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Pathways to Supply Chain Excellence

Edited by Aleš Groznik and Yu Xiong

PATHWAYS TO SUPPLY CHAIN EXCELLENCE

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Notice

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Meet the editors

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Contents

Preface

Over the last decade, supply chain management has advanced from the warehouse and logistics to strategic management. Integrating theory and practices of supply chain management, this book incorporates hands-on literature on selected topics of Value Creation, Supply Chain Management Optimization and Mass-Customization. These topics represent key building blocks in management decisions and highlight the increasing importance of the supply chains supporting the global economy.

The coverage focuses on how to build a competitive supply chain using viable management strategies, operational models, and information technology. It includes a core presentation on supply chain management, collaborative planning, advanced planning and budgeting system, risk management and new initiatives such as incorporating anthropometry into design of products.

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Part 1

Value Creation in Supply Chain Management

1

From Advanced Planning System to Advanced Budgeting System: The Next Step in Supply Chain Management Software

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1. Introduction

A supply chain (Beamon, 1998) is traditionally characterized by three types of flow:

- The forward physical flow (purchase of materials, transformations of the raw materials into products, delivery of the products). The physical flow optimization aims to satisfy the final customers.
- The backward financial flow which circulates in a discontinuous way. The financial flow optimization is made in a local way, in each supply chain link, but seldom in a global way. The financial flow optimization (Badell et al., 2005) will make possible the shareholders satisfaction and the supply chain working improvement.
- The backward information flow which allows the coordination of financial and physical flow between each node, and the global supply chain coordination.

The paper objective is to propose an approach to evaluate logistic process performance in supply chain by discussing connections among the physical and the financial flows across the chain. Judging from the literature, these flows do not always overlap in supply chain management. If there are some works which propose to analyse the impact of physical flow in financial flow in strategic planning (Vidal and Goetschlackx, 2001), very few works show relationships between cash position and planning in tactical or operational dimension. A study of supply chain manager interest for integration of financial impact in operational and tactical planning is done by (Vickery et al., 2003): these authors show that managers are really interested by tools which integrate financial and customer aspects in optimization. Despite their real interest, this kind of tools does not yet exist.

Hence, the challenging problem consists in formalizing relationships between physical and financial flow by their integration in planning processes for an internal supply chain (a company supply chain). Our aim is to propose an approach which allows the use of budