIP = \alpha_{WIP}(WIP^* - WIP) \tag{20}$$

WIP* reflects the excepted value of future delivery situation. For production-oriented enterprises, WIP* reflects the supply capacity of upstream raw materials and production capacity on the node; for distribution firms, WIP* reflects the channel capacity between two nodes. In fact, there are multiple ways to measure WIP* and Eq. (19) adopts the linear approximation method. As this chapter focuses on structure factors, when imposing small disturbance on the system, the estimate precision of WIP* has little influence on the system stability.

According to Eq. (6) and Eq. (20), the ordering policy is defined below:

$$IO = D + \alpha_i (I^* - I) + \alpha_{WIP}(WIP^* - WIP) \tag{21}$$

This ordering policy is still based on the anchoring and adjustment heuristic. Compared to Eq. (7), Eq. (21) considers two anchoring points, that is, I* and WIP*. The ordering policy is one of the dual parameter decision rules. When α_{WIP}=0, figure 6 is equivalent to figure 1. Therefore, the general inventory control model covers the single parameter stock control model.

3.2 Dynamic characteristics analysis of system

3.2.1 Simulation design

Except the parameters involved in WIP, the initial values of the variables are the same as presented in 2.2.1. For the convenience of comparison, we set the value of α_{WIP} to zero, that is, the initial state of the model is equivalent to single parameter stock control model.

We still adopt the small disturbance for stability examination, and the demand function is unchanged:

$$D = D_{t_0}(1+\text{STEP}\ (0.2, 5)) \tag{22}$$

In the presence of small disturbance, the decision parameter α_i is changed from 1 to 0 with a small decrement Δi. At the same time, α_{WIP} varies from 0 to 1 with another small increment ΔWIP, the smaller the values of Δi and ΔWIP, the higher the simulation accuracy. The process can be described by pseudo-code below:

```
For (αi =1; αi≥0; αi =αi -Δi)
{   for (αWIP =0; αWIP≤1; αWIP =αWIP +ΔWIP)
{    Run Model   }
}
```

This section focuses on the interaction of dual-loop and verifying the applicability of stability criterion proposed in the previous section to general inventory control system. Through simulation, we can observe the behavior patterns of general inventory control system and test the system stability in the situation of complete rationality (α_i, $\alpha_{WIP} \in [0,1]$), then the simulation results can be compared with that of single parameter stock control model.

3.2.2 Dynamics characteristics of system

1. First-order system

The first-order lag is described as Eq. (8).

If $\alpha_{WIP}=0$, the general inventory control model is equivalent to single parameter stock control model. From the previous analysis, when α_i changes continuously, the response curves of inventory I* and desired rate OR can always converge to a stable state. There are only two typical behavior patterns: smooth convergence and fluctuant convergence.

If $\alpha_{WIP} \neq 0$, when α_i takes a particular value and α_{WIP} varies from 0 to 1 with a small increment ΔWIP, the shapes of response curves of inventory I* and desired rate OR are still restricted to the above mentioned two typical behavior patterns. The nearer α_{WIP} approaches 1, the more obvious the smoothness of response curves will be. The nearer α_{WIP} approaches 0, the more obvious the fluctuation characteristics of response curves will be. Figure 8 shows the response curves of inventory of the general inventory control system under first-order lag when DT=3 and α_i=0.4.

Together with figure 2, it leads to the conclusion that the general inventory control system under first-order lag is usually stable, but α_{WIP} and α_i have exerted totally different influence on the dynamics characteristics of system. This conclusion also hold in the case when delay time DT takes different values. Therefore, after preliminary analysis, WIP control loop has weakened the fluctuation characteristics of first-order system. The greater the value of α_{WIP}, the weakening more obvious.

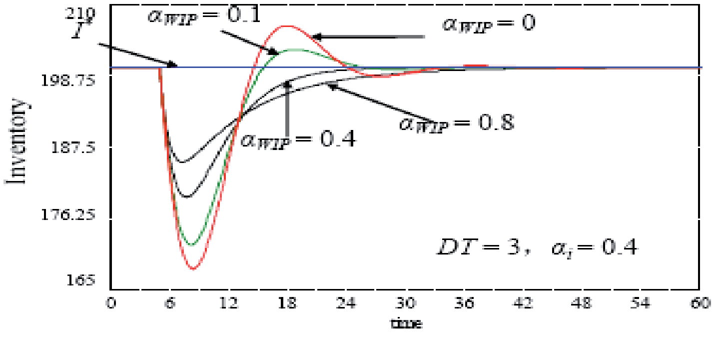

Fig. 8. The response curve of inventory under first-order lag

2. PTD system

The pure time delay is described as Eq. (9).

If α_{WIP}=0, the response curves of inventory and desired rate will not always converge to stable state with a continuous change of α_i and there are four kinds of behavior patterns: smooth convergence; fluctuant convergence; oscillation with equi-amplitude; divergent fluctuation. Therefore, the system exhibits critical stable state and stable boundary.

If α_{WIP}≠0, when α_i takes a particular value andα_{WIP} varies from 0 to 1 with a small increment ΔWIP, the shapes of response curves of inventory I* and desired rate OR are still restricted to the above mentioned four typical behavior patterns. Figure 9 shows the response curves of inventory of the general inventory control system under pure time delay when DT=3 and α_i=0.58.

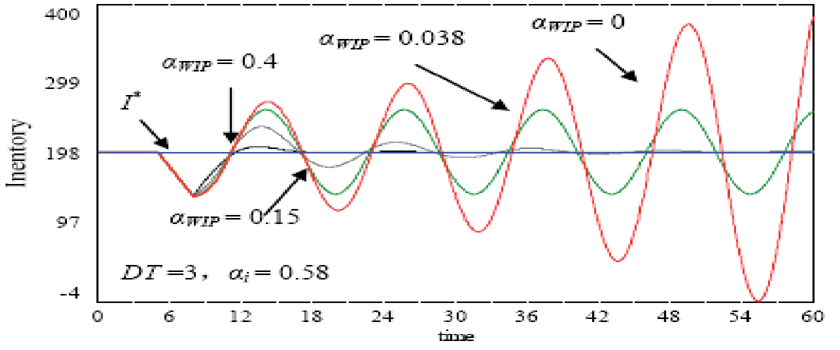

Fig. 9. The response curve of inventory under pure time delay

Although single parameter stock control model exhibits divergent behavior when α_i=0.58, the general inventory control system model with double decision parameters can have convergent behavior as the value of α_{WIP} increases. Together with the response curves in figure 3, it is concluded that the general inventory control system under pure time delay is not always stable, and the parameters α_{WIP} and α_i show entirely opposite effects on the dynamics characteristics of system. For certain single parameter systems that are unstable, by adding decision parameter α_{WIP} and enhancing WIP control loop, the systems can reach stable state. Thus, WIP control loop has also weakened the fluctuation characteristics of PTD system.

3.3 Stability analysis of general inventory control system

3.3.1 Stability criterion

Following definition 2.1, the inventory integral curve is used as the stability criterion of supply chain system. This stability criterion can be generalized to the general inventory control system model with double decision parameters only when the following conditions are satisfied:

First, the response curve of inventory I (or order rate OR) is limited to the range listed in table 2;

Second, the response curve of inventory I (or order rate OR) is gradually changing as the decision parameters α_{WIP} and α_i change, and there is no mutation in this process.

As the WIP control loop has in fact weakened the fluctuation characteristics of single parameter system model, the behavior patterns of general inventory control model will not go beyond that of single parameter stock control model. Therefore, the behavior patterns of system listed in table 2 still apply to general inventory control system model.

Figure 10 shows the traverse of the response curve of inventory under different delay modes. Through the analysis of figure 4, figure 8 and figure9, the increased α_i will increase the fluctuation while the increased α_{WIP} will cushion the fluctuation both in first-order system and PTD system after disturbed, and the processes are smooth. Together with figure 10, the system hasn't appeared other new behavior patterns and mutation points.

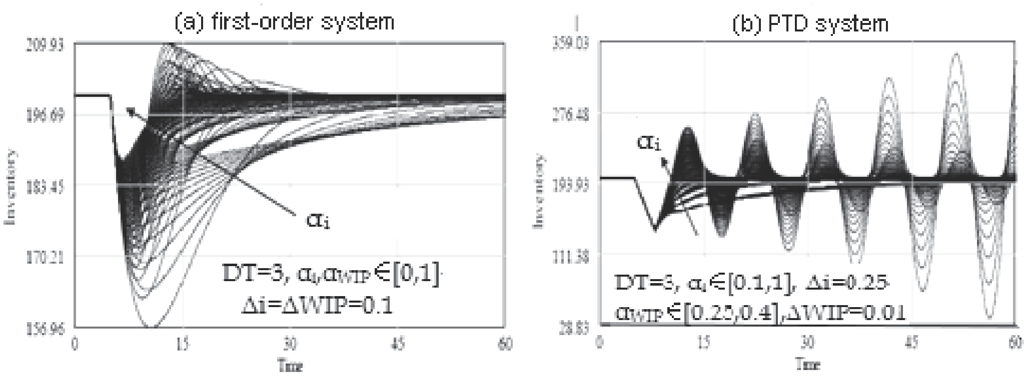

Fig. 10. The traverse graph of inventory curves of general inventory control system model

In conclusion, the dynamic patterns and stability criterion obtained from the analysis of single parameter stock control system model still hold in the general inventory control system model under first-order lag and pure time delay.

3.3.2 Stability of first-order system

This research indicates that the first-order system is always stable and the two decision parameters have different effects on system stability. Figure 8 shows that the system stability is increasing with the increase of α_{WIP}. Similarly, we obtain the S curve of the general inventory control system model under first-order lag (see figure 11). According to definition 2.2, the constant C represents the stable level of system. Figure 11 shows that the value of C will decrease when increasing α_{WIP} under the condition of the given delay time and α_i. But there exists a minimum C*, when the system achieves C*, increase of α_{WIP} won't help improve system stability. Let C* be the minimal stable level which is determined by α_i with a given DT, $\alpha_{WIP,}$ then determines whether the system can achieve the stable level C* or not. Before the system achieves the stable level C*, the response curve of inventory appears to be fluctuant convergence, but when the system has achieved the stable level C*, the response curve of inventory tends to be smooth convergence, and the increase of α_{WIP} can only reduce the deviation between actual inventory I and desired inventory I* and postpone the stabilizing time of the system.

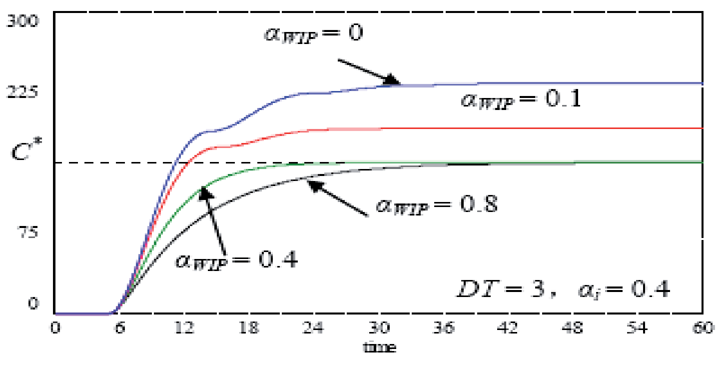

Fig. 11. Inventory integral curve of general inventory control model under first-order lag

Further analysis indicates that there is an exclusive α_{WIP} corresponding to α_i (α_i, α_{WIP}∈[0,1]) to make the system achieve the stable level C*. Based on the analysis, the minimal stability boundary of general inventory control model under first-order lag with different DT is obtained as shown in figure 12 (x-axis is α_i, y-axis is α_{WIP}). We use S* curve to express the minimal stability boundary, each point on the curve can guarantee that the system will achieve the stable level C*.As shown in figure 12, the index of S* represents the value of DT.

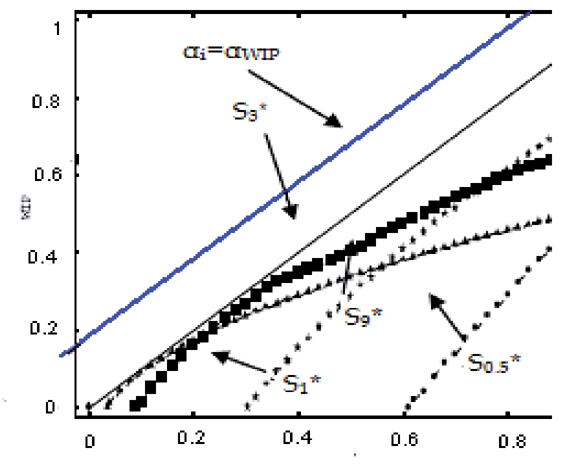

Fig. 12. The minimal stability boundaries of first-order system under different DT

The adjusting parameters (α_i, α_{WIP}) in the lower right region of S* curve will cause the response curve of inventory to be fluctuant convergence while the parameters in the upper left region guarantee the curve to be smooth convergence. The traditional views of system dynamics consider that fluctuant convergence is unstable and only smooth convergence is stable. Therefore, the lower right region of S* curve is the unstable region in the traditional sense. Nonetheless, the actual decisions are influenced by many subjective and objective factors, and the adjusting parameters (α_i, α_{WIP}) may not be the point in the S* curve.

When DT≥1, S* curve is nonlinear, otherwise, S* curve is approximate linear and all S* curves are in the lower right region of an oblique line ($\alpha_i=\alpha_{WIP}$). In conclusion, there exists the adjusting parameters (α_i, α_{WIP}) that make the first-order system achieve the stable level C* only when $\alpha_{WIP}\le\alpha_i$. As α_i and α_{WIP} reflect the attitude of decision-maker on the differences, that is, (I* - I) and (WIP* - WIP), the condition that α_{WIP} is less than or equal to α_i represents the rational choice of decision-maker. In other words, most decision-makers think that the actual inventory is more important than WIP and they pay more attention to the difference between the actual inventory and the desired inventory.

Since all the adjusting parameters (α_i, α_{WIP}) that make the first-order system achieve the stable level C* exist in the lower right region of the oblique line ($\alpha_i=\alpha_{WIP}$), $\alpha_{WIP}\le\alpha_i$ is a necessary condition for first-order system to achieve the minimal stable level and this condition is determined by the structure of first-order system itself. Whether the system can achieve the minimal stable level or not depends on the subjective judgment of the decision-maker and the external and internal factors. Let the oblique line ($\alpha_i=\alpha_{WIP}$) be the conservative stability boundary and the condition that α_{WIP} is less than or equal to α_i be the conservative stability condition. As the conservative stability condition is the result of rational choice, the oblique line ($\alpha_i=\alpha_{WIP}$) can also be called rational stability boundary.

3.3.3 Stability of PTD system

It is known that the PTD system is not always stable and the parameters α_{WIP} and α_i show opposite effects on the dynamics characteristics of system. Like the single parameter stock control system model under pure time delay, we can obtain the critical stable points (α_i^{DT}, α_{WIP}^{DT}) of general inventory control system under pure time delay by finding the critical stable state of inventory curve with a given DT. Therefore, the critical stable condition of general inventory control system under pure time delay is defined as following:

Definition 3.1: Suppose the general inventory control system under pure time delay is stable at the initial time. With a given DT, when imposing a small step disturbance on demand, if there exists the decision parameters (α_i^{DT}, α_{WIP}^{DT}) that can keep the inventory curve to be oscillation with equi-amplitude, then the state is called critical stable state, and (α_i^{DT}, α_{WIP}^{DT}) is the critical stable point of the system under the given DT.

Unlike the single parameter stock control system model, the critical point (α_i^{DT}, α_{WIP}^{DT}) of the general inventory control system model is not unique. Through the traversal simulation of α_i and α_{WIP} under certain DT, several critical stable points are found. After connecting these points in the plane that takes α_i as horizontal axis and α_{WIP} as vertical axis, we obtain the stability boundary of PTD system named s curve. Figure 13 shows some s curves under different DT and the index of s represents the value of DT.

Furthermore, s curve is approximate to linear property and the lower right of s curve is the unstable region. That is, the points (α_i, α_{WIP}) in the lower right of s curves will lead the inventory curve into divergent fluctuation, and the points in the upper left of s curves will make the inventory curve convergent. As DT increases, s curve tends to converge toward the oblique line: $\alpha_{WIP}=\alpha_i/2$. Simulations show that the oblique line ($\alpha_{WIP}=\alpha_i/2$) is the upper bound when s curve moves up to top left with DT increasing. Thus, it can be concluded that the upper left area of oblique line ($\alpha_{WIP}=\alpha_i/2$) is the stable region which is independent of delay (IoD), and the oblique line ($\alpha_{WIP}=\alpha_i/2$) is defined as IoD stability boundary of PTD system. Since the models of supply chain in this research take no account of predictions, the conclusions above not only validate the results obtained by cybernetic method from the point of view of system dynamics, but also prove that IoD stability boundary is only determined by systemic structure.

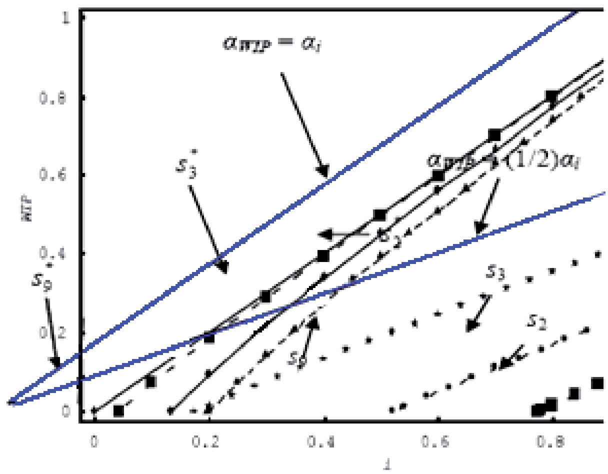

Fig. 13. The stability boundaries of PTD system under different DT

Meanwhile, there also exists a minimal stability boundary of PTD system under the given DT. The minimal stability boundaries of PTD system under different DT are shown in figure 13. The simulation results show that the greater the DT value, the more obvious the linearity of s* curve, when DT≥9, s* curve and the oblique line ($\alpha_{WIP}=\alpha_i$) nearly coincide. Similarly, $\alpha_{WIP}\leq\alpha_i$ is also the necessary condition for PTD system to achieve the minimal stable level and the oblique line ($\alpha_i=\alpha_{WIP}$) is the conservative stability boundary or rational stability boundary of PTD system.

3.3.4 Discussion

The main difference between the general inventory control model and the single parameter stock control model are the WIP control loop and the ordering strategy. The single parameter decision rule is marked IO_1 and the two-parameter decision rule is marked IO_2, that is:

$$IO_1 = D + \alpha_i(I^* - I) \quad (22)$$

$$IO_2 = D + \alpha_i(I^* - I) + \alpha_{WIP}(WIP^* - WIP) \quad (23)$$

As compared with Eq. (22), Eq. (23) contains the new WIP adjustment. From the static perspective, IO_2 is greater than or equal to IO_1 under the same initial conditions and the demand will be enlarged. But through the dynamic methods, it is found that the two-parameter decision rule actually restraints the demand amplification and reduces the fluctuation of inventory and order rate because of the WIP control loop. Some studies on stability of supply chain based on dynamic methods suggest that the increase in α_{WIP} and decrease in α_i can contribute to improving the stability of the system (Disney et al., 2004; Riddalls et al., 2000; Sterman, 1989), but the findings of this section indicate that the above policies are effective only in the lower right region of the minimal stability boundary s* curve.

Second, neither first-order system nor PTD system has the same rational stability boundary. This rational boundary conforms well to the results of beer game (Sterman, 1989). Although Sterman adopted first-order lag as the delay mode when modeling the beer game, the participants hadn't known the delay mode and they didn't estimate the delay mode of WIP control loop. Therefore, the conservative stability boundary or rational stability boundary actually has nothing to do with delay.

Finally, the minimal stable level C* proposed in this section is relevant to the convergence properties of inventory fluctuation, it can't guarantee the minimum cost. From the point of view of cost optimizing, there also exists an optimal boundary which depends on the ability of inventory management and the composition of inventory cost.

4. Conclusions

To conduct quantitative analysis on the stability of supply chain system with Order-Up-To (OUT) policy, we first built the single parameter stock control model of supply chain. By simulation analysis, a system-dynamics-based criterion for stability judgment is proposed. With simulation, the criterion can be used to describe the nonlinearities of supply chain system with 1st order exponential lag and pure time delay (PTD).The criterion can also be used to judge the influences exerted on supply chain stability by decision behavior. The simulation demonstrates two different results. Firstly, the 1st order system is usually stable, but there is fork effect as decision parameter changes. Secondly, there is a critical stable bound in PTD system, which determines the feasible filed of decision.

Then a general inventory control system model is proposed. The model is provided with two typical delay modes: fist-order exponential delay and pure time delay. According to the concept of stability and stability criterion proposed in the previous section, stability borders with different meanings are confirmed, which integrate the results derived from different research methods. It is concluded that the stability of inventory control system is mainly decided by the features of feedback systems, the subjective decision and environment take their effects based on the feedback systems, and information sharing is propitious to increase the stability and weaken bullwhip effect of supply chain system.

This research adopts the method of system dynamics and takes the delay modes as key point to discuss stability of supply chain system. Although preliminary achievements have been made, further research needs to be done on the stability of supply chain. With the development of research, we wish this chapter will contribute to supply chain management theories and practices.

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31

Simulation Study on Dynamic Characteristics of VMI Supply Chain Inventory System Based on Multi-Agent System

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1. Introduction

Supply chain integrates supplier, manufacturer, wholesaler, retailer and end user to a system by logistics, business flow, information flow and cash flow. The enterprises in supply chain system are horizontally integrated and formed a strategic cooperative partnership. The supply chain inventory system is a sub-system of supply chain system. The purpose of inventory management of supply chain is to establish an effective method for controlling inventory by means of cooperation and coordination of various parties related to supply chain.

Design, control and effective operation of a system are based on our good grasp of the inherent law and characteristics of the system through the analysis and study of it. To analyze and study a system, first a model of the system should be set up, which is called modeling. The model is an abstract, intrinsic and simplified description of the real system. In a sense, the process of scientific research is the process of setting up a model of real world.

Usually, there are three approaches to the analysis and study of a system: analytic method, experimental (test) method, and modeling and simulation method. Analytic method needs to set up a mathematical model of the system, which means firstly equations of the system such as algebraic equation, ordinary differential equation, partial differential equation, difference equation or statistics equation are set up through identifying parameters of the system, and then analytical solutions are obtained by solving those equations. Analytic method is generally applicable to linear systems or some particular non-linear systems because it describes the behavior and characteristics of the system instead of real structure of the system. It is difficult to solve equations of complex non-linear system to obtain analytical solutions. Some systems are too complicated to set up their mathematical models. Therefore, the application of analytic method is limited.

Experimental method needs to set up an entity model (or physical model) of the system because it is hard to conduct experiment directly with real system. The adoption of experimental method is comparatively time-consuming with high cost, and the implement is impractical and sometimes even impossible.

Modeling and simulation method refers to a series of complex activities, such as setting up a model of real system and simulating on the computer. Modeling and simulation method is to simulate real system with a model. First a simulation model of real system is set up, then simulations or experiments are conducted on computer to pre-perform or re-produce the operation process or operation rules of the system. Modeling and simulation method is of great flexibility, by which those systems that direct experiments are impossible to be made on could be simulated. It could save a lot of resources and expenses, greatly improve people's abilities to study and analyze complex systems so that it is a brand-new and effective method of systematic study and analysis and has become an important method of studying system behavior, evaluating various kinds of strategy and tactics, and diagnosing, analyzing and designing system.

It is mainly made up of three basic parts in the modeling and simulation system: real system, model and computer, among which modeling and simulation are two basic activities. Modeling is mainly concerned with the relationship between real system and model. By observing real system, an abstract, simplified, approximate model of real system is obtained, ignoring secondary factors and undetectable variables. In this process, the system is simplified according to the purpose of modeling and the essential characteristics of the real system. Hence in the modeling process it is important to single out and tackle the principal contradiction and the principal aspect of the contradiction. Model is the basis of simulation in that correct result of simulation could be got only when correct model and data are set up. Simulation mainly studies the relationship between model and computer, writes computer program and operates it on the computer according to model set up in the modeling process, and then analyzes the dynamic characteristics and operation rules of the system according to computation results.

Modeling and simulation method based on multi-agent system is a new type of computer modeling and simulation method appeared in 1990s and has been widely used in fields like physics, mechanical engineering, biology and social sciences.

Supply chain inventory system is a strong non-linear dynamic complex system. Its whole behavior mode results in the interaction among node enterprises which constitute the system. To study the dynamic characteristics of supply chain inventory system is to know well the operation rules of the system, with both individual and whole dynamic characteristics being the concerns. The main factors that influence the dynamic characteristics of supply chain inventory system are as follows: external demand, lead time, information, system structure and interactive operation mechanism inside of the system.

In this paper, the characteristics of multi-agent system and supply chain system are analyzed and compared, the dynamic characteristics of supply chain system is analyzed with a tool of modeling and simulation method based on multi-agent system, a multi-agent system model of multi-stage supply chain inventory system is sets up, and the dynamic characteristics of VMI supply chain inventory system is studied and analyzed by simulation on the Swarm Platform.

2. Multi-agent system

Agent technology was originated from the series studies on distributed artificial intelligence carried out by researchers in MIT in 1970s. At present, agent technology has been adopted in both the computer and non-computer fields. With the rapid development of agent theory and technology, it is increasingly difficult to give a strict and clear definition of the concept of agent which is universally accepted and is applicable in all fields. So far, there is no unified and exact definition of agent.

The basic idea of agent technology is to make software imitate social behavior and cognition of human beings, that is to say the organizational forms, cooperative relationship, evolutionary mechanism, the way of thinking and cognition, the way to solving problems as well. Compared with corresponding traditional Objective ideas, the concept of agent is more knowledgeable, proactive and cooperative, and is more powerful in solving problems, and is more autonomous.

Although different scholars give different concept and definition of agent, it is believed that agent has the intelligent property of imitating human beings. Its attributes are as follows:

1. Autonomy: Based on its belief, desire and intention (BDI), it can make autonomous decision and take proactive action according to its internal state and perceived environmental information, without control and operation from outside world. Besides, it has the ability to control its behavior and internal state. Autonomy is the embodiment of agent intelligence.
2. Proactive: It shows great initiative in taking proactive action towards intend goal according to internal state and external environment.
3. Reactivity: it can perceive the change of environment (including other agents) and make immediate response to the change.
4. Adaptability: It can gradually adapt itself to environment. It can learn and improve from experience to expand or amend its local knowledge.
5. Sociality: It can interact with other agents. It has interface and means to effectively connect with other agents and to form multi-agent groups to complete the task intended jointly through information exchange, collaboration, undertaking task, job sharing and cooperation, and distributed cooperative solving.
6. Persistence: It can keep operating at least in a rather long period of time.

Also, it has attributes such as honesty, compliance, sensibility, cooperativeness and mobility.

We call entities which possess all the above mentioned attributes or principal attributes as agent. Although there is no precise and unified definition of agent, we present the definition of agent in the light of the above analysis and discussion for the sake of convenience.

Definition of agent: Agent is defined as a certain abstract of a real system (it is generally an abstract of physical entity of the real system, but may be an abstract of the function of the real system as it is required), an entity possessing certain intelligence, which means it can acquire material and information to realize the goals for itself, draw inference and make decision, take proactive action, and interact with environment and other agents.

Multi-agent System is the forefront field in the distributed artificial intelligence (DAI). The idea of multi-agent system appears in Herbert A. Simon's work, Administrative Behavior (Simon, 1976). He argues in the book that a large system that organizes many individuals could make up for the deficiency due to individual's limited working capability. Similarly, the division of labor and each individual in charge of a special task could make up for the deficiency due to individual's limited capability of learning new task. The organized flow of information among administrative organizations could make up for the deficiency due to individual's limited capability of dealing with and making use of information to make decision. Although Simon's theory is in regard to human society, it lays a foundation for the basic idea of multi-agent system: the intelligence of individual agent is limited, but we could organize agents to form multi-agent system through proper systematic topology. In this way, individual agent's deficiency is made up for and the capability of the whole system surpasses that of any individual agent.

Definition of Multi-agent System : Multi-agent system is defined as a system made up of many agents. It is a loosely-coupled network system of many agents formed to solve complex problems which are unsolvable by individual agent and go beyond the individual agent's capability and its scope of knowledge.

Each agent in multi-agent system could act on itself and environment, communicate with other agents, operate asynchronously, and interact with each other to finish tasks by collaboration and cooperation.

Modeling and simulation method based on multi-agent system is suitable for the study of distributed non-linear complex system with medium-scale. Medium-scale indicates that the number of agents that compose the system is neither too many nor too few. A system made up of very few agents is called simple system and could be studied by traditional mathematical methods.

A system with enough agents, for example gas in a container, could be studied by statistic methods. Distributed means the control of the system is distributive, and there is not a global control. The time control mechanism and the problem solving capability of the system and so on are also distributive. Non-linear refers to the interaction of components in the system. It does not conform to the principle of superposition, which means the whole does not equal the sum of the parts.

Compared with the traditional process oriented or object oriented simulation technology, modeling and simulation based on multi-agent system simplifies the modeling structure, reduces the complexity of modeling logic, enhances the capacity of intelligent behavior simulation, the capacity of concurent simulation, and the capacity of interactive and collaborative simulation. At the level of modeling and analysis, it is much more abstract and in particular applicable to modeling and simulation of systems with high complexity and inherent distributivity.

It must be pointed out that modeling and simulation technology based on multi-agent system is not a substitute for traditional technology (for example, nonlinear dynamics, system dynamics and game theory, etc.), instead it synthesizes and makes further improvement on the traditional research technology and techniques. Technically, modeling and simulation technology based on multi-agent system is an advanced technology in which agent is its key concept and multi-agent system its frame, and which is formed as a synthesis of traditional research technology (such as mathematical methods), advanced computer science and technology (such as computer network technology, distributed technology etc.), artificial intelligence (such as neural network, pattern recognition) and game theory. Compared with other traditional technology, it is more effective, more advanced and more promising.

In short, modeling method based on multi-agent system uses modeling thought and methodology that combine reductionism with holism. Its thought process is holistic thinkingreductive thinkingholistic thinking. It starts from holism's way of thinking, knowing well what to analyze in the system in a macroscopic way. Next it uses reductionism's way of thinking, resolving the system from the whole to individuals. Then it uses holism's way of thinking, assembling these individual elements according to the constituting mechanism. It combines individuals into a whole and comes to a comprehensive conclusion by analyzing evolution law of the system.

3. Characteristics of multi-agent system

"To operate in part while to share by the whole" (H. Wang, 2003) is at the very core of multi-agent system. The characteristics of multi-agent system are as follows:

1. Interactivity

Interactivity is the most important characteristic of multi-agent system which is the principal feature that distinguishes multi-agent system from other characteristics. Multi-agent system could describe complex group interaction mode and realize group interaction at a high lever, such as collaboration, coordination, cooperation, consultation and game playing etc.

Coordination means the agents with different goals reasonably arrange their goals, resources and so on to adjust their own behaviors to realize their own goals to the utmost. Coordination is required in multi-agent system.

Collaboration means many agents work together for their common goal.

Cooperation means that many agents cooperate to complete common goal by coordinating their own behaviors. It is a special type of coordination.

Consultation is that all the agents involved in interaction reach an agreement accepted by all.

Agents in multi-agent system intercoupled each other with rich relations, and interact in groups to form rich systematic structure. The relation and the structure evolve constantly with the interaction among the agents. The interaction of multi-agents could be carried out by information transmission. It could also be carried out at the level of knowledge by agent interaction communication language (such as Knowledge Query Manipulation Language (KQML), Agent Communication Language (ACL) etc.). The interaction of multi-agents is flexible and is required to be conducted by observing environment and other agents when the system is at work.

2. Dynamic characteristic

The structure of multi-agent system could either be static or dynamic. The structure, the interaction and interrelation among its members of static multi-agent system are stable and permanent. No change takes place when tasks or environment changes. It is a structure usually designed specifically for a certain goal or task. However, the structure, the interaction and interrelation among its members of dynamic multi-agent system are unstable and temporary. They change when tasks and environment change. The dynamic structure is formed usually as a result of competition among agents and system evolution. Dynamic multi-agent system is usually an unstable structure temporarily formed for a special task or goal. When the task or goal is completed, multi-agent system may be dissolved accordingly. New multi-agent system with different structure or members may be reformed for new task or goal.

The structure of multi-agent system could be either closed or open. Closed multi-agent system does not allow agent members to come in or go out freely. Its agent members are fixed. However, open multi-agent system allow agent members to come or go freely. Its agent members are not fixed but change dynamically.

3. Modularity

Multi-agent system is a system made up of a group of agents. Agent is an entity with higher autonomous capability, operated in dynamic environment. It is the basic element of multi-agent system and each agent could be seen as a module composing multi-agent system.

Agent combines in different ways may constitute different multi-agent system. Therefore, modularity makes multi-agent system more flexible, adaptable and reusable.

4. Complexity

The interaction of simple agent in multi-agent system could generate complex global (holistic) behavior of the system. This phenomenon is called "emergence" in complexity theory.

5. Isomerism

Agent members in multi-agent system could either be isomorphic or isomeric.

6. Distributivity

Knowledge, data and recourses in multi-agent system is discrete and the control is distributive. Each agent could control its own behavior on its own. Generally, there exists no global control.

7. Asynchronism

Calculation in multi-agent system is made asynchronously, each agent having its own behavior time table.

8. Hierarchy

The structure of multi-agent system is hierarchical in which agent at the superior hierarchy controls the agent's behavior at the subordinate hierarchy, while being controlled by agent at the higher hierarchy. The focal point of multi-agent system reserch is the cross-level study of the system.

The characteristics and behavior at the overall hierarchy of structure of the system are the emergence caused by interaction and constantly evolving among all component parts at the partial hierarchy in multi-agent system. The laws and phenomena of the superior hierarchy could be explained or infered from the laws of the subordinate hierarchy in multi-agent system, and it is believed that the subordinate hierarchy is more fundamental.

9. Incompleteness

Agent in multi-agent system is featured with incompleteness. There is no agent who knows what the all other agents are thinking or doing. It obtains information only from a comparatively small subset of the agent set, and the information acquired may also be incomplete. Each agent in the system interacts, makes decision and takes action by processing these bits of partial and incomplete information. As it owes only partial and incomplete information or knowledge, or capacity of solving part of problems, the range of vision of each agent is limited.

10. Variety of system evaluation index

The evaluation index of multi-agent system is various. We could use many different indices to evaluate the system, and every evaluation index gives description of system performance from a certain aspect. The performance evaluation of multi-agent system could be made at overall hierarchy or at individual hierarchy. It could be single index or comprehensive index. But none of them could make an overall evaluation of the system.

It could be seen from the above analysis of characteristics of multi-agent system that multi-agent system lays stress on distributed autonomous decision-making and cooperation among agents to solve problems. Multi-agent system is rich in relations and structures and could describe complex group interaction mode, therefore it is of great flexibility and adaptability. It is particularly fit for studies of problems in real world, in which complexity, coordination, self-organization, self-adaptation, formlessness and uncertainty are involved. It is very suitable for handling problems with distributed knowledge, data, resourses and control. It shows human being's social intelligence to a greater degree, more suitable for the open, dynamic world environment. It is a method closer to problem-solving in natural world and could give a more natural account of the system, so that it has drawn more and more attention to this new and prosperous method of system modeling and simulation in academic circles.

4. Characteristics analysis of supply chain system

From the viewpoint of systematization, supply chain is a system made up of supplier, manufacturer, distributor, retailer and customers. Supply chain system includes four basic subsystems: logistics, information flow, capital flow and trade flow. Supply chain system exhibits the following characteristics in regard to its structure, operation and management:

1. Dynamic characteristic

Dynamic characteristic refers to time-varying characteristic of the system. In order to fit in with changes in market demands and business management strategy, the node enterprises in supply chain system should be updated and renewed often, so does the business management strategy and tactics of node enterprises, and the organization structure of supply chain is combinative, elastic, and dynamic. So that the supply chain system bears a clear dynamic characteristic.

The dynamic characteristic of supply chain system is divided into extrincic and intrinsic dynamic characteristics. The former implies that external environment as well as its related parameters change with time, such as external demand, policy, laws and regulations, and environment of supply chain. The latter is caused by the dynamic change inside of the supply chain system, and is subdivided into structural and operating dynamic characteristics. Structural dynamic characteristic means node enterprises of supply chain often needs to update and renew, and the organizational structure of supply chain is composable, elastic, and dynamic. Structural dynamic characteristic includes dynamic characteristic of members and of its members' interrelations in supply chain system.

The dynamic characteristic of system members means supply chain system allows its members to come in or go out of the system, that is to say the structure of the supply chain is open. It is shown mainly at the forming and breaking up stage of the supply chain system. At that time, stable structure of the supply chain does not yet formed.

The dynamic characteristic of its members' interrelations in supply chain system means although there is no change in members of the supply chain system, the interaction and interrelation among these members change. It is usually shown in the operation process of mature supply chain system. At that time, stable or lasting strategic cooperative partnership has been formed among member enterprises of the supply chain, and the interaction among system members needs to adjust to improve the operation efficiency of the system.

Operating dynamic characteristics means supply chain members often renew and readjust the management tactics and strategy of the enterprises to meet the enterprise tactics and market demands. It is mainly realized by dynamic renewal of operation parameters of the system.

Both the extrincic and intrinsic dynamic characteristics of supply chain system could cause dynamic change of the system. In real supply chain system, these two characteristics are usually interwoven to produce effects on the operation of the supply chain system.

2. Integrity

Supply chain system composites all the node enterprises in the supply chain as a whole. The extent of supply chain management is exercised in the whole chain, involving supplier, manufacturer, distributor, wholesaler and end user, covering the scope of purchase, production, inventory, distribution and sales. The supply chain management strives to make the whole process of supplier, manufacturer, wholesaler, retailer till end user be wholly in optimum state.

3. Crossing

Node enterprises could be a member of this supply chain but at the same time a member of another supply chain. A great number of supply chains forms a crossed structure, increasing the difficulty in coordination of supply chain management.

4. Interaction

In supply chain system, node enterprises interact in groups with each other by way of collaboration, coordination, cooperation, consultation and game playing.

5. Cooperation

In supply chain, the relation between any two nodes is all supply and demand. The relation among node enterprises in supply chain is a kind of long-term and open strategic cooperative partnership, not a life-and-death competition. From the viewpoint of game theory, the relation between node enterprises of supply chain is not zero-sum game.

6. Complexity

As the span of supply chain and the hierarchy of node enterprises constituting supply chain are different, supply chain is usually constituted by a lot of and a wide range of enterprises, and even transnational enterprises, so that the structural pattern of supply chain is more complex than that of one enterprise. Supply chain management involves complex interaction among node enterprises that leads to its holistic performance. Complex holistic behavior mode of system emerges by interaction of node enterprises in supply chain. This is the complexity of system.

7. Agility

Time is money. Supply chain management is a time priority competitive strategy which can shorten the time of delivery, rapid response to market demand.

8. Integration

System integration means two or more elements (unit, subset) combine into an organic whole. Integration is a concept of constructing system and also a synthetic way to solve complex system problems and improve the holistic function of system. Integration is not the simple superposition of elements, but the organic combination of them. In other words, the combination and construction of elements is based on a certain integrated rules to improve the integrated function of the system. Supply chain management uses the idea and method of integration to combine product development, production, inventory, distribution and sales of supply chain, making use of the advanced theory and technology, such as Concurrent Engineering (CE), Just In Time (JIT), Electronic Data Interchange (EDI), Electronic Ordering System (EOS), Database, Bar Code, Customer Relationship Management (CRM), Efficient Consumer Response (ECR), Quick Response (QR), Business Process Reengineering (BPR), Material Requirements Planning (MRP), Manufacturing Resource Planning (MRP II), Enterprise Resource Planning (ERP), Flexible Manufacturing System (FMS), Computer-Integrated Manufacturing System (CIMS). It accomplishes not only the simple connection of resources like node enterprises, technology but seamless connection.

9. Multi-objective

The goal of supply chain management contains efficiency and effectiveness. The multi-objective of supply chain diversifies the evaluation indices of supply chain performance.

The index could be single index or comprehensive index, local index or global index. But no matter whether it is, single index or comprehensive index, local index or global index, evaluation indexes of supply chain system could not make an overall evaluation of system. Supply chain management tries to achieve balance among multi-objective.

10. Hierarchy

Hierarchy of supply chain system consists of the hierarchy of structure and the hierarchy of management. The structure of supply chain system is hierarchical, and the behavior mode of system presented in the whole hierarchy is produced by the interaction of node enterprises in supply chain system. Because of the structural hierarchy of supply chain system, a cross-hierarchy study on supply chain system is requested.

Supply chain management is divided into three levels: strategic plan of supply chain (strategy level), management control of supply chain (tactics level) and operation managementof supply chain (operation level). Strategic plan of supply chain is concerned with decision-making of the design of the whole supply chain. Decision-making at this level is a long-term decision-making and determines the structure of supply chain and the process which all the links in the chain must go through. It is a managing behavior of highest ranking and is completed by the core enterprise. It includes decision-making such as selection of factory location, selection of supplier, selection of means of transportation, choice of information system, determination of means of information transmission, analysis of product demand and choice of product and so on.

Management control of supply chain is the secondary hierarchy of supply chain management with more details than the first hierarchy. At this level, structure of supply chain is determined, and management control decision-making is mainly made at company level for the purpose of increasing the efficiency and effectiveness of the enterprise. It includes decision-making such as purchase, manufacturing, inventory, distribution and sales.

The third hierarchy of supply chain management is operation management including decision-making such as order processing, shop scheduling, vehicle dispatching, package and so on.

11. Stage characteristic

From the perspective of life cycle, supply chain could be divided into forming stage steadily operating stage and breaking up stage.

12. Modularity

Supply chain is set up above the level of enterprise, formed by the interaction among enterprises. Node enterprise is the basic operating unit in supply chain and each node enterprise has its independent decision, independent operation and independent accounting, and enjoys a strong independence in supply chain system, so that each node enterprise in supply chain could be regarded as an independent module in supply chain system. Enterprises combine in different way will form different supply chain. Modularity makes the study of supply chain system simplified in that researchers' only concern is the external characteristics of each node enterprise in supply chain, not the internal structure and operation of the module, and the stress is placed on the interaction among enterprises.

13. Distribution

The knowledge, data and resources of supply chain system are all distributive. The control of supply chain system is also distributive. There is no global control of supply chain system.

14. Adaptability

Each node enterprise in supply chain system is proactive in adapting to environmental change, so that the supply chain system as a whole has also the ability to adapt to environmental change, therefore bears the adaptable characteristic.

15. Concurrency

Each node enterprise in supply chain could operate in accordance with its own behavior time-table and could accomplish concurrent operation apart from necessary interaction operation.

By comparing the above mentioned characteristics of supply chain system with that of multi-agent system, we could conclude that the main characteristics of supply chain system amazingly coincide with that of multi-agent system, so that modeling and simulation method based on multi-agent system is the best tool for the study of dynamic characteristics of supply chain inventory system.

5. Multi-agent system model of VMI supply chain inventory system

Structure and operation mode of system is the key factor that affects the performance of supply chain inventory system. VMI supply chain inventory management strategy breaks traditional division inventory management mode, manages inventory in a systematic and integrated way, by which supply chain inventory system operates synchronically and is quick to adapt to market change. It is a new and representative supply chain inventory management mode and a new effective inventory management method under Supply chain environment.

VMI is a cooperative strategy between superior and subordinate nodes of supply chain which optimizes the availability of products with the cost lowest to the two parties, and with a target framework accepted by mutual parties, the inventory management of subordinate node is exercised by superior node. The target framework like this is constantly supervised and revised to produce an continuous improving environment.

The characteristics of VMI supply chain inventory management mode are as follows,

1. VMI is a cooperative strategy between superior and subordinate nodes of supply chain. When this strategy is implemented, superior and subordinate nodes in supply chain cooperate and trust each other, the information of inventory state is transparent and open to the two parties, and the benefit is shared by both supply and demand parties. The openness of inventory state is key to implementing VMI in that superior node could keep an eye on and check the inventory state of subordinate node at any time, make quick response to the change of market demand and make corresponding adjustments to the state of production and supply of enterprise.
2. The target of VMI is to make the lowest total cost of inventory system. VMI is not concerned with how cost is distributed or by whom it is paid, but the reduction of cost. By implementing VMI, the costs of both supply and demand parties are lowered and the costs of the whole supply chain inventory system are lowered accordingly.
3. VMI is a proxy model of decision-making for supply chain integration operation. In essence, it authorizes superior node to make decision for subordinate node inventory in supply chain. The superior node draws up inventory allowed by subordinate node, decides on inventory level and replenishment strategy, and holds the control of inventory. To delegate inventory decision-making of subordinate node to superior node reduces the levels of management decision-making in supply chain inventory system.

4. Superior and subordinate nodes in VMI must reach a target framework agreement on inventory management. In the target framework agreement, the common target of VMI, duties of superior and subordinate nodes etc. should be agreed on. It should also make clear where to place inventory, when to pay, whether to pay management fee or not, how much it will cost etc.
5. VMI adopts Continuous Replenishment Program (CRP). Traditional means of ordering is that subordinate node enterprises offer orders to superior node enterprises. However, as to VMI, it is superior node enterprises that decide on the replenishment amount of goods according to inventory and sales information of subordinate node enterprises. It is a powerful means to implement VMI inventory management strategy.

In order to make a quick response to subordinate node enterprises' requirement of reducing inventory, superior node enterprises, by establishing cooperative partnership with subordinate node enterprises, proactively heighten the frequency of delivery to subordinate node enterprises. In doing so, superior node enterprises turn out to be responsible for replenishing inventory for subordinate node enterprises, instead of only acting on purchase orderings of subordinate node enterprises. While superior node enterprises quicken their responses to its customers' needs, the inventory level of subordinate node enterprises is also lowered.

A typical topology structure of VMI supply chain inventory system is shown in Fig. 1.

In order to set up multi-agent system model of VMI Supply Chain Inventory System, node enterprises of VMI supply chain inventory system are simplified as agents. The model of multi-agent system model of VMI supply chain inventory system shown in Fig.1 consists of four agents, namely, retailer agent A_1, Wholesaler agent A_2, distributor agent A_3 and manufacturer agent A_4.

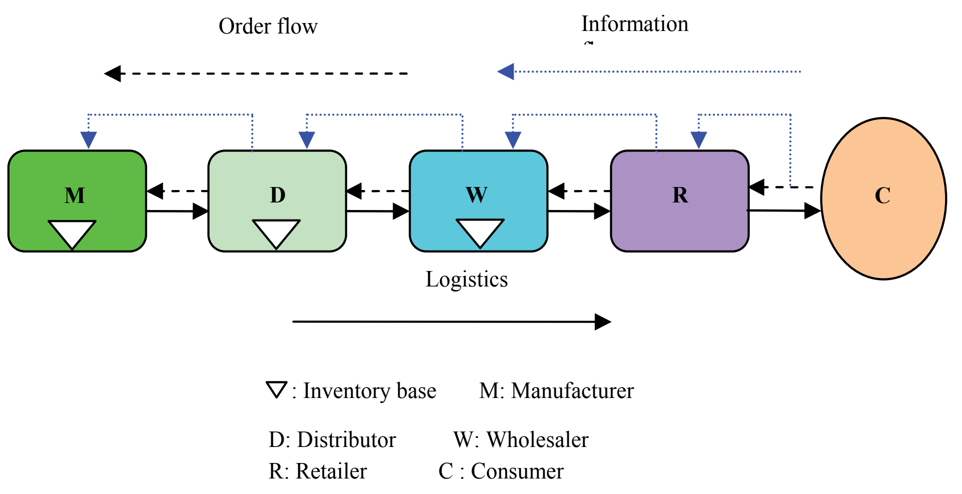

Fig. 1. Topology structure of VMI supply chain inventory system

The model of each agent $A_i(i=1,2,3,4)$ in multi-agent system model can be expressed with the following six tuple set:

$$A_i = \langle T_i, S_i, B_i, R_i, P_i, N_E \rangle \tag{1}$$

In the above expression, T_i is the partial time base of $A_i (i = 1,2,3,4)$. Each agent A_i has its own partial time base which can be used to control the partial process of agent. The supply chain inventory system is operated periodically. Therefore it is a discrete time system and the partial time base is a set of integer. S_i is the internal state set. Each agent A_i in the model of multi-agent system has its own internal state set. In the multi-agent system model of supply chain inventory system, S_i includes the actual inventory, backorder, effective inventory and inventory cost etc. The variation of state is determined by state set and behavior set. B_i is behavior set. In the operation process of supply chain inventory system, the behavior set B_i of node enterprise agent includes demand forecasting, confirming quantities of order, making an order, making a delivery, renewing the record of state, etc. R_i is familiar relationship set. $FR = \bigcup_{i=1}^{n} R_i$. P_i is attribute set. Attribute set P_i represents the unique and indispensable quality of agent. N_e is external environment.

It is the most important to establish the decision-making model for each node enterprise agent in setting up the multi-agent system model of supply chain inventory system. In the practical operating process of VMI supply chain inventory system, decision-making is done by each node agent independently. Each node agent makes decision according to its preference, policy of decision-making and information obtained. For simplicity, it is assumed that each agent is isomorphic.

Information sharing is implemented in VMI supply chain inventory system. The Information sharing agreements are reached between the adjacent node enterprise agents. The real variations of requirement are passed on from the downstream node enterprise agent to the adjacent upstream node enterprise agent. One decision making levels are decreased in VMI compared with normal multi-echelon supply chain inventory management system. The decision-making policies of all agents in the model are described as (2)-(12).

$$\forall i, IO_t^i = \hat{L}_t^i + AS_t^i + ASL_t^i \tag{2}$$

$$\forall i, O_t^i = Max(0, IO_t^i) \tag{3}$$

$$\forall i, \hat{L}_t^i = \Theta^i L_{t-1}^1 + (1-\Theta^i)\hat{L}_{t-1}^1 \quad 0 \le \Theta^i \le 1, \ i = 2,3,4 \tag{4}$$

$$\forall i, AS_t^i = \alpha_s^i (S_t^{i*} - S_t^i) \tag{5}$$

$$\forall i, S_t^{i*} = \delta^i \hat{L}_t^i \tag{6}$$

$$\forall i, ASL_t^i = \alpha_{sl}^i (SL_t^{i*} - SL_t^i) \tag{7}$$

$$\forall i, SL_t^{i*} = \gamma_t^i \hat{L}_t^i \tag{8}$$

$$\forall i, I_t^i = I_{t-1}^i + Min(I_{t-LT^i}^{i+1}, O_{t-LT^i}^i) - O_t^{i-1} \tag{9}$$

$$\forall i, C_t^i = h^i Max(0, I_t^i) + p^i Max(0, -I_t^i) \tag{10}$$

$$C_t = \sum_{i=1}^{n} C_t^i \tag{11}$$

$$C = \sum_{t=1}^{N} C_t = \sum_{t=1}^{N} \sum_{i=1}^{n} C_t^i \quad (12)$$

Where:
i : the sequence number of node enterprise Agent.
IO_t^i : nominal orders of the ith node enterprise in period t.
$\hat{L}_t^i$: forecasting demand of the *i*th node enterprise in period *t*.
AS_t^i : adjustment parameter of inventory level of the *i*th node enterprise.
ASL_t^i : adjustment parameter of inventory in transit of the *i*th node enterprise.
O_t^i : actual orders of the *i*th node enterprise in period *t*.
L_{t-1}^1 : actual demand of the *1*th node enterprise in period *t-1*.
$\hat{L}_{t-1}^1$: forecasting demand of the *1*th node enterprise in period *t-1*.
Θ^i :forecasting coefficient of update rate of the *i*th node enterprise.
S_t^{i*} : expected level of inventory of the *i*th node enterprise in period *t*.
S_t^i : actual level of inventory of the *i*th node enterprise in period *t*.
α_s^i : adjustment coefficient of the inventory level of the *i*th node enterprise.
δ^i : adjustment coefficient of the expected level of inventory for the *i*th node enterprise.
SL_t^{i*} : expected level of inventory in transit for the *i*th node enterprise in period *t*.
SL_t^i :actual level of inventory in transit for the *i*th node enterprise in period *t.*
α_{sl}^i : adjustment coefficient to the expected level of inventory in transit for the *i*th node enterprise.
γ_t^i : ordering lead time for the *i*th node enterprise.
I_t^i : actual inventory of the *i*th node enterprise.
C_t^i : inventory cost of the *i*th node enterprise in the period *t*.
h^i : holding cost of inventory per unit per week for the *i*th node enterprise.
p^i : shortage cost per unit per week for the *i*th node enterprise.
C_t : inventory cost of the whole supply chain in the period t.
C : total cost of the whole supply chain.
N: number of period for simulation.
n: total numbers of node enterprises in supply chain.
LT^i : lead time of the ith node enterprise.

6. Simulation and analysis of VMI supply chain inventory system

Simulation is conducted to VMI supply chain inventory system on Swarm Platform. Simulation parameters are as follows:
Initial conditions: The initial value of inventory in all node enterprises is 12 units. The orders of each node and inventory in transit are both 4 units per week.
System parameters: The system parameters are as follows:
Θ^i =0.25, δ^i =3, α_s^i =0.6, α_{sl}^i =0.5, LT^i =1, h^i =0.5 yuan/unit/week, p^i =2.0 Yuan/unit/week.
External demands: The external demand orders of customers remain 4 units per week.
The simulation results are shown in Fig. 2-Fig.5.

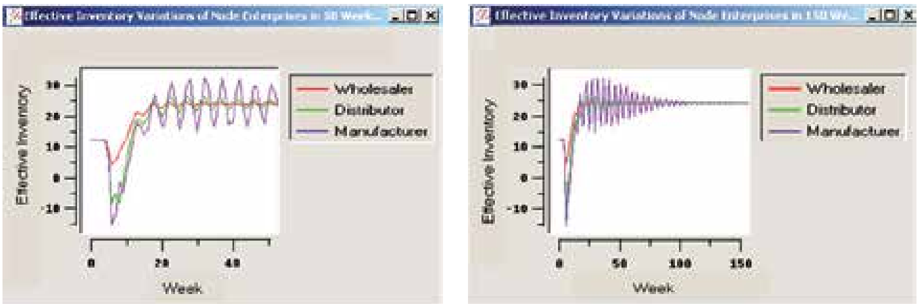

Fig. 2. Effective inventory variations of node enterprises in 50 weeks and in 150 weeks

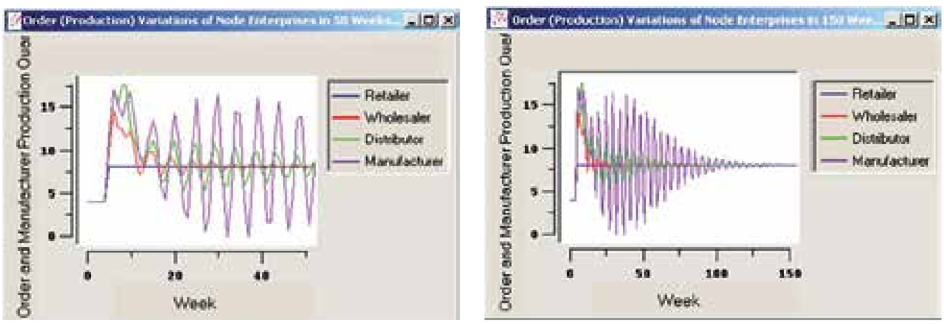

Fig. 3. Order (production) variations of node enterprises in 50 weeks and in 150 weeks

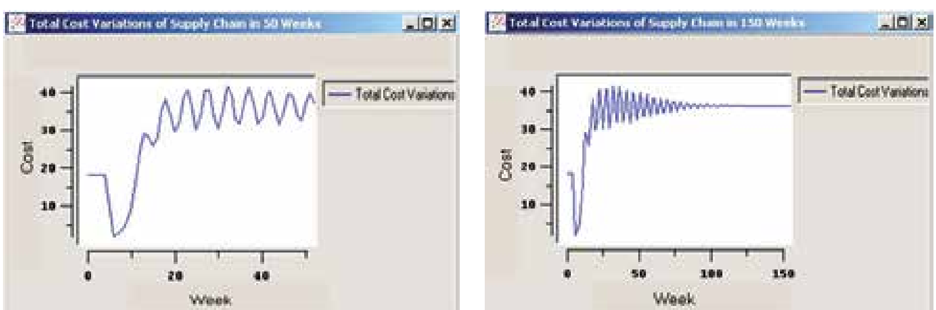

Fig. 4. Total cost variations of supply chain in 50 weeks and in 150 weeks

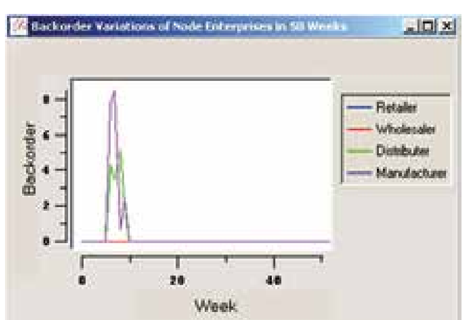

Fig. 5. Backorder variations of node enterprises in 50 weeks

7. Conclusion

By comparing the characteristics of multi-agent system with that of supply chain system, it is concluded that the main characteristics of supply chain system amazingly coincide with that of multi-agent system, so that modelling and simulation method based on multi-agent system is the best tool for the study of dynamic characteristics of supply chain inventory system.

It is concluded that the variation amplitudes of effective inventory of each node enterprise in supply chain shall decrease more effectively by adopting the VMI supply chain inventory management strategy (Fig. 2.), by comparing the above simulation results with (J. Li et al., 2007) and(J. Wang et al.,2005), especially for the upstream node enterprises. The responses of upstream and downstream enterprises to the variation of external demands are synchronous. The response delaying phenomena of effective inventory of upstream node enterprises are mitigated.

The orders to upstream node enterprise decrease obviously. The orders of the upstream node enterprise decrease more evidently than that of the downstream node enterprise. The variations of orders of each node enterprise are synchronous. The Bullwhip Effect of the whole supply chain alleviates greatly, but it does not disappear.

The backorders decrease apparently and sharply. There are no backorders in retailer and wholesaler. That means the serve levels are not lowered. The operation states of the whole supply chain are improved.

The whole costs of the supply chain are lowered obviously. The time from oscillation states to stable states of supply chain inventory, order and the whole costs are shortened, which is caused by the pulse variation of external demand.

From the analysis above, it is obvious that VMI is an effective inventory management method. The performance of supply chain inventory system can be enhanced effectively by adopting VMI strategy. The whole operation costs of supply chain can also be lowered greatly.

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Improving E-Procurement in Supply Chain Through Web Technologies: The HYDRA Approach

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1. Introduction

A supply chain is a network that enables the distribution options for procurement of both raw and finished materials, which can be transformed into finished goods and distributed to the end customer through various distribution channels. Commonly, the main goal of a supply chain is satisfy the customer's requests as soon as they appear. This process is well-known as e-procurement. E-Procurement is more than just a system for making purchases online. It provides an organized way to keep an open line of communication with potential suppliers during a business process. E-Procurement helps with the decision-making process by keeping relevant information neatly organized and time-stamped. In this book chapter, we covered the e-procurement process in Supply Chain Management borrowing features from service-oriented and event-driven architectures to provide support for supply chain management collaborations, covering the basic concepts and the participants in e-procurement, describing the main functions from the roles of producers, distributors, retailers, customers, and service providers in the e-procurement process, identifying the main information technologies for developing Web-based systems for e-procurement, presenting some selection criteria, implementation strategies, and process redesign initiatives for successful e-procurement deployment and finally discussing research and new trends for e-procurement in order to provide a guide for designing effective and well-planed process models in e-procurement which is an important prerequisite for implementation success. With these aspects, Well-managed e-procurement systems can be developed to help reducing inventory levels. A properly implemented e-procurement system can connect companies and their business processes directly with suppliers while managing all interactions between them. A good e-procurement system helps a firm organize its interactions with its most crucial suppliers. It provides those who use it with a set of built-in monitoring tools to help control costs and assure maximum supplier performance.

2. Basic concepts in e-procurement for supply chain management

As the world's economy becomes increasingly competitive, sustaining competitiveness and the resulting profitability depends less on the ability to raise prices. Instead, firms need to compete on the basis of product innovation, higher quality, and faster response times, all of which must be delivered, in most cases simultaneously and always at the lowest costs attainable. Those competitive dimensions cannot be delivered without an effectively managed supply chain. Firms with the most competitive supply chains are and will continue to be the big winners in contemporary business. The supply chain encompasses all activities associated with the flow and transformation of goods from the raw materials stage through to the end user, as well as associated information flows. Supply Chain Management is the integration of these activities through improved supply chain relationships to achieve sustainable competitive advantage (Handfield & Nichols Jr, 1999).

The definition suggests that all of the links in the supply chain must be strong and well integrated. However, it is argued here that the key link, the one that sets the foundation for the others, is supply management on the input end of the chain (Dobler & Burt, 1996). It is the link in the supply chain that serves as the boundary-spanning activity on the input end of the business where the supplier base is built based on the suppliers' ability to help the firm deliver on the competitive dimensions. It is where industrial marketers come face to face with the demands of the buying firm's supply chain.

The increasing emphasis on supply chain management has sharpened top management's focus on the valued-added potential of supply management. A recent survey suggests that 76% of CEOs expect supply management to contribute to shareholder value as firms continue to move toward more outsourcing (Nelson et. al., 2002). The potential impact on competitiveness and profitability is enormous because the average manufacturing firm spends about 50% of its sales revenue on the purchases of goods and services needed to produce its final product. It is at the supply end of the supply chain where most of the expenditures on supply chain activities exist. This increasing emphasis on supply management, rather than on the more traditional ''purchasing,'' requires that the professional supply manager move beyond the typical transaction focus of purchasing where price and availability were the key factors to be considered in the purchase decision.

The new basics of supply management require that supply managers take a more strategic view of what they do. Those new basics include a comprehensive understanding of target costing, value engineering, supplier development, and electronic procurement (Nelson et. al., 2002). The first three are not really new, having existed as an implicit part of supply management for some time. It is more accurate to say they are being rediscovered. It is electronic procurement, the productive use of the Internet to improve the effectiveness and efficiency of the supply end of the supply chain that is new.

Strategic supply management has the potential for significant value creation for the firm. Business professionals who have long been involved in supply management understand its power to create value. The emergence of e-procurement in the last few years is creating a higher profile for supply management, boosting its visibility to top management. The challenge to those operating on the supply end of the supply chain is to make a convincing business case for what they do. Although CEOs expect supply management to contribute to shareholder value, effective supply managers need to get comfortable with the language of top management to communicate how that value is created. The move to e-procurement provides a unique opportunity for supply managers for two reasons. First, the application of technology to boost competitiveness and profitability is on the agenda of any forward-thinking CEO. Second, the application of technology to supply management, where firms spend most operating dollars, is focusing more top-management attention on that issue. A recent study by Deloitte Consulting of 200 global firms indicates that 30% have begun

implementing at least a basic e-procurement solution whereas 61% are either planning or are considering an implementation (Whyte, 2000).
E-procurement is the linking and integration of inter-organizational business process and systems with the automation of the requisitioning, the approval purchase order management and accounting processes through and Internet-based protocol (Podlogar, 2007). In the Figure 1, the main terms in the e-procurement are shown. According to Kalakota & Robison (1999), the purchasing process is within the procurement process and refers to the actual buying of materials and those activities associated with the buying process.

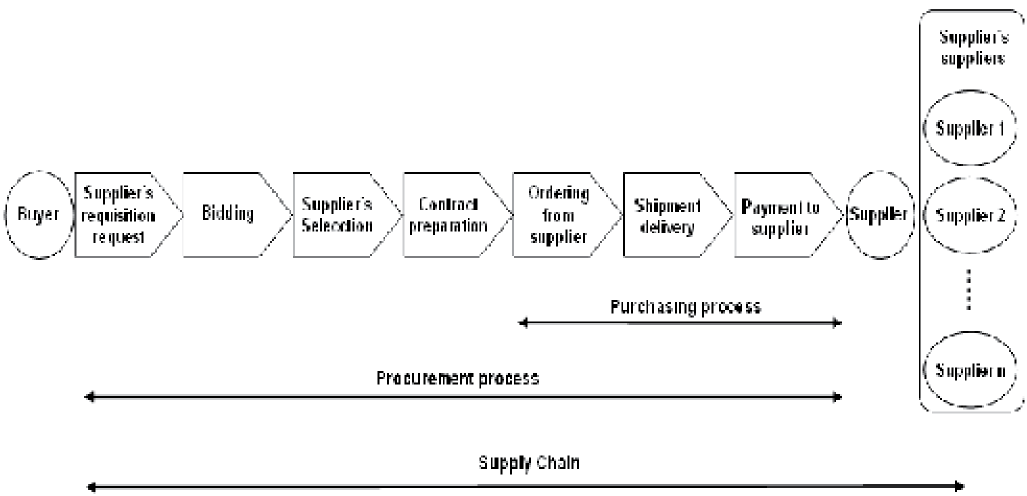

Fig. 1. Main concepts in e-procurement (Podlogar, 2007)

In the supply chain, the procurement process is important, because includes business partners as: suppliers, manufacturers, distributors and customers that use transactions to purchase, manufacture, assemble, or distribute products and services to the customers.
Different structures of supply chain management are discussed below by some authors.

2.1 Different structures of supply chain management

Moreno-Luzon & Peris (1998) addressed level of decision-making centralization and level of formalization-standardization as the basic organizational design variables of the contingency model relating to quality management. Formalization can be defined as the degree to which roles and tasks performed in the organization are governed by formal rules, and standard policies and procedures. If higher level of flexibility is required by the organization, then level of formalization should be low whereas if the organization requires a rigid structure then higher level of formalization will be suitable. Degree of formalization can be explained by the existence of independent department responsible for supply chain management and the strategic positioning of the department and the degree of centralization which reflects the scope of responsibilities and the power of supply chain department within the organization (Kim, 2007). The concept of formalization refers to "the extent that the rules governing behavior are precisely and explicitly formulated and the extent that roles and role relations are prescribed independently of the personal attributes of individuals occupying positions in the structure''. In other words, formalization describes the degree to which work and tasks performed in the organization are standardized (Dewsnap & Jobber, 2000; Mollenkopf et al., 2000; Manolis et al., 2004).

Bowersox & Daugherty (1995) and Daugherty et al. (1992) suggest that the concept of formalization in supply chain management perspective can be consistent with it in organizational perspective. They define formalization as the degree to which decisions and working relationships for supply chain activities are governed by formal rules and standard policies and procedures.

Centralization can be defined as the pattern of authority distribution for various departments within the organization. The management decides the authority distribution pattern on the basis of objectives to be achieved and type of strategy to be followed by the organization. For example, defender's strategy is cost oriented, so centralization should be high whereas prospector's strategy is product innovation oriented, so lower level of centralization will be suitable. Centralization is defined as the extent to which the power to make supply chain management decisions is concentrated in an organization (Mollenkopf et al., 2000; Manolis et al., 2004). Higher degrees of centralization correspond with concentration of decision making authority at more senior levels (Dewsnap & Jobber, 2000).

The degree of centralization is determined partly by hierarchical relationship between supply chain management department and other functional areas over the control and responsibilities for supply chain management activities (Leenders et al., 2002). According to Bowersox & Daugherty (1995) and Tsai (2002), three structural components-formalization, centralization and specialization have considerable influence on organization performance. Factors favouring centralization include standardization of products and business processes, cost reductions created through opportunities to allocate resources efficiently and economies of scale and improved levels of knowledge and expertise through the dedication of staff and resources (Droge & Germain, 1989). Decentralization offers business units autonomy and control over key functional activities, supporting the principle that business units must carry responsibility for major decisions if they are to be held accountable for performance (Johnson & Leenders, 2006). Potential advantages of centralization include greater buying specialization, coordination of policies and systems and consolidation of requirements. Meanwhile, decentralization improves service and lowers costs by pushing decision-making responsibility closer to the end user, promotes closer working relationships between suppliers and end users and provides increased opportunities for end users to manage total cost of ownership factors (Leenders & Johnson, 2000). There can be other objectives like cost, flexibility, quality and innovation on the basis of which organization structure can be decided. The competitive dimensions can include cost, quality, flexibility, and delivery performance among others (Corbett & Van Wessenhove, 1993; Minor et al., 1994; Vickery, 1991). Supply chain structure can be defined on the bases of organization's strategy. As defenders, prospectors and analysers have different strategies, there should be a strategic fit between their supply chain and competitive strategies. To achieve strategic fit, supply chain activities of an organization must support their objectives.

Supply chain structure has been defined and classified in a number of ways in the literature. A very simple way of describing supply chain structure differentiates between organizations on the dimension of centralization or decentralization (Ghoshal, 1994). One of the major problem of decentralized organization is that the goals of the agents are not aligned with the overall goal of organization (Dirickx & Jennergren, 1979; Milgrom & Roberts, 1992).Different business subunits have their own objectives .To pursue their private interests, these units may choose to send false, or biased, information to headquarters and other departments (Jennergren & Muller, 1973). Companies must adjust their organizational structure and management processes to adapt to changes in the external competitive environment or its strategy in order to maximize performance (Galunic & Eisenhardt, 1994). The two extremes (prospector and defender) are consistent with findings put forward by the other authors, e.g. Burns and Stalker (1961) and Porter (1980). They labelled these extremes the mechanistic and organic management system, respectively. Burns and Stalker (1961) explicitly mention that mechanistic firms have a functional organization structure with high level of formalization i.e. extent to which rules and roles are precisely and explicitly formulated. Organic firms, on the other hand, have low level of formalization.

Mechanistic firms have a hierarchical structure and the way of coordination between the members of the organization is limited to vertical, that is, between superior and subordinate. Mechanistic systems are appropriate in stable conditions and have a functional organization structure, a high degree of formalization, and many rules and procedures. Organic systems are most appropriate in changing conditions and are characterized by loose structures and few rules. Miles & Snow's (1978) prospector corresponds with Burns and Stalker's organic system and Porter's differentiation strategy, while the defender strategy corresponds with Burns and Stalker's mechanistic system and Porter's cost leadership strategy. Analysers combine cost-leadership and a mechanistic system orthogonally with differentiation and an organic system. That is, they either spatially or temporally separate innovation and operation, but do not do both in the same part of the company or at the same time (Volberda, 1998). According to Chopra & Meindl (2001), a product-focused organization performs many different functions in producing a single product whereas a functional-focused organization performs few functions on many types of products. A product focus tends to result in more expertise about a particular type of product at the expense of functional expertise that comes from a functional manufacturing methodology. Hybrid organizational structure approach is defined as the structure having features of both centralized and decentralized structures (Leenders & Johnson, 2000). While previous research has found that the hybrid organizational model is the most commonly used within large supply organizations (Johnson & Leenders, 2006), there is still considerable variation with respect to how the hybrid model is implemented.

In 1960s, matrix structures became a popular organizational framework for managing new product and service development. Matrix organization approach manages coordination of activities across unit lines within the organization. The matrix combines the benefits of project and functional organizations by integrating the work of various specialists. The matrix structure operates through a two-dimensional system of control: a project/product-line chain of command and a functional chain of command (Lawrence et. al., 1982). Project managers retain responsibility for developing products, while functional managers concentrate on the organization's capability to make use of up-to-date technical knowledge (Katz & Allen, 1985). On the basis of above arguments we have main organization structure types of supply chain departments as mechanistic, organic and matrix structure.

According to Min & Zhou (2002), when structuring a supply chain network, it is necessary to identify who the partners of the supply chain are. Meanwhile, Cooper et al. (1997), suggest a guideline to structure a supply chain network, these structures are: (1) the type of a supply chain partnership; (2) the structural dimensions of a supply chain network and (3) the characteristics of process link among supply chain partners.

The supply chain can be analysed in two dimensions, horizontal and vertical structure. According to Lambert et al. (1998), the horizontal structure refers to the number of tiers across the supply chain, while the vertical structure refers to the numbers of suppliers and customers represented within each tier (See Figure 2).

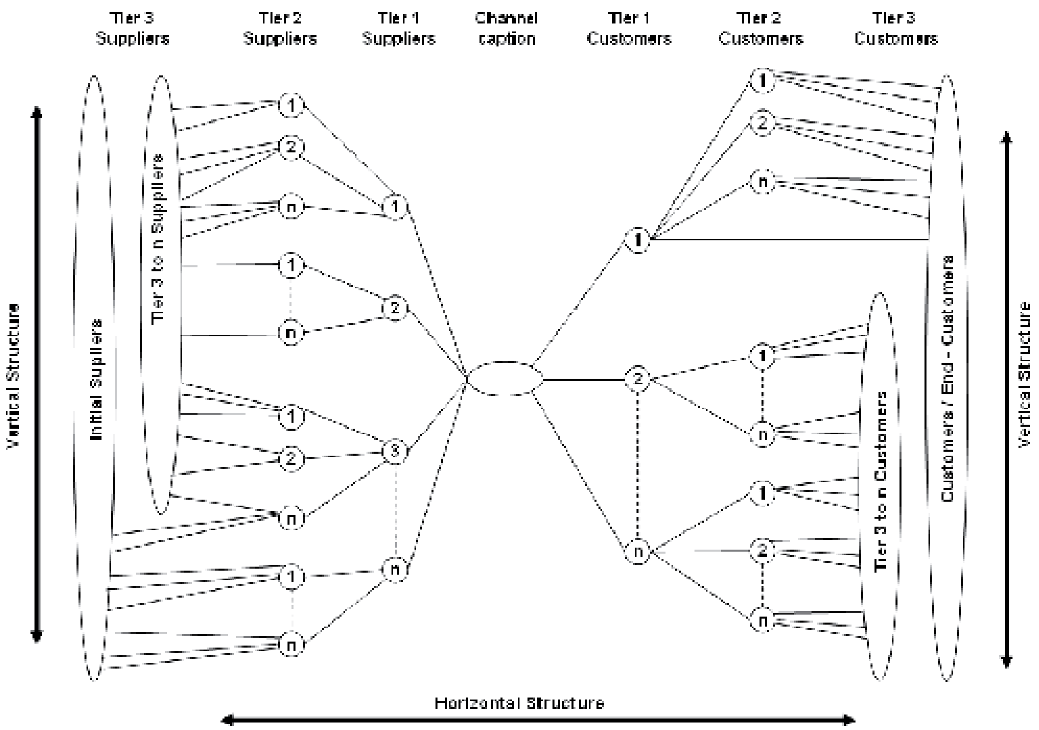

Fig. 2. Supply chain network structure (Adapted from: Lambert et al, 1998)

In its simplest form, a supply chain is composed of a company and the suppliers and customers of that company. This is the basic group of participants that creates a simple supply chain. These participants are discussed below.

2.2 Elements and participants in e-procurement supply chain management

E-procurement (electronic procurement, sometimes also known as supplier exchange) is the business-to-business or business-to-consumer or Business-to-government purchase and sale of supplies, work and services through the Internet as well as other information and networking systems, such as Electronic Data Interchange and Enterprise Resource Planning (Baily, 2008). Typically, e-procurement Web sites allow qualified and registered users to look for buyers or sellers of goods and services. Depending on the approach, buyers or sellers may specify costs or invite bids. Transactions can be initiated and completed. Ongoing purchases may qualify customers for volume discounts or special offers. E-procurement software may make it possible to automate some buying and selling. Companies participating expect to be able to control parts inventories more effectively, reduce purchasing agent overhead, and improve manufacturing cycles. E-procurement is expected to be integrated into the wider Purchase-to-pay (P2P) value chain with the trend toward computerized supply chain management. E-procurement is done with a software application that includes features for supplier management and complex auctions. The new generation of E-Procurement is now on-demand or a software-as-a-service.

There are seven main types of e-procurement:

1. **Web-based ERP (Enterprise Resource Planning):** Creating and approving purchasing requisitions, placing purchase orders and receiving goods and services by using a software system based on Internet technology.
2. **e-MRO (Maintenance, Repair and Overhaul):** The same as web-based ERP except that the goods and services ordered are non-product related MRO supplies.
3. **e-sourcing:** Identifying new suppliers for a specific category of purchasing requirements using Internet technology.
4. **e-tendering:** Sending requests for information and prices to suppliers and receiving the responses of suppliers using Internet technology.
5. **e-reverse auctioning:** Using Internet technology to buy goods and services from a number of known or unknown suppliers.
6. **e-informing:** Gathering and distributing purchasing information both from and to internal and external parties using Internet technology.

e-marketsites: Expands on Web-based ERP to open up value chains. Buying communities can access preferred suppliers' products and services, add to shopping carts, create requisition, seek approval, receipt purchase orders and process electronic invoices with integration to suppliers' supply chains and buyers' financial systems.

The e-procurement value chain consists of Indent Management, e-Tendering, e-Auctioning, Vendor Management, Catalogue Management, and Contract Management. Indent Management is the workflow involved in the preparation of tenders. This part of the value chain is optional, with individual procuring departments defining their indenting process. In works procurement, administrative approval and technical sanction are obtained in electronic format. In goods procurement, indent generation activity is done online. The end result of the stage is taken as inputs for issuing the NIT. Elements of e-procurement include Request for Information, Request for Proposal, Request for Quotation, RFx (the previous three together), and eRFx (software for managing RFx projects). In Figure 3, an e-procurement business model is presented. According to Podlogar (2007), the main elements in the e-procurement are buyers, suppliers and Internet access system. Through this system, the buyer can input their needs using the e-catalog included in the e-procurement program, these needs are the request for procurement. The entire process is totally automated through the electronic interchange. The approval is accomplished online, helping cutting the cycle time.

Due to importance of the e-procurement in the supply chain, some historical developments in supply chain management are described below.

2.3 Historical developments in supply chain management

In today market most of firms have realize the importance of designing, planning and controlling an efficient supply chain. The effect over competitiveness and profit has been analysed form different perspective: economical (Atkins & Liang., 2010), social (Griffith, 2006), technological (Min & Zhou, 2002) and recently from an environmental perspective (Türkay et al., 2004), (Laínez et al., 2008). All those research point out that a modern enterprise does not contend in the market as independent unit, but inside a common network or high level supply chain. Supply chain is a synergy among several business processes with common goals: the acquisition of raw material and its transformation into

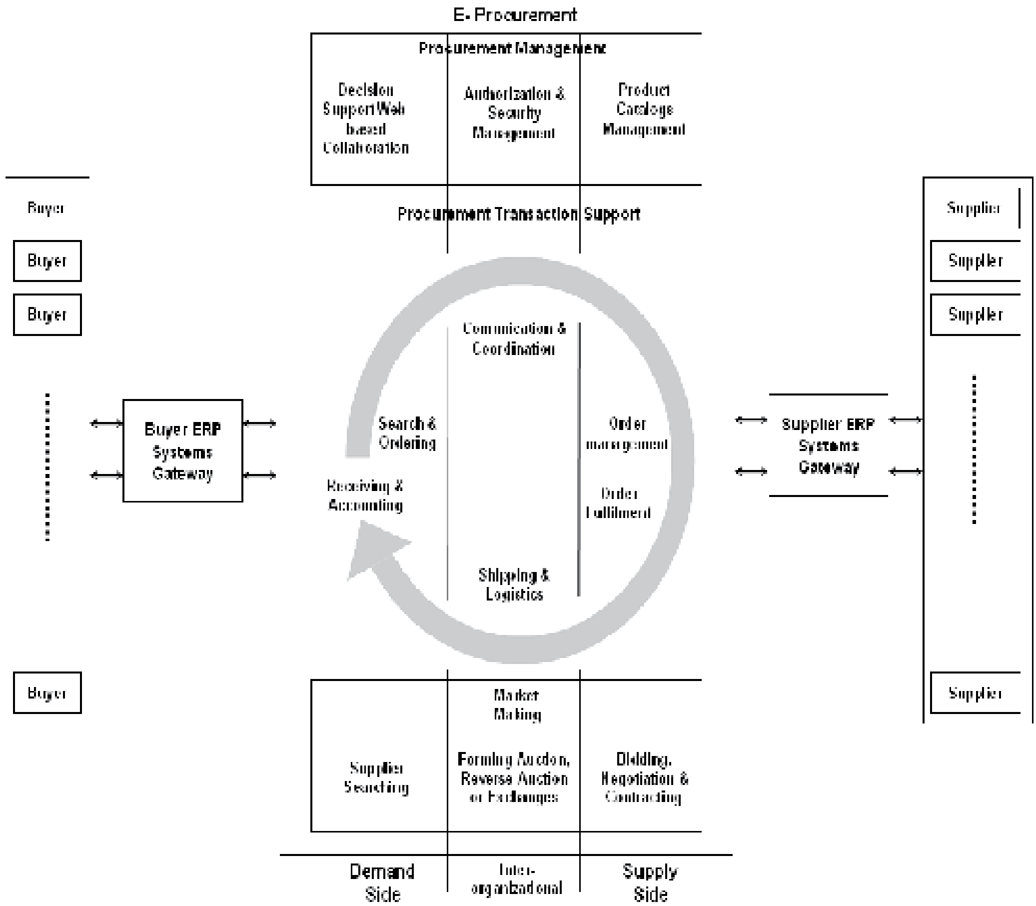

Fig. 3. An e-procurement business model (Gebauer and Shaw, 2002)

consumer goods, the creation of value and common wealth, distribution and promotion to retailer or costumers and information/knowledge exchange among diverse business entities. The capital objective in the supply chain is to improve the operational efficiency, to increase profitability and competitiveness of all stakeholders involved in the supply chain (Chopra & Meindl, 2001). The evolution in the supply chain is a complex process that could be analysed from different point of view:

1. The quantity and relationship among business entities and components. Concerning their components, a supply chain is integrated for many components -element, system or any other function- required to fulfill a customer request. The term function comprises design, operation, distribution, pricing, marketing and customer service among other functions. This definition involves evidently, the manufacturer and its suppliers, but also transporters, warehouses, retailers, and even customers themselves.
2. Due to the variety of functions and components, the evolution of the supply chain is a very complex process (Min & Zhou, 2002).
3. As well, the supply chain posses a forward flow of finished goods and materials and, a second one of information in opposite direction. These are business processes evolving

at their own rhythm and thus, considerably increasing the complexity in the evolution of the supply chain.

Evolution tendencies could be extracted from these perspectives. In first place, there is a clear problem of interoperability because many organizations must cooperate in network through the supply chain. The quantity, frequency and intensity of this cooperation are increasing continually. To solve this problem and to minimize heterogeneity, there is an evident tendency in the search of synchronization and standardization in the core business processes (Cellarius, 1998), (Blanc et al., 2006). The number of connections and functions in the supply chain affects its performance, thus a considerable effort was allowed to manage this complexity (Perona & Miragliotta, 2004). Then, the inherent complexity of the supply chain is one of the subjacent reasons for the creation of managerial approaches that aims to ameliorate the operation and integration of the supply chain. Concerning the information flow, this is maybe the most dynamic research field. Companies are continually searching for means and strategies to improve their flexibility, responsiveness and in consequence its competitiveness by changing their methods and technologies, which include the implementation of supply chain management paradigm and information technology (IT) (Gunasekaran & Ngai, 2004), (Bailey & Francis, 2008), (Verissimo, 2009), (Huang & Lin, 2010). Information Technology (IT) is responsible for an important change in the evolution of the supply chain: that knowledge could be a decisive success factor (Hult et al., 2006), (Craighead et al., 2009).

The supply chain environment is very flexible due to changing demand and pressure from competitors. Determine the software architecture is needed to allow information systems to be realigned with the changing supply chain without effort or delay. In next section, an historical overview of Web technologies for e-procurement is presented.

Some experiences and success stories of adapting e-procurement systems are presented below.

3. E-Procurement systems in supply chain management

3.1 Experiences and success stories

E-procurement is gaining in popularity in business practice and its benefits encourage its adoption in huge domain diversity. Its positive impact on several key performance indicators in different kind of business it is not questioned. As an example (Ronchi et al., 2010) shown the importance of e-procurement for an information technology chain. (Kothari et al., 2007) explain how the adoption and implementation of e-procurement technology within a hotel chain can generate important benefits. (Panayiotou et al., 2004), presents a case study concerning the analysis of the Greek governmental purchasing process, revealing the importance of new services design in this process. Maybe one of the most dynamics domains in e-procurement and typical procurement is the automotive industry; (Perrone et al., 2010) for example, explain how multi-attribute auctions can improve the procurement process in the context of new product development while (Kim, 2006) explain that the supply chain can generate more value if e-procurement is synchronized and involves corporate executives. Thus e-procurement enable: (1) On-line procurement and access to the global supply chain, (2) Effective auction process (quality, quantity and adequate price) and (3) Effective cost reduction.

3.2 Web technologies for e-procurement

The features and requirements of the supply chain of the future match the advantages and features of a software component architecture. Information technology support for the next generation supply chain systems is critical. This information technology needs to be: (1) Reusable, and (2) Rapidly changeable. Furthermore, it can be seen that the underlying software architecture of a supply chain solution also needs to be: (1) Agile, (2) Flexible, (3) Deployable over a multi-enterprise scope, (4) Multi-function support when used as a suite, (5) Handle complexity, (6) Enable collaboration, and (7) Enable coordination. We identify the main information technologies for developing Web-based systems for e-procurement.

EDI (Electronic Data Interchange): EDI is the computer-to-computer exchange of formatted electronic messages called transaction sets. The most widely used formats are specified in a U.S. standard, ANSI (American National Standards Institute) X.12, and in an international standard called EDIFACT. An EDI message contains a string of data elements, each one of which represents a piece of information, such as a price, or model number, separated by delimiters. The entire string is called a data segment (Zilbert, 2000). A transaction set usually corresponds to an equivalent paper document or form, e.g. Set 850 Purchase Order. For security, messages can be encrypted. With forms-based software, including Web pages, users can create or display an EDI transaction in a familiar way, without needing to know the transaction number or any details of the underlying formats. With the growing use of Internet, the transmission costs of EDI-based documents have been reduced. However, the development of EDI translators is still expensive because the codification of EDI documents is complicated due to their emphasis in the data consistency. An alternative to this proposal that eliminates several problems of business process integration was CORBA/IIOP.

CORBA/IIOP: CORBA/IIOP stands for Common Object Request Broker Architecture/Internet Inter-ORB Protocol. CORBA is an industry standard from the Object Management Group -- largely the UNIX/Linux/not Microsoft community. Client programs send requests to a common interface called the Object Request Broker. The ORB sends each request to the appropriate object (application code and data) and returns the results. The standard allows this to be accomplished in a distributed computing environment, across languages, operating systems, hosts and networks. CORBA is essentially a messaging protocol and has helped promote the use of messaging (store & forward/publish & subscribe) as a technical approach to systems integration (Boldt, 1995). IIOP makes CORBA usable on a TCP/IP network (the Internet). CORBA objects can be embedded in a Web page and executed via Java applet. This allows a Web page to be interoperable with remote applications accessible via the Internet. However, CORBA does not offer interoperability for the business processes in a supply chain management. This is mainly to that each commercial partner (represented as a node in CORBA) must execute its own ORB which is highly dependent of the CORBA implementations. This originates a great problem of interoperability in the development of commercial activities among the participants of the supply chain. In order to solve the interoperability among the CORBA implementations, Microsoft proposed an alternative approach well-known as DCOM.

COM/DCOM and ActiveX: Component Object Model/Distributed Component Object Model and ActiveX are Microsoft's Windows-oriented methods for developing and supporting interoperable program component objects. Together, these tools provide ways for Windows-based applications to interact and exchange data (Horstmann & Kritland, 1997). DCOM supports the TCP/IP protocol necessary for Internet- and web-based data interoperability. However, DCOM presents certain lacks of interoperability in the supply chain management. All the business processes of the participants in a supply chain should be executed under the Windows platform. Furthermore, in DCOM the messages that are sent between a client and a server have a format defined by the DCOM Object RPC (ORPC) protocol. By this reason is necessary to use mechanisms for translating the messages in order to a different system can interpret and to act in the request/responses of involved participants. Although DCOM solves some issues of interoperability caused by the incompatibilities among the implementations developed by different technology suppliers, these still persist when diverse operating system platforms are involved. The Java programming language was designed with the purpose of solving these issues of interoperability.

Remote Method Invocation (RMI): Java Remote Method Invocation (Java RMI) enables the programmer to create distributed Java technology-based to Java technology-based applications, in which the methods of remote Java objects can be invoked from other Java virtual machines, possibly on different hosts (Hughes et. al, 1999). Java RMI is a mechanism that allows one to invoke a method on an object that exists in another address space. The RMI mechanism is basically an object-oriented RPC mechanism. Java RMI has recently been evolving toward becoming more compatible with CORBA. In particular, there is now a form of RMI called RMI/IIOP ("RMI over IIOP") that uses the Internet Inter-ORB Protocol (IIOP) of CORBA as the underlying protocol for RMI communication. Java/RMI presents difficulties of interoperability. These difficulties reside in the use of the marshalling/unmarshalling of objects which is specific of the Java programming language. In the context of the supply chain, this means the business processes should be written in Java. In order to solve this issue, the World Wide Web Consortium (W3C) proposed a platform-independent description language well-known as XML

XML (eXtensible Markup Language): XML was developed as a way to tag or identify pieces of data within a file or Web page. It is a subset of a 20-year old language called the Standard Generalized Mark-Up Language (SGML). XML is similar in form to HTML (Hypertext Markup Language) which describes the content of a Web page in terms of how it is to be displayed (text and graphics) and interacted with. XML is called extensible because it defines only the techniques of tagging (Bray et. al, 2008). However, XML's flexibility has given rise to many industry-specific and proprietary vocabularies. These now threaten its potential to serve as a single, global standard for exchanging business-to-business electronic transactions. Just as different companies and industries use a variety of different documents and terms to accomplish the same transactions, so must XML be adapted to the specifics of a company or industry practice (Chen, 2003). By some estimates, more than 30 industry-specific initiatives are underway. RosettaNet is a good example of industry-specific standards being developed upon XML. This consortium of 40 companies in the computer industry have published XML dictionaries for 50 partner interface processes (PIPs) related to catalog updates, pricing, order management, purchasing, and inventory availability (Kraemer et. al., 2007). Another consortium, The Open Applications Group, Inc., has developed PaperXML for paper industry transactions and SMDX for semiconductor manufacturing (Savoie & Lee, 2001). The Chemical Industry Data Exchange (CIDX) has defined more than 700 data elements and 50 transactions based upon XML. Proprietary versions of XML abound -- for example, Ariba's cXML and CommerceOne's xCBL, both for procurement, and Microsoft's BizTalk, a general purpose development tool for XML-based applications (Savoie & Lee, 2001).

Web services: A Web service is a software component that is accessible by means of messages sent using standard web protocols, notations and naming conventions, including the XML protocol (Vinoski, 2003). The notorious success that the application of the Web service technology has achieved in B2B e-Commerce has also lead it to be viewed as a promising technology for designing and building effective business collaboration in supply chains. Deploying Web services reduces the integration costs and brings in the required infrastructure for business automation, obtaining a quality of service that could not be achieved otherwise (Adams et. al, 2003), (Samtani & Sadhwani, 2002). SOA (Service-Oriented Architecture) is an architectural paradigm for creating and managing "business services" that can access these functions, assets, and pieces of information with a common interface regardless of the location or technical makeup of the function or piece of data (Papazoglou, 2003). This interface must be agreed upon within the environment of systems that are expected to access or invoke that service.

BPEL (Business Process Execution Language for Web Services): BPEL is a process modelling language for the representation of compositional workflow structures to coordinate elementary Web service invocations. BPEL builds on Microsoft's XLANG (Web Services for Business Process Design) (Thatte, 2001) and IBM's WSFL (Web Services Flow Language) (Leymann, 2001) combining block structured language constructs borrowed from XLANG with a graph-oriented notation originated from WSDL (Web Services Description Language). BPEL closely follows the WS/Coordination and WS/Transaction specifications. The former describes how Web services may use predefined coordination contexts to be associated to a particular role in a collaboration activity (Cabrera et. al, 2005b). The latter provides an infrastructure that provides transaction semantics to the coordinated activities (Cabrera et. al, 2005a). A BPEL document consists of three parts describing data, coordination activities and communication activities (Little & Webber, 2003). Data tags are used to define a set of external partners and the state of the workflow. Coordination activity tags define the process behaviour by means of traditional control flow structures. Finally, communication activity tags define communication with other Web services through coordination activities by sending and receiving information.

3.3 Best practices in e-procurement

Best-in-class e-procurement performers have long-term, well-thought-out strategies for e-procurement implementation. Many such systems have been implemented in phases, with each new phase building off the successes – and lesson learned – of prior phases. However, all examples of Best Practices in e-Procurement have many things in common. AberdeenGroup, Inc. (2005) identified key strategies used by companies that have achieved best practice status in e-procurement:

- Solicit top management support to help drive system compliance and ensure sufficient funding and resources are made available.
- Focus on ease of use to improve end users' acceptance of the system.
- Don't underestimate change management. Insufficient focus on change management has held back acceptance of many e-procurement systems.
- Make sure processes are efficient before applying automated solutions.
- Clearly define and reinforce metrics for measuring costs, process efficiency, and performance of e-procurement technologies and processes. Where possible, link incentives for both procurement and business units to these metrics.

Though much progress has been made, significant challenges to successful e-procurement implementation remain. Specifically:

- **Supplier enablement.** In the early days of e-procurement, buying enterprises and solution providers underestimated the time, effort, and resources required to enable suppliers to transaction business electronically. Leading enterprises typically use a combination of supplier-enablement approaches. Though tremendous progress has been made in supplier enablement, all involved parties – end users, suppliers, and solution providers – continue to work to make enablement as simple and cost effective as possible.
- **User adoption.** Individual end users and entire business units will naturally resist any change in business processes that takes away buying power and buying flexibility. Over the past few years, user adoption has increased at essentially the same pace as the increase in suppliers enabled. With more products and suppliers on the e-procurement system, users have less reason to try to circumvent the system. Still, end users report that several factors continue to hold back user adoption, including inadequate representation of spending categories within the system, inconsistent purchase requirements, procedures, and supply bases by site or region, and a lack of executive mandates or policies to drive adoption and system compliance. Best Practice enterprises have worked on user adoption for years, and many supply executives at these enterprises have become leading "sellers" of the e-procurement system to end users.
- **Budget and policy support**. In AberdeenGroup, Inc. (2005) e-procurement benchmark research late last year, more than half of research respondents reported that securing budget/policy support for their e-procurement initiative was a challenge that delayed or muted the benefits of e-procurement.

In contrast, the best practice enterprises depicted in AberdeenGroup, Inc. (2005) received top management support and a level of investment needed to gain cost savings, process efficiencies, and the other benefits of e-procurement. However, even supply executives at best practice enterprises would like to see more investment and support of their e-procurement systems.

Research and new trends for e-procurement is presented below in order to provide a guide for designing effective and well-planed process models in e-procurement which is an important prerequisite for implementation success.

3.4 Research and new trends for e-procurement

Today businesses need to constantly adapt and reconfigure their IT assets, systems, and business operations to meet changing customer demands; compress business cycles; and differentiate from competition. New trends for developing e-procurement system are addressed in adopting different architectural styles. For instance, when an enterprise uses the SOA architectural style, it does not address all the capabilities needed in a typical supply chain management scenario. SOA does not have the ability to monitor, filter, analyze, correlate, and respond in real time to events. These limitations are addressed with an EDA (Event-Driven Architecture). An EDA combined with SOA, provides that ability to create a supply chain management architecture that enables business. An EDA is an architectural paradigm based on using events that initiate the immediate delivery of a message that informs to numerous recipients about the event so they can take appropriate action (Sriraman & Radhakrishnan, 2005). In this context, an event is a trigger that typically corresponds to the occurrence of some business activities, for instance, the receipt of an order. An EDA comprises event consumers and event producers. Event consumers subscribe to an intermediary event manager, and event producers publish to this manager. When the event manager receives an event from a producer, the manager forwards the event to the consumer. If the consumer is unavailable, the manager can store the event and try to forward it later. Then, the primary value of EDA is that it allows companies to identify and respond to events coming from supply chain management collaborations that need to be addressed by one or more systems through event management. The events, collected via an EDA, can be analysed and correlated to identify relevant patterns, and then aggregated to build up information that is needed to solve the procurement problem. With this process, companies can proactively address and respond to real-world scenarios in real time. A commercial toolkit is provided by TIBCO™ in order to enabling real-time business through a Service-Oriented and Event-Driven Architecture. TIBCO™ developed a set of applications in order to provide the following benefits where an enterprise can: 1) Improve ability to support new and changing business objectives, 2) Expand and extend the value of existing applications, and 3) Reduce the cost and risk of deploying new business services.

Another trend is to simplify the enterprise integration and middleware problem. As a solution, the ESB (Enterprise Service Bus) has emerged as software architecture in order to provide fundamental services for complex architectures via an event-driven and standards-based messaging engine (the bus). The ESB is an enterprise platform that implements standardized interfaces for communication, connectivity, transformation, portability, and security. An ESB implementation must cover: 1) Standards-based communication infrastructure, 2) Standards-based connectivity, 3) Standards-based transformation engines, 4) SOA for application composition and deployment, and 5) Standards-based security. Unlike the EAI (Enterprise Application Integration) approach, an enterprise service bus builds on base functions broken up into their constituent parts, with distributed deployment where needed, working in harmony as necessary. An example of an ESB implementation is the Fiorano ESB™ (Fiorano Enterprise Service Bus™) that incorporates tools and infrastructure enabling businesses to easily integrate existing systems both within and across enterprises with standards-based technology.

As proof-of-concept, we developed a middleware-oriented integrated architecture that offers a brokerage service for the procurement of products in Supply Chain Management scenarios. This brokerage service is called HYDRA.

4. HYDRA as an e-procurement system

HYDRA provides a hybrid architecture combining features of both SOA and EDA and a set of mechanisms for business processes pattern management, monitoring based on UML sequence diagrams, Web services-based management, event publish/subscription and reliable messaging service. In e-procurement scenarios, a wide variety of distributed applications needs support of a brokerage service. A typical application example is a workflow management system on top of a distributed platform in an organization with a few departments. A brokerage service with reduced functionality should for instance meet the requirements of local transactional processing of data and business processes. As another example, a distributed application can also work between different organizations. The nature of such an application can be very generic, i.e. the system must be capable of working with different locations and changing communication media, for example it might also include mobile users. A brokerage service needs to cooperate with a whole spectrum of underlying services, as mentioned above. In next section, we present and describe the internals and layer of our middleware-oriented integrated architecture for e-procurement.

4.1 Middleware-oriented integrated architecture for e-procurement

The middleware-oriented integrated architecture has a layered design. Furthermore, our proposal presents a component-based and hybrid architecture, borrowing features from SOA and EDA. In an SOA context, our approach acts as a BPM (Business Process Management) platform based on the SOA paradigm, facilitating the creation and execution of highly transparent and modular process-oriented applications and enterprise workflows. In an EDA context, our approach provides a software infrastructure designed to support a more real-time method of integrating event-driven application processes that occur throughout existing applications, and are largely defined by their meaning to the business and their granularity. Regardless of the event's granularity, our proposal focuses on ensuring that interested parties, usually other applications, are notified immediately when an event happens. These features are performed by our brokerage service. Its general architecture is shown in Fig. 4. Each component has a function explained as follows:

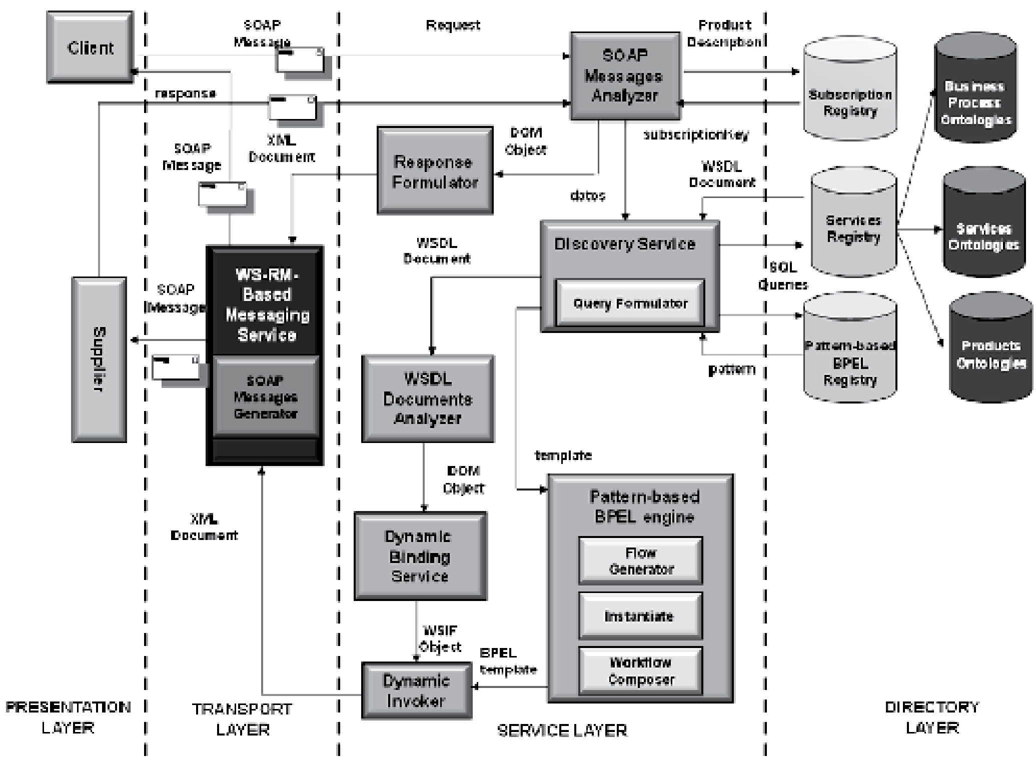

Fig. 4. The middleware-oriented integrated architecture for e-procurement

SOAP Message Analyzer: This internal determines the structure and content of the documents exchanged in business processes involved in supply chain management collaborations.

Service Registry: it is the mechanism for registering and publishing information about business processes, products and services among supply chain partners, and to update and adapt to supply chain management scenarios.

Subscription Registry: it is the mechanism for registering interactions in which systems publish information about an event to the network so that other systems, which have subscribed and authorized to receive such messages, can receive that information and act on it appropriately.

Discovery Service: This module is used to discover business processes implementations.

Given the dynamic environment in supply chain management, the power of being able to find business processes on the fly to create new business processes is highly desirable.

Dynamic Binding Service: This component binds compatible business processes described as Web services. The binding of a Web Service refers to how strong the degree of coupling with other Web Services is.

Dynamic Invoker: This module transforms data from one format to another.

WSDL Document Analyzer: it validates WSDL documents that describe business processes by their interfaces which are provided and used by supply chain partners.

WS-RM-based Messaging Service: it is the communication mechanism for the collaboration among the actors involved along the whole chain.

Response Formulator: This component receives the responses from the suppliers about a requested product/service.

Workflow Engine: This internal coordinates Web services by using a BPEL-based business process language. It consists of building a fully instantiated workflow description at design time, where business partners are dynamically defined at execution time.

According to the emphasis on automation, our architecture can be accessed in two modes of interaction, either as a proxy server or as an Internet portal. In the first mode, the brokerage service can interoperate with other systems or software agents. In the second mode, our architecture acts as an Internet portal that provides to the users a range of options among the Web services available through the brokerage service. Finally, the HYDRA architecture has a layered design following four principles: (1) Integration, (2) Coordination, (3) Monitoring and (4) Management, which are described next.

4.2 Supply chain coordination in HYDRA

Orchestration is currently presented as a way to coordinate Web services in order to define business processes. The utility of Web services is further enhanced by the introduction of mechanisms for composing them in order to generate new Web services and applications. The composition of Web services is defined as a process that enables the creation of composite services, which can be dynamically discovered, integrated, and executed to meet user requirements. In HYDRA, a composite Web service is obtained by the orchestration of several simple Web services. Composite Web services can be created in both design and execution time. In HYDRA, for the execution of a composite Web service it is firstly necessary to locate a suitable template from the BPEL repository that describes the intended commercial activities. In this schema, the templates are completely determined since commercial partners are known beforehand. For instance, in a purchase order scenario of books, the client might be interested in buying a book in the store that offers either the lowest price or the minimum delivery time. If a client wants to buy several books at the lowest price, HYDRA will retrieve the location of the BPEL workflow template that uses the purchase- criteria selected from a database. Once the template is located, HYDRA uses the

WSDL document and the related configuration files in order to instantiate them. HYDRA obtains the templates that can be used to find the suppliers that offer the product required by the client. A query to a database containing the WSDL documents provided by HYDRA can retrieve the appropriate Web services to obtain a number of pieces of commercial information like price, delivery time, quantity, and purchase access point of the product. The related WSDL documents are then analysed, and all the relevant information is retrieved and used to complete the templates. The instantiated templates are allocated in a BPEL engine for execution. To communicate with the running workflow, HYDRA builds SOAP messages containing the information provided by the client. Following our example, the client sends to the running workflow, the book code and the required quantity in a SOAP message. The workflow verifies also that the sum of all the quantities is at least the quantity requested by the client. If it is not true, an empty list is sent back to the client as response, which means that client's request could not be completely fulfilled by any of the registered stores. Whenever the workflow has been successfully terminated, it sends back to the client the list of suppliers satisfying his requirements. Then, the workflow is de-allocated from the workflow engine. After the client selects the suppliers, a BPEL template for placing a purchase order is now retrieved from the repository, completed and executed as described before. By enacting this workflow the purchase orders are sent to the suppliers and the corresponding answers from each supplier are eventually received.

A wide variety of other composite Web services involving some optimization criteria have also been developed and tested, like minimum delivery time and distributed purchases, to mention a few. In the next section, we describe how business processes descriptions can be monitored at execution time. This is one of the more relevant aspects of HYDRA in relation to the deployment of business processes.

4.3 Process activity monitoring and process management in HYDRA

The need to conduct business in real-time is among the most daunting yet strategic challenges facing today's enterprise. Enterprises that operate in a supply chain management scenario can instantly detect significant events to identify problems and opportunities, and manage the appropriate response to reap significant profits and build competitive advantage. For these reasons, enterprises are turning their attention toward implementing solutions for real-time business activity monitoring (BAM) (Dresner, 2002). In this context, HYDRA offers capabilities for business activities monitoring. For the monitoring process, it is necessary to listen to the request/response SOAP messaging of Web service-based business collaboration. The SOAP messaging identifies the participants and their communications during the long-running interactions of the participants in the collaboration. For this end, HYDRA intercepts all SOAP messages to generate a UML sequence diagram from the information about the participants and the order in which the messages are exchanged. For the monitoring of activities, a set of Java classes has been developed to represent a UML diagram in a SVG (Scalable Vector Graphics) representation that can be visualized in an SVG enabled Internet browser. The exchange of SOAP messages during some kinds of business collaboration may be developed very quickly. Therefore, to avoid reducing the performance of the Web services execution, the dynamic generation of UML diagrams uses a buffered mechanism to deal with a fast pacing production of SOAP messages.

As Web services become pervasive and critical to business operations, the task of managing Web services and implementations of our brokerage service architecture is imperative to the success of business operations involved in supply chain management. Web services Management refers to the problem of monitoring and controlling the Web services themselves and their execution environment, to ensure they operate with the desired levels of quality (Casati et.al, 2003). In this sense, we developed a basic web services manager with capabilities for discovering the availability, performance, and usage, as well as the control and configuration of Web services provided by HYDRA. The underlying technology used for the implementation is JMX (Java Management eXtension), but conceptually could be extended to support other management technologies such as CIM (Common Information Model) and SNMP (Simple Network Management Protocol) (Sidnie, 1994). The JMX architecture consists of three levels: instrumentation, agent, and distributed services. JMX provides interfaces and services adequate for monitoring and managing systems requirements. This functionality involves abstracting resources by using components called MBeans (Managed Beans) and remote instrumented resources, accessible through JMX connectors. The main component for web services management is a JMX Bridge, which acts as a bridge between the collection of resources managed by JMX and Web services. In HYDRA, Web services interfaces to JMX are available. Rather than provide a JMX specific Web service interface, HYDRA provides a Web service interface to a manageable resource. Under our approach, the resources can be implemented on different technologies because it is only necessary to define a Web service interface for a resource. In order to do this, we used MBeans to represent the resource being managed.

To illustrate the functionality of HYDRA, we describe next an e-procurement scenario that integrates several products and services among clients, suppliers and providers that has already been implemented.

4.4 An e-procurement scenario in HYDRA

The case study describes how our brokerage service facilitates the shopping distributed that is offered by an enterprise namely SurteTuDespensa that sell first-necessity products.

Suppose the following scenario:

1. There are a set of enterprises that sell first-necessity products, which have been registered previously in HYDRA. In particular, an enterprise namely SurteTuDespensa that has registered its products and its business processes as Web services in the UDDI node of our brokerage service. Screenshots of the enterprise SurteTuDespensa are depicted in Fig. 5.
2. A potential client (enterprise) starts a supply chain to procure products by requesting a purchase order by means of Web services.
3. In this scenario, we approach the fundamental problem of determining how a client can discover and invoke the Web services available to carry out e-procurement?

HYDRA offers the modality of interaction as an Internet portal. In this mode, there is an option in the main menu called “Distributed Shopping”. In this option, HYDRA displays a graphic interface where the clients can select some products registered and their respective quantities that want to find. The graphic interface of products selection is shown in Fig 6. Once selected the products list, HYDRA displays another graphic interface where the client must choose a sorting criteria. This sorting criterion indicates the form in HYDRA will display the search result. Among the criteria available are lowest price, minimum delivery time, lowest price and minimum delivery time, and all their combinations. Next, HYDRA builds a request to the corresponding Web service. This request returns a list of providers that supply that product according to the selected sorting criteria. The result is shown as a HTML document. At this point, a list of enterprises appears as the product suppliers. Fig 7 shows the graphic interface with the result of the invocation.

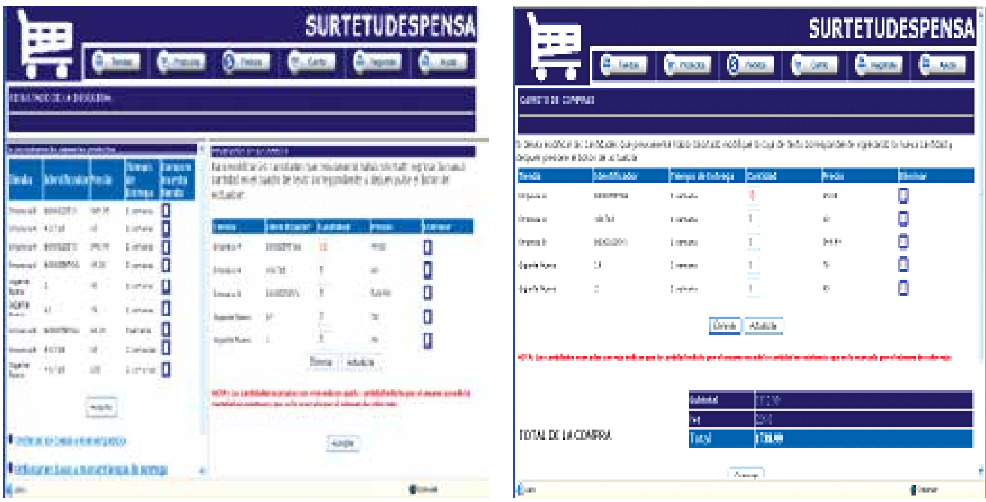

Fig. 5. Graphic Interfaces of the SurteTuDespensa enterprise.

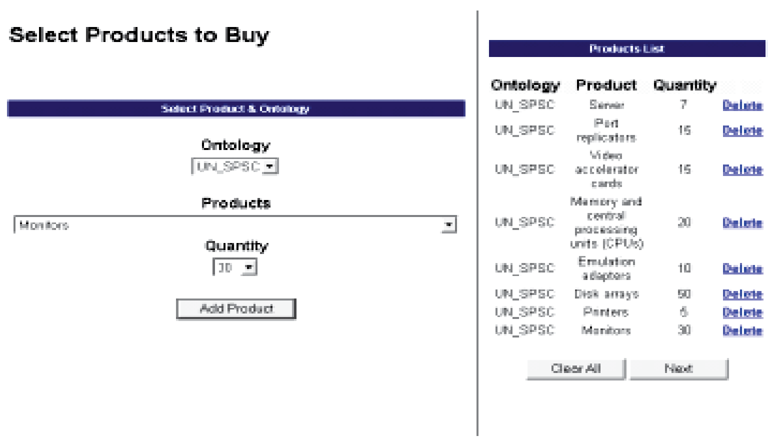

Fig. 6. Graphic interfaces of products selection in BPIMS-WS

Next, the client selects a provider from this list to buy a product. Once selected, HYDRA makes a query to the UDDI node to locate the URL where the PIP 3A4 (Request Purchase Order) is located to obtain and analyze the Web service specification. HYDRA uses sophisticated techniques to dynamically discover web services and to formulate queries to UDDI nodes.

At this point, HYDRA displays a graphic user interface of the Web service specification, enabling the visualization the activities involved in the purchasing order process.The client is then asked to provide the information required to complete the purchase. This graphic interface is shown in Fig 8.

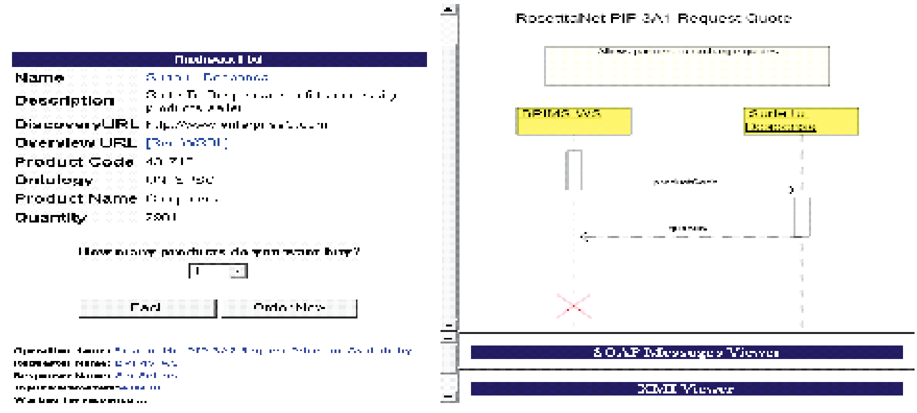

Fig. 7. Screenshot of the result of invoking Web services in HYDRA

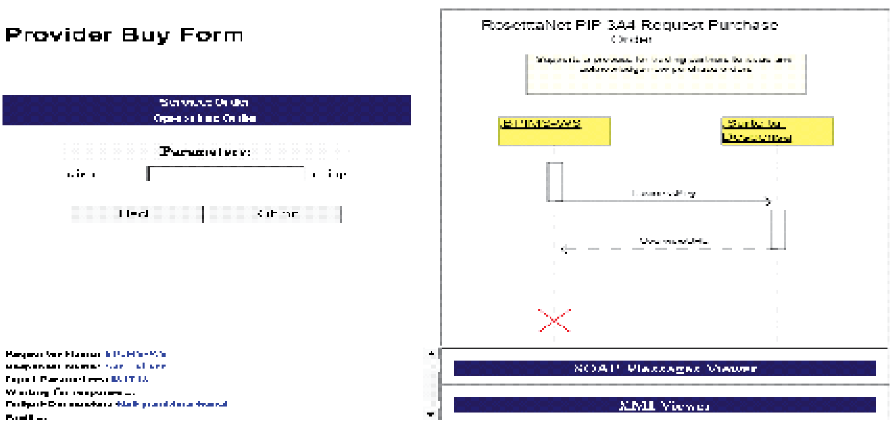

Fig. 8. Screenshot of the Web service specification of a supplier in HYDRA

Upon completion, HYDRA invokes the Web service. Finally, HYDRA shows to the user the results. So far, we have shown only one example that illustrates the business processes integration in HYDRA. However, a wide variety of other cases study involving several optimization criteria have been developed and tested such as shopping with the minimum delivery time, lowest price, specified quantity, and finally with no constraints too.
We envisioned for our proposal, the orchestration of long-term supply chains involving operation research methods to minimize costs, reduce delivery times and maximize quality of service along with artificial intelligence methods to provide semantic matching and to define business partners profile management is now under consideration.

5. Conclusions

Supply chain management is an important yet difficult problem to be addressed in its full complexity. However, we believe that hybrid architecture, borrowing features from SOA and EDA, may provide the fundamental structure in which the solutions to the diverse problems that supply chain management conveys can be accommodated. In this book chapter, we covered the basic concepts and the participants in e-procurement for supply chain management. Next, we reviewed in depth the main e-procurement system reported in the literature. We presented some experiences and success stories. Furthermore, we identified the main information technologies for developing Web-based systems for e-procurement. In this sense, we addressed web services technologies. We have presented some selection criteria, implementation strategies, and process redesign initiatives for successful e-procurement deployment. Research and new trends for e-procurement were also presented in this book chapter in order to provide a guide for designing effective and well-planed process models in e-procurement which is an important prerequisite for implementation success. Finally as proof-of-concept, we presented a Web-based system namely HYDRA which is a middleware-oriented integrated architecture having a layered design and providing a comprehensive framework for developing business integration, collaboration and monitoring in supply chain management scenarios.

We believe this book chapter will provide a guide for selecting emergent approaches based on internet standards in order to achieve interoperability in the e-procurement process among different participants in the supply chain management. Furthermore, we have provided an architectural style where agile solutions with dynamic compositions of reusable services, integration of real assets and virtual services and context aware and responsive services rendering were discussed.

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Districting and Customer Clustering Within Supply Chain Planning: A Review of Modeling and Solution Approaches

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1. Introduction

Districting, geographic demand zone segmentation, and customer clustering subjects, in their different varieties, are rather common and well studied problems within the literature of design and planning of logistic and supply chain networks, mainly focused on distribution/collection supply chain subsystems. Moreover, when a product distribution fleet must be defined and designed, customer-vehicle assignments appear as relevant decisions to be addressed, which can be indirectly considered as a customer clustering/segmentation method. Finally, other kinds of company operations might require some type of demand segmentation, such as territory sales balance as in Zoltners and Sinha (1983), among others.

These problems have been addressed with a wide variety of approaches, such as cluster analysis, that are a collection of statistical methods and graphic/computational tools (such as Geographic Information System, GIS). For instance, in Barreto et al. (2007) a clustering analysis was employed to solving a capacitated location-routing problem. GIS systems are commonly used in districting problems, such as in (Kalcsiscs et al. 2005) where the integration of districting models into Geographic Information Systems is discussed.

Within the field of operations research (focus of the present chapter), several techniques have been considered to deal with this type of problems. The main approaches are: vehicle routing problems (Crainic and Laporte, 1998; Laporte and Osman, 1995), continuous approximation of routing cost (Novaes and Graciolli, 1999, Novaes et al., 2000), and location-allocation modeling structures (Koskosidis and Powell, 1992; Miranda and Garrido, 2004a; Gonzalez-Ramirez et al., 2010-2011). In all these cases, the general framework requires defining a set of decision variables and a mathematical optimization model (e.g. inclusion of customers into demand zones), in which a single or a set of performance indicators should be optimized (e.g. expected routing costs, workload balance, fleet size, demand zone compactness, etc.). These previously mentioned tasks must be addressed observing several practical, logical or mathematical constraints, in order to assure that the optimal solution found is feasible to be implemented.

In addition to the previously mentioned modeling process, the need to solve these models must be addressed by building and implementing computational algorithms for searching optimal or near optimal solutions. Moreover, let us note the high complexity of this type of problems (usually considered NP-Hard), which means that the majority of the employed methods are heuristics and meta-heuristics (i.e. near optimal algorithms). Among the heuristic techniques are those based on evolutionary techniques (Novaes et al., 2000), construction and improvement algorithms (Gonzalez-Ramirez et al., 2010-2011; Koskosidis and Powell, 1992), and those based on mathematical programming (Miranda and Garrido, 2004a).

Based on the different problems and formulations observed, several criteria have been considered as performance indicator for the customer clustering, depending on the stage and level within Supply Chain Planning process addressed (i.e., strategic, tactical, or operational level). For example, when customer grouping is developed in order to reduce the size of the problem, or when the objective is designing preliminary areas for sale purposes or physical distribution, concepts such as compactness and closeness between customers appear as relevant criteria (in the objective function or as restrictions of the optimization model). On the other hand, considering the case of distribution/collection fleet sizing, transportation cost generated by different routes defined for each vehicle is considered as one of the most frequently used criterion to be optimized, along with vehicle capacity constraints.

Finally, given the wide variety of criteria observed to address customer clustering and geographic demand zoning problems, multi objective optimization appears as a rather common approach in the related literature, in which a set of Pareto efficient or Pareto optimal solutions must be found. A Pareto efficient solution is one for which it is not possible to reach any other feasible solution presenting a better performance for a single criterion, without observing a worse performance of any other criterion. According to the aforementioned concerns, this chapter presents a review and taxonomy of different criteria and modeling approaches employed to address different customer clustering problems, along with a review of solution approaches observed in the literature.

Section 2 presents a literature discussion focused on districting or customer clustering problems, including analyses of problem context, design criteria, and modeling and solution approaches. Particularly, this section includes a description of different cost modeling structure for vehicle routing based customer clustering problems. Section 3 summarizes two researches addressing districting/customer clustering problems, with different context, design criteria and solution approaches, considering a similar Mixed Integer Programming (MIP) modeling structure, based on location-allocation decision variables. Section 4 proposes a general framework for addressing the problem of strategic supply chain network design problems, including integrated districting/customer clustering decisions, based on vehicle routing considerations within a more general inventory location modeling structure. Finally, Section 5 presents the main conclusion of this chapter, along with a discussion of further research, perspectives, and final remarks.

2. Literature review and discussion

2.1 Districting /customer clustering applications

Districting or territory design is a geographical problem that involves the partitioning of a region into smaller areas in order to optimize operations for a given criterion (Muyldermans et al., 2003). A district is designed to be used for a long period of time (at least one year) because of the big effort required for adapting the system, physically, operationally and managerially. For this reason, districting is considered a strategic or tactical decision with the aim of yielding good performance of the operations and system robustness to deal with small changes in a variety of environmental factors.

Districting emerges in different contexts such as politics, health care, sales territory planning, covering planning for emergency centers (fireman and police stations), public schools planning, logistics and routing applications. In each case, the districting process serves different purposes and can be economically motivated or have socio-demographic aims (Kalcsics et al., 2005). For instance, in political districting problems, the region under consideration is partitioned into smaller regions to which each candidate belongs. On the other hand, logistics districting is mainly associated with the routing activities of a company, having a strong impact in their performance (Van Oudheusden et al., 1998). The most common contexts of the logistics districting problem are: distribution/collection services, emergency services, medical, fire and police (Moonen, 2004).

Tavares-Pereira et al. (2007a) highlight that districting problems can be classified in terms of two factors: the number of criteria and the solution method (exact and non-exact algorithms). However, since Altman (1997) showed that districting problem belongs to the class of NP-Complete problems (a very complex class of problems which cannot be solved by polynomial algorithms), all the reviewed works propose heuristic methods. According to Grilli di Cortone et al. (1999), there are two main constructive techniques for districting problems: division and agglomeration. In the former, the service region is considered as a whole and divided into pieces. In the latter, a region is already split into small areas, which are aggregated to build the districts. Accordingly, in this chapter heuristic approaches are also presented.

2.1.1 Contributions in logistics districting problems

One of the earliest works in the area of logistics districting is proposed by Keeney (1972). He addresses the problem of partitioning an area such that each district is assigned to an existing facility, considering a single greedy criterion. Hardy (1980) compares the method for vehicle routing proposed by Clarke and Wright (1964) with a methodology based on a districting approach. Wong et al. (1984) consider a problem very similar to districting known as the Vehicle Routing Using Fixed Delivery Areas (VRFDA), where a service area is divided into fixed sub areas in which the daily route may change from day to day. The authors propose a methodology in which total travel distance is minimized. A special case of the VRFDA is the Fixed Routes Problem (FRP) studied by Beasley (1984) in which the service region is divided into sub areas in which the route is fixed from day to day.

Daganzo (1984a) proposes an approximation method for the design of multiple-vehicle delivery zones, seeking tours of minimum total length. The objective of his work is to explore the impact that the zone shape has on the expected length of each route. Daganzo (1984b) presents a methodology in which the region is partitioned into zones of nearly rectangular shape elongated toward the source. In his work, the number of points is large compared to vehicle capacity. Newell and Daganzo (1986a) analyze the districting of a region in which the underlying network of roads is a dense ring-radial network. They propose an approximation method for the design of multiple-vehicle delivery tours in which the aim is to minimize total travel distance. Han and Daganzo (1986) investigate the design of delivery zones for distributing perishable freight without transshipment.

Daganzo (1987a, 1987b) investigates and models distribution problems with time windows.

Langevin and Soumis (1989) study the problem of designing multiple vehicle delivery tours satisfying time constraints for the letter and parcel pick-up and delivery problem using a continuous approximation model. The authors propose a methodology that involves partitioning the region into approximately rectangular delivery zones that are arranged into concentric rings around the depot. Rosenfield et al. (1992) study the problem of planning service districts with a time constraint and derive analytical expressions to determine the optimal number of service districts for the U.S. postal system. Robusté et al. (1990) employ continuous approximations for fleet design vehicle routing problems. Novaes and Graciolli (1999) present a methodology to design multi-delivery tours associated with the servicing of an urban region of irregular shape, assuming a discrete grid-cell representation of the served region. In contrast, Novaes et al. (2000) present a methodology for solving the same problem but using continuous approach to represent the region. Both, Novaes and Graciolli (1999) and Novaes et al. (2000), assume a polar coordinate system (known as a ring-radial system), model capacity probabilistically based on chance constraint programming, and employ a continuous approximation to determine routing costs and times.

Muyldermans et al. (2002, 2003) address the problem of districting for salt spreading operations on roads. They present a graph based model, assuming that each district is served by a single facility. The objective is to minimize the deadheading distances, and the number of vehicles required. Miranda and Garrido (2004a), extending the work of Koskosidis and Powell (1992), propose a Location-Allocation modeling structure along with a Lagrangian relaxation based heuristic, in which a Hub and Spokes cost structure is considered as a performance indicator to be optimized. Their research addresses a fleet design problem within a supply chain network, with a set of fixed and known distribution centers. Each distribution center will be assigned to a set of vehicle routing zones, which is a set of problem decision variables. A greedy assignment non-capacitated criterion is considered for assigning fleet zones or clusters to existent distribution centers.

Haugland et al. (2005) consider the districting problem for vehicle routing problems with stochastic demands, along with a Tabu Search (TS) and a multistart heuristic to solve the problem. They address a two-stage stochastic problem with recourse that seeks to minimize the expected travel time for each district. Galvao et al. (2006) extend the model presented by Novaes et al. (2000) and present a special case of a Voronoi diagram. Tavares-Pereira et al. (2007a) consider the districting problem with multiple criteria. They propose a method to approximate the Pareto front based on an evolutionary algorithm with local search. Tavares-Pereira et al. (2009) propose metrics to compare partitions obtained in a districting configuration, specifically for the case of a connected, undirected, with a graph representation. Novaes et al. (2009) develop two continuous location-districting models applied to logistics problems combining a Voronoi diagram with an optimization algorithm.

González-Ramírez et al. (2010, 2011) analyze a logistics districting problem for package pick-up and delivery within a region, motivated by a real-world application. The region is divided into districts, each served by a single vehicle that departs from a central depot. The districting process aims to optimize two criteria: compactness and workload balance, but the problem is formulated as a single objective problem, with the weighted sum of the two criteria under consideration. The authors propose a heuristic solution approach combining elements of Grasp and Tabu Search.

2.1.2 Contributions in other fields

Some applications of districting include politics. In this field we can mention the work of Hess et al. (1965), who present a Location-Allocation heuristic under population equality, compactness, and contiguity considerations. Garfinkel and Nemhauser (1970) present an exact algorithm to solve this problem under contiguity, compactness, and limited population deviation. Hojati (1996) proposes a three-stage approach and Mehrotra et al. (1998) propose a column generation approach based on branch and price. A review on political redistricting is presented by Williams (1995).

Regarding sales territory design, the first reviews are provided by Zoltners, (1979) and Zoltners and Sinha, (1983). Fleishman and Paraschis, (1988) study a sales territory alignment for a German company for consumer goods and develop a procedure based on a location-allocation. Drexl and Haase (1999) study the problem simultaneously with sales force sizing, salesman location, and sales resource allocation. More recently, a commercial territory design was introduced by Rios-Mercado and Fernandez (2009) that differs from traditional sales territory design in that rather than placing salesmen in territories the authors are interested in locating service centers.

Regarding school districting problems, Diamond and Wright (1987) consider the case where a limited number of schools are allowed. Church and Murray (1993) consider the problem of redesigning school districts to achieve racial balance. Elizondo et al. (1997) present a model to minimize the travel distances of the students. For a review of the most relevant work on this problem refer to Caro et al. (2004).

Within health care system applications, Blais et al. (2003) study a districting problem for a local community health clinic optimizing "visit personnel mobility" and "workload equilibrium", both criteria combined into a single objective function. Baker et al. (1989) study the redistricting problem of primary response areas for county ambulance services. Regarding the police context, Bodily (1978) designs patrol sectors using multi attribute utility theory to include preferences of the interest groups. More recently, D'Amico et al. (2002) present a simulated annealing algorithm for the redistricting police command boundaries. For a more extensive review of the districting problem in the context of emergency sites, refer to Moonen (2004).

2.2 Design criteria issues

As can be observed in the previous section, there are several research works and applications addressing decisions of districting/customer clustering, routing and location issues, motivated and based on a wide variety of criteria for solution performance evaluation. According to Muyldermans (2002), objective functions for evaluating the performance of location and routing decisions are very intuitive, and usually strongly related to the optimization of economic criteria. For instance, facility location models typically deal with minimizing total or maximal distance from depots to customers, and vehicle routing problems normally aim to optimize the number of tours or vehicles, the total distance traveled, time spent on service and travel, violation of capacity an time constraints, etc. (some details about these performance indicators and modeling approaches are presented in sections 2.4, for routing problems, and 4.2, for location problems).

However, as stated by Muyldermans (2002), it seems to be much more difficult to specify measurements for achieving a good districting configuration, due partially to the fact that these measurements rely strongly on the districting context and practical concerns. For a districting problem, the most common requirement is the *workload balance* among districts (or population equality for some other applications), and geographic *compactness* of the districts. Compactness definition may vary according to the districting context, but in general, it implies districts to be as round or square as possible, avoiding elongated shape districts. Another metric that is commonly found in the literature is *contiguity*, which **is** related to the possibility of walking from any point to any other location within the same district without leaving it, as if it were a single land parcel (Ricca, 2004). Another criterion is the *inner variance,* which looks for districts composed of customers as homogeneous as possible. Naturally, homogeneity may be defined according to the problem context and features. Others requirements in districting are *integrity*, which means that a point should not partially allocated to different districts, and *hole absence*, which means that if one draws any closed curve in a district, all points within the inner domain of the curve belong to the same district. This last constraint has been shown to be fully satisfied when the problem is modeled as a connected graph in (Ricca, 2004). Some other common requirements are to satisfy time or capacity constraints or a maximum budget for routing costs.

2.3 Modeling approaches

We distinguish in the literature two main modeling approaches: Mixed Integer Programming (MIP) and Continuous Modeling (CM). Within MIP, districting/clustering decisions are usually modeled through binary variables, which model the inclusion of customers, demand points, or nodes, to each district. Some works using MIP modeling approaches are Hardy (1980), Haugland et al. (2005), Tavares-Pereira et al. (2007a), González-Ramírez et al. (2010, 2011), Koskosidis and Powel (1992), Miranda and Garrido (2004a), Marianov and Serra (2003) and Caro et al. (2004). On the other hand, CM assumes a continuous segmentation of the region, in which districts are defined by a specific shape, representing decision variables of the problem. For example, in CM category we can mention Newell and Daganzo (1986a), Langevin and Soumis (1989), Novaes et al. (2000), Galvao et al. (2006), Novaes et al. (2009), Novaes and Graciolli (1999). In addition, MIP and CM can be considered as Mathematical Programming (MP) approaches.
Finally, we define a third category refereed to as the "*Algorithmic Approach* (AA)", which does not explicitly model the problem as a standard optimization problem (mono or multi criterion objective function, mathematical constraints, decision variables, etc.), but pays more attention to performance indicators (mono or multi criterion) and solution methodologies to obtain well performing districting configurations (usually consisting of heuristic approaches). Some examples are Keeney (1912), Deckro (1977), Wong et al. (1984), Muyldermans et al. (2002, 2003).

2.4 Vehicle routing modeling structures for districting/customer clustering

Focusing on vehicle routing based clustering, four main approaches can be found in the literature, which model routing costs and decisions explicitly, but based on different objectives, hierarchical levels, problem characteristics and assumptions: standard Vehicle Routing Problems (VRP), Hub and Spokes Structures (H&S), Continuous Approximation (CA), and more recently, the Probabilistic Traveling Salesman Problem (PTSP).

2.4.1 Standard vehicle routing modeling structure

Vehicle Routing Problems (VRP), one of the most studied problems in Operation Research and Mathematical Programming, are based on the well known Traveling Salesman Problem

(TSP). In the TSP, an optimal visit sequence for a known set of customers must be found, as indicated in Figure 1, minimizing total cost, distance, time, or any other related metric. In general, for the VRP under deterministic assumptions, a specific visit sequence for each vehicle considered is the standard output or decision modeled. In the VRP with time windows, the specific instant in which every single customer is visited is specified, instant that must observe minimum and maximum values. We refer to Crainic and Laporte (1998), Laporte and Osman (1995), Dantzig, Fulkerson and Johnson (1954), Hoffman and Wolfe (1985), for thorough reviews on the VRP and other related problems.

However, when a strategic perspective is considered, and moreover when assuming stochastic behavior in customer demand and appearance, this modeling structure diminishes in attractiveness and appropriateness, mainly due to:

- Specific visit sequences are not required in the long run, and they are usually modified and re-optimized in the short run, according to customer requirements.
- Specific visit sequences are not feasible and applicable in all days, due to the set of customer to be visited each day is not the same, and more over, not known in advance.
- Routing costs provided by standard deterministic VRP models may not be a good estimate of expected costs in stochastic long-run scenarios.

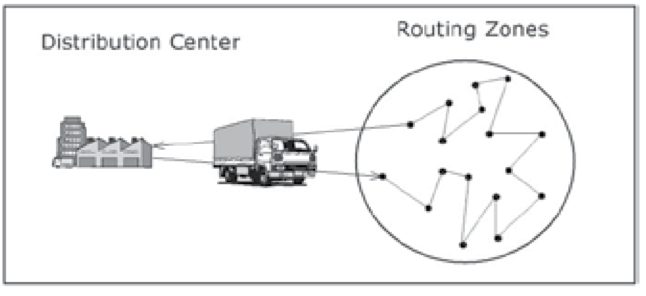

Fig. 1. TSP Modeling Structure

2.4.2 Hub & spokes cost structure

Recently, Miranda et al. (2009) analyze the inclusion of fleet design decisions and routing costs within a known inventory location model, based on a Hub & Spokes cost structure. These modeling structures for routing costs and decisions are previously developed in Miranda and Garrido (2004a), assuming a fixed and known distribution network configuration. These models propose the inclusion of an approximated cost estimation for fleet design and customer clustering (demand zoning) into previous Inventory-Location Problems, which address supply chain network design problems, neglecting specific visit sequences decisions as in the VRP and TSP.

The Hub & Spokes modeling structure, as shown in Figure 2, models two types of transportation costs: a direct cost from each warehouse to a hub or centroid of each customer cluster; and a second inner cluster cost, from each hub or centroid to each customer included in the respective cluster. Accordingly, hub selection and customer-hub assignments, define entirely the routing system and costs. Hub & Spokes cost structure and models are studied and analyzed by Marianov and Serra (2003), Sasaki et al. (1999), Mayer and Wagner (2002), Koskosidis and Powell (1992), and Campbell (1994), among several other works in the Hubs and Facility Location literature.

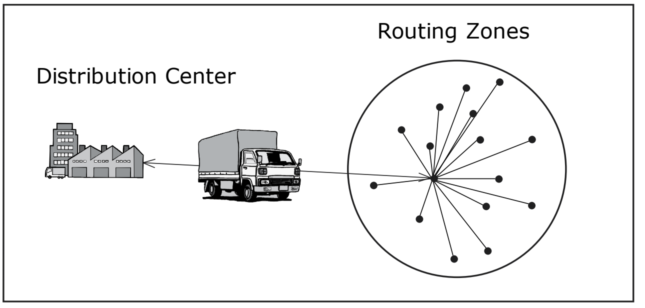

Fig. 2. Hub And Spokes Cost Structure

2.4.3 Continuous approximation of routing costs

One of the main contributions in the last decades, within Logistics and Supply Chain Management, is the computation of the expected distance or cost of vehicle routing systems (similar to the TSP and its extensions), based on Continuous Approximation (CA). These computations are usually required previous to the design and operation of distributing systems. Daganzo (1984a, 1984b, 2005) propose the use of CA in order to develop simple closed mathematical expressions for TSP, and also for other logistic issues, presenting good empirical results.

Figure 3 indicates that routing cost, RC, is estimated by a continuous approximation *RCCA* (Routing Cost Continuous Approximation), in terms of the number of points or nodes (*N*) and the dimension of the area involved (*A*).

For example, in the most basic case, for a given compact and convex area *A* containing *n* demand points or customers, the optimal TSP distance can be accurately approximated by $\alpha \cdot \sqrt{A \cdot n}$, where α is a proportionality constant equal to 0.75 when the Euclidean metric is considered (different values must be considered for other metrics). As extensions and variations of this basic model, several studies have been developed, addressing different routing scenarios. See for example, Newell and Daganzo (1986a, 1986b), Novaes et al. (2000), Robusté et al. (1990, 2003), and Robusté (2003).

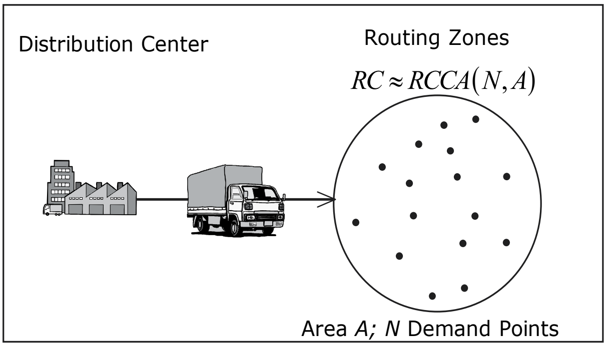

Fig. 3. Routing Cost Continuous Approximation

2.4.4 Probabilistic traveling salesman problem

The Probabilistic Traveling Salesman Problem (PTSP), introduced by Jaillet (1985, 1988) and reviewed later by Powell et al. (1995), is an extension of the TSP. In this problem each

known existent customer i has a probability p_i to require a visit in a specific routing period. Accordingly, an optimal *a-priori* solution must be found in which all customers must be included (independent of their requirements), for which an *a-posteriori* solution is defined for each possible scenario or realization, just skipping each absent customer, as shown in Figure 4. The optimal *a-priori* solution is defined by the minimization of the expected costs considering all possible realizations, in which a weighted summation of distances is considered, where the occurrence probabilities of the realizations are the weights. Thus, the expected cost of any given *a-priori* tour can be obtained estimating the cost for each possible realizations of the problem. For n nodes this has a complexity of $O(n{\cdot}2^n)$, which makes the simple process of computing the costs of a single *a-priori* tour prohibitive.
However, the tour length can also be computed with a lower complexity. Without loss of generality, it is assumed that in the *a-priori* sequence (τ), the nodes are visited in an ascending numbering order, namely, τ = 1, 2, 3, … , n. Then, the expected value of the associated costs of this *a-priori* sequence can be computed with the following expresion:

$$E\left[L(\tau)\right] = \sum_{i=1}^{n}\sum_{j=i+1}^{n} d_{ij} p_i p_j \prod_{k=i+1}^{j-1} q_k + \sum_{i=1}^{n}\sum_{j=1}^{i-1} d_{ij} p_i p_j \prod_{k=i+1}^{n} q_k \prod_{l=1}^{j-1} q_l \qquad (1)$$

In expression (1), $E[L(\tau)]$ is the expected cost of an *a-priori* tour τ; p_i is the node i appearance probability; and q_i is the probability of node i not appearing in the problem's realization (1-p_i). In the first summation of (1), the term multiplying d_{ij} represents the probability of making a trip between i and j for any realization of the problem, where $p_i p_j$ is the probability of nodes i and j being present, and $\prod q_k$ is the probability of all nodes between i and j being absent in the realization. Similarly, in the second summation, the term that multiplies d_{ij} is associated to the return trip made from the last visited node, i, to the node where the tour started, j. This calculation of $E[L(\tau)]$ can be obtained with $O(n^2)$ complexity.
Given the high complexity of PTSP (NP-Complete Probabilistic Combinatorial Optimization Problem), it has been solved mainly by heuristic approaches, which usually are extensions of well known heuristics of the TSP, as presented in Bianchi and Campbell (2007), Bianchi et al. (2005), Lamas et al. (2007), Tang and Miller-Hooks (2005), and Branke and Guntsch (2004). However, Laporte et al. (1994) developed an exact algorithm to solve the PTSP, but it is applicable only for small instances.

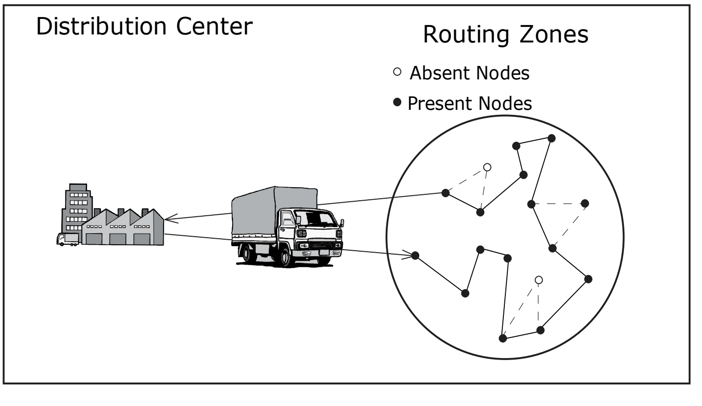

Fig. 4. PTSP Modeling Structure

3. Two cases for logistics districting and customer clustering

In addition to a review of different approaches that can be employed to address clustering problems, we present two different cases based on MIP approaches, assuming location-allocation decision variables, and addressing different practical concerns.

The first one, based on Gonzalez-Ramirez et al. (2010 and 2011), is focused on a general view of the districting problem, in which routing costs are not considered, and where district shapes and workload balancing issues are the main focus of the research. The number of districts is known and predetermined by a planner, and a known single depot is considered.

In contrast, in Miranda and Garrido (2004a), a similar modeling structure is proposed to design a distribution system, in which approximated routing costs and stochastic vehicle capacity constraints are modeled explicitly as design criteria. In this problem, the number of districts (equivalent to the fleet size) is a decision to be optimized. Finally, in this paper a set of pre-existent warehouses is considered, and a simple greedy criterion is consider to assign the clusters to the existent warehouses.

3.1 District design for a parcel and pickup problem

3.1.1 Problem description and mathematical formulation

Consider a connected, undirected graph $G(V,E)$ where V is the vertex set and E the edge set. The graph is generally not complete. We assume that all the edges $e_{rs}=(v_r, v_s)$ have a positive length and represent a real road between adjacent points v_r and v_s. Distances between points are edge lengths for those points that are connected in the graph and shortest path distances for other pairs of points. A district is defined as a subset of the points. Each vertex may require either a pickup or a delivery. The aim of the districting procedure is to optimize two criteria: balance of the workload content among the districts and compactness of district shapes. The mathematical model proposed for this problem consists of a single objective model in which the weighted sum of both criteria is minimized.

Compactness is not defined precisely for all the districting problems in the literature and it is generally defined according to the application context. For this problem we define it as the distance between the two furthest apart points in a district and we proposed a minimax objective in which we attempt to obtain compact districts when the maximum compactness metric is minimized.

The workload content of a district is defined as the time required to perform all required pickups and deliveries plus the time needed to drive from the depot to the farthest point in the district. In order to balance the workload content among districts, we propose to minimize the maximum workload allocated to a district. We also attempt to obtain districts with balanced workload content by minimizing the dispersion of the workload assigned to each district, which is represented by the sum of the absolute value of the differences between the workload content of each district with respect to the average workload.

We propose a single objective mathematical formulation in which the weighted sum of the compactness metric and the maximum workload content assigned to a district is minimized, each of them normalized. The following notation is defined:

α : Maximum number of pickups for each district.

β : Maximum number of deliveries for each district.

J : District set, $J=\{1,\ldots,m\}$.

wp_i, wd_i : Number of pickups or deliveries respectively, requested by demand point i, $i \in V$.

Stp, Std	:	Stopping time per pickup and delivery respectively in each node.
d_{ik}	:	Distance from point *i* to point *k*, $i,k \in V$, λ= Scale factor, $0 \le \lambda \le 1$.
d_{0i}	:	Distance from the depot to the point *i*, $i \in V$.
Sp	:	Average speed.
Nz	:	Normalization parameter for the compactness metric.
Nw	:	Normalization parameter for the workload metric.
		The following decision variables are defined:
X_{ij}	:	Binary variable. 1 indicates that customer *i* is assigned to district *j*.
		And the following auxiliary variables are defined:
W	:	Continuous variable that represent the maximum workload content assigned to a district.
Z	:	Continuous variable that measure the compactness as the maximum travel time between the furthest apart points of a district.
D_j	:	Continuous variable that takes the value of the traveling time from the depot to the farthest point of district *j*.
M_j	:	Continuous variable that takes the value of the traveling time between the two furthest apart points of district *j*.

The mathematical formulation model is as follows:

$$Min \quad OF1 = \frac{\lambda W}{Nw} + \frac{(1-\lambda)Z}{Nz} \qquad GR-(1)$$

Subject to:

$$\sum_{j \in J} X_{ij} = 1 \qquad \forall i \in V \qquad GR-(2)$$

$$\sum_{i \in V} wp_i X_{ij} \le \alpha \qquad \forall j \in J \qquad GR-(3)$$

$$\sum_{i \in V} wd_i X_{ij} \le \beta \qquad \forall j \in J \qquad GR-(4)$$

$$M_j \ge \frac{d_{ik}(X_{ij} + X_{kj} - 1)}{Sp} \qquad \forall j \in J, i \in I, k \ne i \in V \qquad GR-(5)$$

$$Z \ge M_j \qquad \forall j \in J \qquad GR-(6)$$

$$D_j \ge d_{i0} X_{ij} \qquad \forall i \in V, \forall j \in J \qquad GR-(7)$$

$$W \ge Std \sum_{i \in V} wd_i X_{ij} + Stp \sum_{i \in V} wp_i X_{ij} + D_j / Sp \qquad \forall j \in J \qquad GR-(8)$$

$$X_{ij} \in \{1,0\} \qquad \forall i \in V, \forall j \in J \qquad GR-(9)$$

Equation GR–(1) is the objective function that minimizes a weighted average of the maximum workload and maximum compactness metrics. The objectives are normalized and the relative weighting is given by λ. Constraints GR–(2) guarantee that each demand point is assigned to only one district. Constraints GR–(3) and GR–(4) guarantee that each district has a maximum of α pickups and β deliveries, respectively. These constraints help to balance the number of pickups and deliveries allocated to a district so that the capacity of the vehicles is not exceeded. Constraints GR–(5) guarantee that M_j takes the value of the maximum travel time between the points assigned to each district in time units. Constraints GR–(6) guarantee that *Z* takes the maximum value over M_j. Constraints GR–(7) guarantee that D_j takes the value of the time from the depot to the farthest point of each district *j*. Constraints GR–(8) guarantee that *W* takes the maximum amount of workload of a district. Constraints GR–(9) are the binary requirements. Normalization parameters are estimated with respect to the optimal values of the compactness and workload content

3.1.2 Solution approach

A multi-start heuristic algorithm that hybridizes GRASP with Tabu Search is proposed. It consists of two phases as it is typical of a GRASP approach: construction of a feasible initial solution and improvement by local search.

GRASP is a multi-start constructive metaheuristic proposed by Feo and Resende (1989) in which a single iteration consists of two phases: i) construction of an initial solution, and then ii) improvement of the solution by a local search approach. The construction phase includes greedy criteria, and it is randomized by the definition of a list with the best candidates, from which a candidate is selected randomly. Among all the solutions created, the best solution is reported as the final step of the algorithm. For a detailed description of GRASP, see Resende and Ribeiro (2002), in which the authors present details of different solution construction mechanisms, techniques to speed up the search, strategies for the implementation of memory, hybridization with other metaheuristics, and some applications.

Tabu Search (TS), proposed by Glover (1977), is a technique based on an adaptive memory, which enhances the performance of a basic local search procedure, aiding to escape from local optima by accepting even non-improving moves. To prevent cycling to previously visited solutions, last moves are labeled as "tabu-active" during a predetermined number of iterations. However, good quality solutions that are currently tabu active may be visited under some criteria that are referred to as "aspiration criteria". Comprehensive tutorials on Tabu Search are found in Glover and Laguna (1993) and (1997).

In the combined GRASP-Tabu Search algorithm, a solution is considered to be feasible if all the points are allocated to a district and the capacity limits with respect to both services (pickups and deliveries) are respected for all the districts, as established by constraints *RG*-(2), *RG*-(3) and *RG*-(4). Among all the solutions created and improved, the best one is reported as the final solution for a given instance. In case of ties, the solution that provides the lowest dispersion value for the workload content among districts is selected.

A key concept is the *adjacency* among points and districts, which is a condition that should be updated when a point is assigned or moved to a district. This requirement is imposed as part of the procedure with the aim of constructing districts of compact shape. A point is considered *adjacent* to a district if there exists at least an edge connecting the point with one of the points already allocated to the district. Knowledge of the adjacency helps to avoid unnecessary evaluations that may result in long computational times and also enhance compactness of the solution constructed. Each time that a point is assigned to a district, adjacency among districts needs to be updated.

a) Construction phase

We propose two main steps to construct the initial feasible solution: Selection of a set of m seeds and allocation of points to the districts formed by a seed. Throughout the procedure, every time that a point is assigned to a district, the adjacency among points and districts is updated. To enhance compactness, points are attempted to be assigned to the closest seed as long as adjacency conditions are fulfilled. In a number of iterations, points are attempted to be assigned to an adjacent district respecting capacity constraints. Then, if required, the remaining points are assigned to an adjacent district even if capacity constraints are violated and a local search procedure is applied with the aim of achieving feasibility. If no feasible solution is constructed, then the solution is discarded.

b) Local search phase

This procedure implements a TS short term memory with an aspiration criterion that allows a *tabu active* move only if the resulting solution is better than the current best solution. The

search space consists of the solutions yielded after transferring a point between adjacent districts. The best solution found is reported after a number of iterations. In the case of ties, the solution with the less dispersion on the workload content of the districts is selected.
The neighborhood structure is a greedy approach that consists of a quick evaluation of all the feasible moves between adjacent districts. The best solution is selected and the corresponding move of a point is performed during each of the iterations. Given that the best move may result in a worse solution than current solution, during the procedure a list of the three best solutions is maintained. At the end of the procedure a final attempt is made to improve these three best solutions in hopes of finding a better solution with a small amount of additional effort. The overall best solution found is reported as the final solution for the given initial feasible solution.

3.1.3 Results and discussion

To test the performance of the proposed solution procedure, a set of instances was randomly generated. All problem instances were solved on a 2.00 GHz Pentium processor with 2 GB of RAM running under Windows XP. Five different instance sizes were defined, which are classified by the number of points and districts: 50_5, 200_10, 450_15, 1000_20 and 1500_30. The instances were solved by the proposed heuristic and CPLEX 11.0.
Points were uniformly generated over a plane, and a set of edges was generated by forming a spanning tree and adding additional edges. Euclidean distances were computed only for the points connected by an edge, and for the rest shortest paths are found using the Floyd-Marshall algorithm (Floyd, 1962). Stopping times were fixed at a realistic value for all the instances generated, considering that the service activities are performed within an urban region and that a pickup usually requires more time than a delivery. Three levels of average speed were considered, assuming that all the vehicles assigned to the districts travel on average at the same speed over the entire service region: 25, 30 and 35 kilometers/hour. Two levels of capacity are defined: tight and less restricted. The relative weighting factor was varied over three values: λ=0.25, 0.5 and 0.75. Three replicates were generated for each of the five instance sizes. Each instance was solved varying the three values of the relative weighting factor, the two levels of capacity limits and the three values of speed resulting in a total of $5\times3\times3\times2\times3 = 270$ instances. A limit time of 3600 seconds was set for the instances, both for CPLEX and the heuristic.
For each instance solved by CPLEX and the heuristic, we compute a gap between the best integer solution reported by CPLEX (that in some cases corresponds to the optimal) and the heuristic. Positive gaps are obtained when CPLEX finds a better solution than the heuristic. A negative gap indicates that the solution found by the heuristic is better than the best integer solution found by CPLEX under the limit time that was set.
Table 1 presents the results of the heuristic with respect to CPLEX solutions by instance size in which we can observe that CPLEX found at least an integer solution only for the instances of size 50_5 and 200_10. The maximum, average, and minimum gap is shown. We can observe that CPLEX did not find the optimal solution for the 200_10 instances, for which the heuristic found a better solution. For the smaller size instances of 50_5, CPLEX found the optimal solution for almost all the instances. We can also observe that on average, the heuristic yielded small gaps, with a maximum gap of less than 8.7%.
For further research, we propose the formulation of a stochastic version of the problem and the analysis of different demand scenarios. A model containing chance constraints could also be formulated. The problem may also be solved as a bi-objective optimization problem to find the efficient frontier instead of a single solution. We also propose to analyze different

metrics of the workload content of a district (such as the closest point or a centroid line hauls metric) and their effects on the performance of the heuristics. We could also analyze different metrics to measure the compactness of the districts. Another extension is to propose a decomposition approach in which the sub problems consist of defining each of the districts and the master problem selects a set of districts so that all the points are allocated to a district. We may also try to find a better mathematical formulation for the problem that may allow CPLEX to solve larger instances. We could also try to find a tight lower bound for the procedure.

SIZE	Metric	Computational Time		GAP
		CPLEX	Heuristic	
50_5	Max	3603.24	0.563	0.087
	Average	3200.69	0.414	0.0158
	Min	166.485	0.296	0
200_10	Max	3609.93	16.437	-0.197
	Average	4604.938	14.005	-0.402
	min	0.641	12.172	-0.555
450_15	max		140.048	
	average		116.517	
	Min		95.877	
1000_20	Max		1173.827	
	Average		1032.099	
	Min		924.799	
1500_30	Max		3829.187	
	Average		3733.512	
	Min		3608.015	

Table 1. Gaps with respect to CPLEX by instance size.

3.2 Fleet design and customer clustering based on a hub & spokes costs structure approximation

3.2.1 Problem description and mathematical formulation

Miranda and Garrido (2004a) propose an approach for the design of a fleet for delivery or distribution, considering a known set of depots or distribution centers, and including stochastic constraints for vehicle capacity for each zone or district. Two additional distinctive elements compared to the model presented in section 3.1 are that the number of zones or vehicles is a decision variable, and an approximated routing cost function is included based on a hub and spokes modeling structure, as stated in Section 2.5.2.

The model notation is the following:

X_j	:	Binary variable. 1 indicates that customer j is a hub.
W_{jl}	:	Binary variable. 1 indicates that customer l is assigned to cluster j.
D_j	:	Mean daily demand for the whole cluster j (variable).
V_j	:	Variance of the daily demand for the whole cluster j (variable).
$RCap$	:	Vehicles capacity (parameter).
μ_j	:	Mean of the daily demand for customer j (parameter).
σ_j^2	:	Variance of the daily demand of customer j (parameter).
TC_{ij}	:	Transportation cost between the customer j and depot i (parameter).

RC_{jl} : Transportation cost between the customer l and the hub j (parameter).
FC : Fixed daily cost due to operate each vehicle (parameter).
$Z_{1-\theta}$: Standard normal value, accumulating a probability of 1-θ (parameter).
Potentially, each customer can be chosen as a hub, then, CR_{jl} must be defined for each pair of customers. Furthermore, in this paper we assume each hub is assigned to its closest depot or warehouse, representing a debatable assumption, but it suggests an important opportunity for future research: it is possible to integrate this model into a facility location problem, in which the optimal assignment of hubs to depots will be solved by the model, considering some kind of capacity constraint.
Then the cost of choosing the customer j as a hub is defined as:

$$FC + TC_j = FC + \underset{i}{Min} \qquad TC_{ij} \tag{2}$$

Thus, the optimization model can be formulated as follows:

$$Min \qquad \sum_{j=1}^{M}\left(FC + TC_j\right)\cdot X_j + \sum_{j=1}^{M}\sum_{l=1}^{M} RC_{jl}\cdot W_{jl} \qquad MG-(1)$$

Subect to:

$$\sum_{j=1}^{M} W_{jl} = 1 \qquad \forall l = 1,\dots,M \qquad MG-(2)$$

$$W_{jl} \le X_j \qquad \forall j,l = 1,\dots,M \qquad MG-(3)$$

$$D_j = \sum_{l=1}^{M} W_{jl}\cdot \mu_l \qquad \forall j = 1,\dots,M \qquad MG-(4)$$

$$V_j = \sum_{l=1}^{M} W_{jl}\cdot \sigma_l^2 \qquad \forall j = 1,\dots,M \qquad MG-(5)$$

$$D_i + Z_{1-\theta}\cdot\sqrt{V_i} \le RCap\cdot X_j \qquad \forall j = 1,\dots,M \qquad MG-(6)$$

$$W_{jl}, X_j \in \{0,1\} \qquad \forall j,l = 1,\dots,M \qquad MG-(7)$$

Expression *MG*-(1) represents the total system cost, considering a cost structure based on a Hub & Spokes approximation. The first term considers the total fixed cost associated to each vehicle and the transportation cost between the depots and the hubs. Note that each cluster is assigned to the nearest depot (with respect to its hub). The second term represents the total transportation cots between hubs and customers, grouped into the respective clusters.
Constraints *MG*-(2) assure that each customer is assigned to a single cluster. Note that each customer j can also be assigned to itself, with zero transportation cost. Constraints *MG*-(3) state that if some customer was not chosen as a hub, it is not possible assign customers to him. Constraints *MG*-(4) represent the stochastic capacity constraints, which assure that the probability of violating the vehicle capacity for each cluster does not exceed θ. These constraints assume normality for demand of clusters. Finally, constraints *MG*-(5) assure the integrality of the variables X and Y.

3.2.2 Solution approach

The solution approach proposed comprises two subroutines: A construction-improvement local search heuristic and a Lagrangian relaxation-based algorithm to compute upper bounds to errors for heuristic solutions provided by the first subroutine.

a) Construction-improvement local search heuristics

The construction-improvement heuristic, defined by Steps I to V, iteratively improves (based on Steps III, IV and V) an initial feasible solution (obtained through Step I and II), using a local search algorithm.

- Step I : Selecting an initial set of hubs.
- Step II : Greedy assignment of customers to initial hubs.
- Step III : 2-Opt hubs update within each cluster.
- Step IV : 1-Opt customers interchange (between each pair of clusters).
- Step V : 2-Opt customers interchange (between each pair of clusters).

b) Lower bounds with lagrangian relaxation

This section describes a Lagrangian relaxation (LR) approach used to obtain a lower bound for the optimal value of the SMDCCP. The LR technique gives the optimal value of the dual problem, which sets a lower bound for the optimal value of the primal SMDCCP. Furthermore, the difference between the optimal value of the dual problem and the primal objective function (found through the heuristic stated in the last section), represents an upper bound for the duality-gap and heuristic solution error.

The LR implemented in this paper relies on the subgradient method to update and optimize dual penalty variables, ϕ^1, ϕ^2, andϕ^3 (see Crowder, 1976, Nozick, 2001, and Miranda and Garrido, 2004b, among others).

Next the relaxation method is described, in which the constraints MG-(2), MG-(5) and MG-(6) are relaxed, obtaining M sub-problems, one sub-problem for each customer j. If ϕ^1, ϕ^2, andϕ^3 are the vectors of the dual variables associated with each relaxed constraints, the dual-lagrangian function can be written as follows:

$$\begin{aligned}&\sum_{j=1}^{M}\left(FC+TC_j\right)\cdot X_j+\sum_{j=1}^{M}\sum_{l=1}^{M}RC_{jl}\cdot W_{jl}+\\&\sum_{l=1}^{M}\phi_l^1\cdot\left(1-\sum_{j=1}^{M}W_{jl}\right)+\sum_{j=1}^{M}\phi_j^2\cdot\left(\sum_{l=1}^{M}W_{jl}\cdot\mu_j-D_j\right)+\sum_{j=1}^{M}\phi_j^3\cdot\left(\sum_{l=1}^{M}W_{jl}\cdot\sigma_l^2-V_j\right)\end{aligned}\tag{3}$$

Clearly, the problem of minimizing expression (3), in terms of X, W, D, and V, for fixed values of ϕ^1, ϕ^2, and ϕ^3, is equivalent to solve one sub-problem for each cluster j, given by:

$$\begin{aligned}&Min\left(FC+TC_j\right)\cdot X_j-\phi_j^2\cdot D_j-\phi_j^3\cdot V_j+\sum_{l=1}^{M}\left(RC_{jl}+\phi_j^2\cdot\mu_l+\phi_j^3\cdot\sigma_l^2-\phi_l^1\right)\cdot W_{jl} && (i)\\&subejct\ to:\\&W_{jl}\le X_j \qquad \forall l=1,....,M && (ii)\\&D_j+Z_{1-\theta}\cdot\sqrt{V_j}\le RCap\cdot X_j \qquad \forall j=1,....,M && (iii)\\&W_{jl},X_j\in\{0,1\} \qquad \forall l=1,....,M && (iv)\end{aligned}\tag{4}$$

This problem can be easily solved, as described in Miranda and Garrido (2004a), by a procedure very similar to basic applications of lagrangian relaxation to standard facility location problems, as shown in Daskin (1995) and Simchi-Levi et al. (2003). This procedure, for a set of known values of ϕ^1, ϕ^2, and ϕ^3, relies on observation of weather benefits (or negative costs) related to expressions $-\phi_j^2 \cdot D_j - \phi_j^3 \cdot V_j$ and $RC_{jl} + \phi_j^2 \cdot \mu_l + \phi_j^3 \cdot \sigma_l^2 - \phi_l^1$ in (4)-(*i*), compensate fixed costs FC+TC_j. Aforementioned benefits are previously computed observing constraints (4)-(*ii*), (4)-(*iii*), and (4)-(*iv*), assuming X_j=1

3.2.3 Results and discussion

The procedures described in previous sections were applied to a numerical example, considering 20 depots, and 200 customers. The customers were located randomly in a square area with sides 1,000 km long. The depots were uniformly distributed over this area. The daily fixed cost, *FC*, was set to $16, $19.2, $22.4, $25.6, $29.8 and $32, while the transportation costs (TC_{ij} and RC_{jl}) were estimated based on a unitary cost of 8 cents/km. The customers mean demands were randomly simulated around 14 units, and the variances were generated considering a coefficient of variation close to 1. For the vehicle capacities we considered values of 150, 170, 190, 210, 230 and 250 units, while the level of service for capacity constraints was fixed at 85%, 90%, and 95% (1.036, 1.282 and 1.645). Thus, we consider 108 instances.

Figure 5 and Figure 6 show the evolution of the objective function obtained by the heuristic, and through Lagrangian relaxation (dual bound), in terms of the fixed cost *FC*, for capacity values of 150 and 250, respectively. Each figure shows these results for level of service values of 85% and 95%. Firstly, we observe that both functions vary in a reasonable way in terms of fixed cost, capacities, and level of service. Second, we observe that the dual bound is always lower than the objective function of the heuristic solutions, with an optimal objective value between the heuristic and dual bound values. It must be noted that the difference between these functions is the sum of the error of heuristic and the duality gap (the difference between primal and dual optimums). Thus a small difference between these functions indicates that the solutions found are nearly optimal.

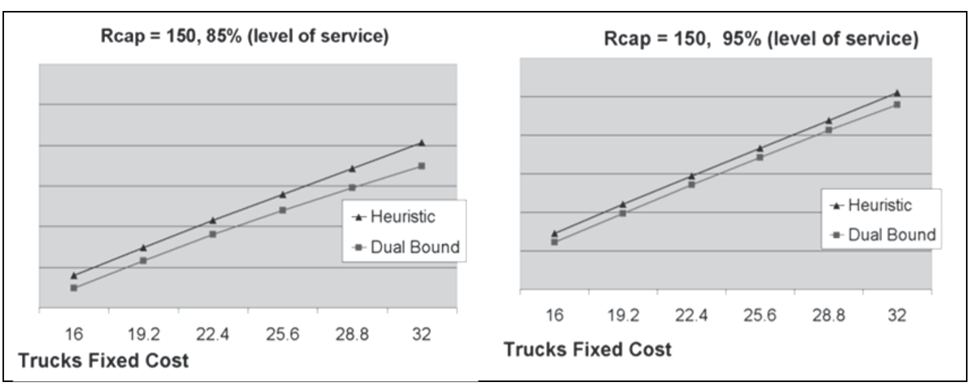

Fig. 5. Evolution of the Objective Function of Heuristic and Dual bound, For RCap = 150

In terms of heuristic quality, Figure 7 shows a histogram of error upper bound for the 108 instances considered, obtaining an average of 2.76%. It is worth noting that in 65.4% of the cases, we obtain an error upper bound lower than 3%. Finally, only for 6.37 % of cases the error upper bound was greater than 5%, and in all cases lower than 7.5%.

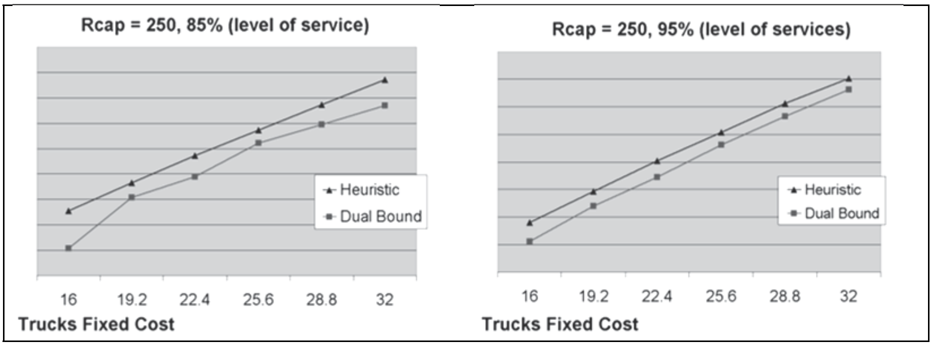

Fig. 6. Evolution of the Objective Function of Heuristic and Dual bound, For RCap = 250

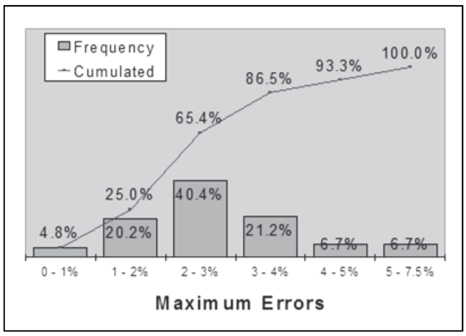

Fig. 7. Histogram of Error Upper Bounds for 108 Instances

4. Integrative approaches for supply chain network design

4.1 Hierarchical discussion of supply chain network design

In this final section, we discuss the districting or customer clustering problem in a wider context, focusing on an integrative approach for addressing strategic network design and planning problems within the scope of Supply Chain Management (SCM) and Logistics. In this context, districting or customer clustering problems are usually conceived based on fleet design and vehicle routing considerations. More specifically, customer clustering decisions consist of assignment of customers into routing zones or vehicle routes, where the number of vehicles, zones, or clusters might be considered as an additional required outcome of the problem. For the aforementioned reasons, MIP based methodologies (modeling and solution techniques) arise as very common and widely studied approaches, mainly based on VRP modeling structure.

In terms of existent problems and state of the art literature and methodologies, Logistics and SCM comprises several problems at different hierarchical levels of decision making. Some problems at the strategic long-run level are production capacity planning and supply chain network design. At a tactical level, the most relevant examples are fleet design problems and production and inventory planning. Finally, the operational short-run level includes daily routing decisions and daily ordering and inventory decisions. For a thorough review of hierarchical levels and problems in SCM see Miranda (2004), Miranda and Garrido (2004c), Garrido (2001), Simchi-Levi et al. (2003), Coyle et al. (2003), Ballou (1999), Mourits y Evers (1995) and Bradley and Arntzen (1999).

One of the main problems in Logistics and SCM is Distribution or Supply Chain Network Design (SCND). This problem consists of finding optimal sites to install plants, warehouses, and distribution centers, as well as assigning the customers to be served by these facilities, and finally how theses facilities are connected with each other. One likely objective for these networks is to serve customer demands for a set of products or commodities, minimizing system costs and maximizing, or observing, specific system service levels. Usually, customers are geographically distributed in wide areas, requiring significant efforts for distributing their products from immediate upstream facilities (distribution centers and warehouses), typically based on a complex vehicle routing systems.

The specific problem that must be modeled and solved strongly depends on several features of the real application. Some examples are: customer requirements and characteristics, logistic and technological product requirements, geographic issues, and operational and managerial insights of the involved firms, among others elements.

Although SCND, along with its decisions and costs, has been considered as strategic in Logistics and SCM, it strongly interacts with other tactical and operational problems such as inventory planning, fleet design, vehicle routing, warehouse design and management, etc. However, standard and traditional approaches to tackle SCND might consider only a sequential approach, in which tactical and operational decisions are only attended once strategic decisions have already been solved. For example, inventory planning and control are solved only assuming the pre-existent locations. The same happens with fleet design and routing decisions, which are addressed only for each existent distribution center or warehouse. Several published works focus on specific SCND problems considering only strategic, tactical and operational viewpoint.

This sequential approach is described by Figure 8, considering routing and inventory decisions in addition to SCND problem, and considering the three hierarchical levels: strategic, tactical, and operational. As suggested by the dotted lines, several interactions among the decisions involved are not modeled, in contrast to the continuous lines, which represent standard interactions usually modeled by a sequential approach.

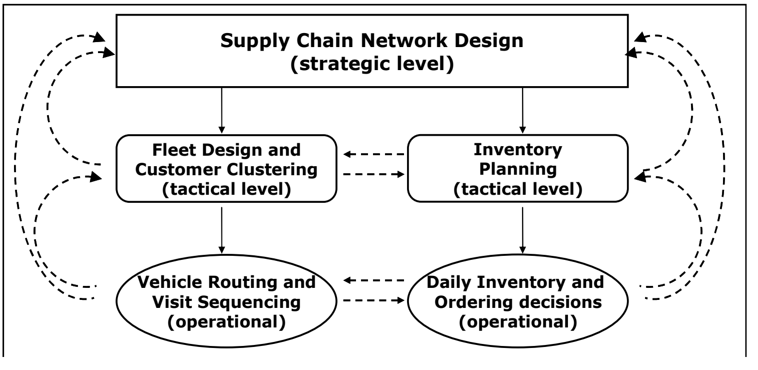

Fig. 8. Three Hierarchical Levels View of the Distribution Network Design Problem

Being consistent with this viewpoint, this section focuses on an integrative approach including tactical routing and inventory decisions into the SCND modeling structure, as suggested in Figure 9, where continuous lines represent interactions modeled by the proposed approach. Naturally, it is possible to consider, at least for future research, the inclusion of operational costs and decisions within the framework; however, including these is expected to provide less significant results compared to the present proposal. Therefore, operational modeling is not considered in the proposal.

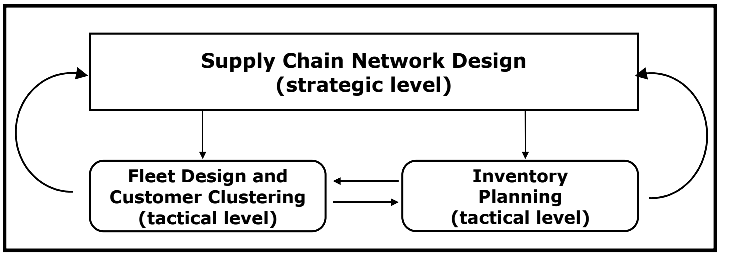

Fig. 9. Hierarchical Level Representation of the Proposed Methodology

Mainly assuming the sequential approach stated in Figure 8, SCND is one of the most studied problems in SCM. Related literature includes numerous reports addressing diverse aspects of the general problem, considering a wide range of degrees of interaction between strategic and tactical decisions.

At the strategic level, facility location theory is one of the most commonly used approaches. For a comprehensive review of Facility Location Problems (FLP), see Drezner and Hamacher (2002), Drezner (1995), Daskin (1995), and Simchi-Levi et al. (2005). Traditional FLP consider deterministic parameters, demands, constraints, and an objective function within a mixed-integer modeling structure. However, based on the traditional FLP framework, it is hard to model interactions with other tactical and operational issues of SCM, such as inventory control and fleet design problems. These potential interactions are shown in Figure 9, where inventory control and vehicle routing decisions (within tactical and operational levels) interact with the strategic SCND problem.

Accordingly, any integrative approaches for coping with strategic network design problems should incorporate VRP decision and costs into Facility Location based models.

4.2 Standard facility location modeling structure

As stated in previous sections, Supply Chain Network Design problems are traditionally tackled within facility location literature, assuming a strategic perspective in its modeling structure and costs. In this framework, main decisions are modeled using binary decisions variables for selecting facilities and assigning customers to these facilities. The objective function expressed in (5) represents a typical cost function to be minimized in a FLP.

$$Min \quad \sum_{i=1}^{N} F_i \cdot X_i + \sum_{i=1}^{N}\sum_{j=1}^{M}\left(R_i \cdot d_j + T_{ij}\right)\cdot Y_{ij} \tag{5}$$

In this expression, M is the set of customers to be served, each one having an expected demand d_j, in the specific considered planning horizon; N is the set of potential sites to install warehouses; F_i is the total fixed cost when installing a warehouse in site i; R_i is the transportation unit costs from a single existent plant to each warehouse i, and T_{ij} is the full-truckload transportation cost from each warehouse i to each assigned customer j; X_i is the binary variable that models locating decision on each site i; and finally Y_{ij} is the binary variable that models assignment decisions between each customer j and each potential warehouse on site i. First term of (5) represents warehouse fixed setup cost, and the second expression represents the system transportation costs, including plant-warehouse and warehouse-customer flows. According to these definitions, the network is entirely defined by the binary decisions variables X and Y.

Depending on the specific problem assumptions and features, some standard constraints that can be found in well known FLP, based on the previous notation, as follows:

$$\sum_{i=1}^{N} Y_{ij} = 1 \quad \forall j = 1,...,M \tag{6}$$

$$Y_{ij} \le X_i \quad \forall i = 1,...,N \quad \forall j = 1,...,M \tag{7}$$

$$\sum_{j=1}^{M} Y_{ij} \cdot d_j \le WC_i \qquad \forall i = 1,...,N \tag{8}$$

$$Y_{ij}, X_i \in \{0,1\} \quad \forall i = 1,...,N \;\; \forall j = 1,...,M \tag{9}$$

Equation (6) assures that each customer j is served by exactly one warehouse. Equation (7) assures that customers are assigned to previously installed warehouses (X_i = 1). Equation (8) assures that the expected demand assigned to each warehouse does not exceed the corresponding warehouse capacity, WC_i. Finally, constraints (9) enforce the integrality (0-1) of the decisions variables. The highly unrealistic nature of this basic modeling structure is evident due to the lack of modeling of other cost elements and more general cost structures, such as those related to warehouses inventory and fixed ordering costs.

4.3 Simultaneous modeling of facility location and inventory planning decisions

The need for modeling interactions between locations and inventory decisions, as introduced in previous sections, has generated several works, yielding simultaneous inventory-location models to address SCND. For example, Miranda and Garrido (2004b), Daskin et al. (2002), Shu et al. (2005), Shen et al. (2003), and Erlebacher and Meller (2000), present similar of inventory-location models, along with different solution approaches.

In general terms, in all the above inventory-location models, the two costs terms of the equation (10) are incorporated into the objective function (5): expected safety stock costs, corresponding to the first term in (10), and expected cyclic inventory costs, second term in (10), both per time unit (daily, monthly or yearly).

$$\sum_{i=1}^{N} HC_i \cdot Z_{1-\alpha} \cdot \sqrt{LT_i} \cdot \sqrt{V_i} + \sum_{i=1}^{N} \left(HC \cdot \frac{Q_i}{2} + OC_i \cdot \frac{D_i}{Q_i} \right) \tag{10}$$

Expression (10) is based on the following notation:

LT_i	:	Deterministic lead time when ordering from the warehouse i (parameter).
D_i	:	Mean daily demand to be assigned to the warehouse i (dependent variable).
V_i	:	Variance of the daily demand assigned to the warehouse i (dependent variable).
HC_i	:	Inventory holding cost at warehouse i (\$/unit-time).

OC_i	:	Fixed ordering cost at warehouse *i* ($/order).
Q_i	:	Order size for each warehouse *i* (items / order).
$1 - \alpha$	:	Service level associated to warehouse safety stocks, service level that corresponds to the probability that demand during lead time does not exceed the reorder point.

This service level is strictly related to the safety stock at each warehouse, given by expression $Z_{1-\alpha} \cdot \sqrt{LT_i} \cdot \sqrt{V_i}$; where $Z_{1-\alpha}$ is the value of the Standard Normal distribution, which accumulates a probability of $1 - \alpha$.
Dependent variables D_i and V_i are strictly related to, and defined by, the mean and variance of the assigned customer demand. Accordingly, expressions (11) and (12) link the mean and variance of warehouse demands to the mean and variance of demand for each customer *j*, d_j and v_j, assuming independency. It is worth noting that these sets of constraints link facility location decisions (*X* and *Y*) to inventory decisions and costs as stated in equation (10).

$$\sum_{j=1}^{M} Y_{ij} \cdot d_j = D_i \quad \forall i = 1,\ldots,N \tag{11}$$

$$\sum_{j=1}^{M} Y_{ij} \cdot v_j = V_i \quad \forall i = 1,\ldots,N \tag{12}$$

Ozsen (2004) and Ozsen et al. (2008) propose a deterministic 100% service level constraint for inventory capacity, which requires the inventory capacity be observed every ordering period. In this constraint, maximum inventory levels are defined as the reorder point (initial inventory level just prior to an order) in addition to the order quantity. Consequently, this maximum level is required to respect inventory capacity, *ICap*, as stated in in (13).

$$RP_i + Q_i \leq Icap \tag{13}$$

The peak inventory level considered in (13), (RP_i + Q_i) corresponds to the maximum inventory level when "no demand has arisen during the lead time". Consequently, this constraint might be considered extremely protective, because a no-demand situation is, in general, quite unlikely. Considering previous observation, and based on Chance Constraint Programming, Miranda (2004) and Miranda and Garrido (2006, 2008) propose an inventory capacity constraint based on a probabilistic service level, in which a minimum probability, 1-β, is required for observing inventory capacity. It is assumed that the maximum inventory level is a stochastic variable, as a consequence of stochastic nature of demand during lead-time, $SD(LT_i)$, as shown in equation (14).

$$\Pr\left(\begin{array}{c} \underbrace{RP_i - SD\left(LT_i\right) + Q_i}_{} \qquad \leq Icap \\ \textit{Stochastic Maximum Inventory} \\ \textit{Level for each warehouse } i \end{array} \right) \geq 1 - \beta \tag{14}$$

Miranda, (2004) and Miranda and Garrido, (2008) showed that this constraint can be reformulated as a deterministic nonlinear constraint (which assures that the probabilistic constraint is satisfied) as follows:

$$Q_i + \left(Z_{1-\alpha} + Z_{1-\beta}\right) \cdot \sqrt{LT_i} \cdot \sqrt{V_i} \leq ICap \cdot X_i \quad \forall i = 1,\ldots,N \tag{15}$$

Finally, Miranda and Garrido (2009) propose an iterative approach to optimize inventory service level, based on the integrative inventory location models previously described. For a deep review and analysis of Stochastic Programming methodologies, see Birge and Louveaux (1997).

4.4 Simultaneous modeling of inventory, location and routing decisions

One of the problems and remaining inconsistencies of the previously described inventory location modeling structure, which as inherited from standard FLP literature, is related to the routing costs and the modeling structure considered in SCND models. As suggested by expression (5), transportation costs from warehouses to customers are modeled as a direct shipment - full truckload strategy or approximation, ignoring routing costs and decisions, particularly in less-than truckload situations.

Quite earlier, Webb (1968), Christofides and Eilon (1969), and Elion et al. (1971) made an explicit discussion about the error of not considering explicitly the routing costs when warehouses serve assigned customers in FLP. More recently, Salhi and Rand (1989) analyze and evaluate the effects of ignoring routing costs and decisions. Their work, based on a sequential approach, shows that an effectively local optimal facility location solution (consistent to the first strategic stage in Figure 8 and Figure 9) does not necessarily represent the optimal solution when exact routing costs are included. In addition, and in agreement with these results, several works have been focused on simultaneous modeling of location and routing decisions and costs, in order to achieve simultaneously optimal solutions. Laporte (1988), Perl and Daskin (1985), and Min et al. (1998), present reviews of several formulation for different Location Routing Problems (LRP), considering deterministic demands and standard VRP formulations of routing costs between warehouses and customers. For examples of different LRP formulations, along with related heuristic and exact solution approaches, see Laporte, Nobert and Taillefer (1988), Laporte and Nobert (1981), Laporte et al. (1986), Prins et al. (2006), and Prins et al. (2007).

Finally, recent works in Location-Routing literature are:

Albareda-Sambola et al. (2007) and Albareda-Sambola (2004): A stochastic LRP is proposed. The stochastic nature considered is focused on customer appearance, similar to the Probabilistic Traveling salesman Problem, PTSP (discussed later in section II.2), as introduced by Jaillet (1985-1988). The remaining costs, decisions and assumptions, are based on the previously described deterministic LRP, without considering inventory control decisions and costs. Additionally, fleet design and related demand zoning decisions are not considered as outcomes.

Orman (2005): In this research a LRP formulation with inventory decisions is proposed in which customers display stochastic demand, but whose appearance is considered deterministic (in contrast to Albareda-Sambola et al., 2007). Consequently, routing costs are modeled based on a standard VRP modeling structure. Fleet design decisions are considered assuming deterministic warehouse and vehicle capacity constraints.

Shen and Qi (2007): The authors proposed a model that deals simultaneously with inventory control and routing costs within a FLP model, considering nonlinear routing and inventory costs and stochastic demands. The proposed model is based on a continuous approximation of routing costs for a multi-vehicle distribution system. The model does not consider the number of vehicles or routing zones as decision variables. Warehouse and vehicle capacity constraints are not considered in the formulation.

Miranda et al. (2009): The authors propose an integrative model for addressing Inventory, Location and Customer Clustering, based on a Hub & Spokes cost structure, as in Koskosidis and Powell (1992) and Miranda and Garrido (2004a). The customer clustering decisions are aimed at defining a preliminary solution for fleet design within SCNDP.

4.5 A General integrative approach for customer clustering within SCNDP

Based on the discussion about different routing modeling structures presented in Section 2.4, and similar to the model presented in Miranda et al. (2009), the present section proposes a general modeling framework to include routing costs and clustering decisions within existent models in the facility location and inventory location literature.

Considering the aforementioned inventory location modeling structure of Section 4.3 , a preliminary objective function proposed for a simultaneous inventory location model with routing costs and decisions might be as follows:

$$\begin{aligned} Min \quad & \sum_{i=1}^{N} F_i \cdot X_i + \sum_{i=1}^{N} HC_i \cdot Z_{1-\alpha} \cdot \sqrt{LT_i} \cdot \sqrt{V_i} + \sum_{i=1}^{N} \left(HC \cdot \frac{Q_i}{2} + OC_i \cdot \frac{D_i}{Q_i} \right) \\ & + \sum_{i=1}^{N} \sum_{j \in M} \left(R_i \cdot d_j + T_{ij} \right) \cdot Y_{ij} + SRC(W) \end{aligned} \tag{16}$$

In expression (16), W is a matrix of binary decision variables, where element W_{jl} indicates if customer l is assigned to cluster j, which also defines the customer clusters of the distribution network; M is a variable set of customer clusters to be assigned to installed warehouses; d_j is the mean demand for each customer cluster, which is actually a dependent variable defined by matrix W; and finally $SRC(W)$ represents System Routing Costs as a function of the decision variable matrix W. All other elements (parameters and variables) are as previously defined in Sections 4.2 and 4.3.

One advantage of this formulation is that it allows considering a general modeling structure for routing costs and decisions. For instance, when modeling routing costs via a continuous approximation, we should include the following constraint:

$$SRC(W) = \sum_{j \in M} RC_j \left(C_j, A_j \right) \tag{17}$$

where C_j is the variable set of customers included on each cluster j, A_j is the area defined by assigned customers, and RC_j is the respective approximation routing cost of each cluster j, as a function of C_j and A_j. For example, following Shen and Qi (2007), an acceptable expression for routing costs within a cluster with multiple vehicles, RC_j, might be as follows:

$$RC_j \left(C_j, A_j \right) = 2 \cdot \left(\sum_{l \in C_j} \frac{\mu_l \cdot d_{jl}}{n} \right) \Bigg/ \left(q + (1 - 1/q) \cdot \phi \cdot \left| C_j \right| \cdot \sqrt{\frac{A_j}{M}} \right) \tag{18}$$

In (18), q is the capacity of the vehicles employed; n is the number of visits in a year; μ_l is the expected yearly demand for each customer l; d_{jl} is the distance between the cluster hub j and the customer l, and ϕ is a scale factor depending on the considered metric. For example, when a Euclidean metric is used, ϕ=0.75.

Furthermore, in case of a Hub & Spokes cost structure, the following constraints should be included, assuming an additional variable H_l, which indicates if customer l is selected as a hub of a cluster:

$$SRC(W) = \sum_{k=1}^{L}\sum_{l=1}^{L} R_{kl} \cdot W_{kl} \tag{19}$$

$$W_{kl} \le H_l \quad \forall l = 1,...,L \tag{20}$$

Equation (19) computes total routing costs within all clusters, in accordance with the Hub & Spokes structure, and constraints (20) assure that customers are assigned to cluster hubs that are effectively selected. Notice that the consideration of a variable set of clusters should be consistent with facility location decisions, X and Y. For example, it is possible to include a constraint to ensure that each cluster hub is assigned to a single warehouse, as stated in (21).

$$\sum_{j=i}^{N} Y_{ij} = H_l \quad l = 1,...,L \tag{21}$$

5. Conclusions

In this chapter we present an updated literature review for works related to districting or customer clustering problems, and we classify the different contributions according to the modeling and solution approaches. Additionally, we illustrate a wide variety of applications, models, solution approaches and design criteria, focused on logistic operations and supply chain network planning. One of the main difficulties found in the literature are the definitions and measurements of objectives and criteria, for achieving good districting configurations, which in general are much more difficult to specify, compared to other problems within Supply Chain Management and Supply Chain Network Design problems.

For instance, compactness is a common metric in districting,which implies to design districts as square or circular as possible. As an estimate, some examples of compactness metrics observed in the literature are the length of the minimum spanning tree formed within each district, or the maximum distance between two points that belong to the district, or based on a Hub & Spokes structure (line-haul and inner transportation costs). None of these metrics is exact and only approximates the desire shape of the district, in contrast to other logistic problems (e.g. vehicle routing or facility location problems), in which a usual metric consists of a sum of costs. Hence there is room for improvements for estimating the performance metrics of a districting configuration.

We conclude that the representation of an instance based on a graph topology is also a difficult task, because there are no clear and obvious criteria for setting the node adjacency or the set of edges. Finally, we observed that only few works present a solution approach based on mathematical programming techniques, and most of the proposed methodologies are based on heuristic approaches.

Two application examples of Mixed Integer Programming models are presented, both of them based on a location-allocation modeling structure.

The first example consists of a pickup and delivery parcel logistics districting problem for which a hybrid metaheuristic is proposed. The aim of the procedure is to optimize two criteria: balance the workload content among the districts and obtain districts of compact shape. Workload content is defined as the sum of the required time to perform the service (either pickup or delivery a package), the required time to travel from the depot to the district (line-haul cost), and an estimated time of inner transportation costs within the district. Compactness metric is defined as the travel time between the furthest apart points within the district. The mathematical formulation presented is a weighted sum of both criterion, with the aim of minimize the maximum workload and compactness metrics of a district. The solution approach is based on a GRASP and Tabu Search procedure with two phases: construction and local search. Numerical results showed a good performance of the algorithm with low computational times.

It is suggested as an extension of this work to analyze different modeling structures, especially for the compactness metric, which is approximately estimated by the maximum distance between a pair of points within the district. Also, provided the stochastic nature of the problem it is desired to extend the work and consider different demand scenarios instead of using a single and representative day and provide a more robust configuration. More realistic issues of the geographical region should be also considered, such as geographical barriers and the street configuration of the city.

A second example is presented, in which customer clustering is addressed focused on fleet design. In this problem, vehicle capacity constraints are explicitly modeled based on chance constraint programming with stochastic demands. Solution approach is based on lagrangian relaxation with valid inequalities, along with a two-step local search heuristic. This work shows that vehicle routing issues can be effectively considered as criteria to address districting problems, in which vehicle capacity and routing cost can be considered as relevant performance measurements to design districts or customer clusters. Additionally, it illustrates the usefulness of decomposition methods based on mathematical programming and dual relaxation, to address districting/customer clustering models. In both cases, modeling and solution approaches, we highlight the consideration of stochastic demands. In this work, a known set of existent warehouses is considered, assuming a greedy cluster-warehouse assignment criterion, yielding a promising modeling approach to be integrated in a more general framework to address strategic network design problems.

For districting and customer clustering problems, we propose as a further research to explore solution methods based on mathematical programming such as relaxation and decomposition approaches based on Column Generation, Lagrangian Relaxation, Branch and Cut, among others. This is mainly motivated from that few contributions of this type have been observed in the literature. We also propose to explore different modeling structures and define clear metrics to compare different districting configurations over a defined operation horizon. For these matters, simulation techniques might be employed. We also propose to explore stochastic programming models and approaches, such as chance constraint programming, scenarios analysis, and two stages stochastic program with resource.

As a further challenge we propose a basic and general framework to analyze the inclusion of logistics districting and customer clustering within strategic Supply Chain Network Design problems, integrating this type of decisions into some other strategic problems such as facility location. This framework should be based on vehicle routing consideration, along with the modeling of inventory planning and control considerations. This research might be useful to analyze the impacts of customer clustering and districting decision into strategic Supply Chain Network Design problems.

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Over the past few decades the rapid spread of information and knowledge, the increasing expectations of customers and stakeholders, intensified competition, and searching for superior performance and low costs at the same time have made supply chain a critical management area. Since supply chain is the network of organizations that are involved in moving materials, documents and information through on their journey from initial suppliers to final customers, it encompasses a number of key flows: physical flow of materials, flows of information, and tangible and intangible resources which enable supply chain members to operate effectively. This book gives an up-to-date view of supply chain, emphasizing current trends and developments in the area of supply chain management.

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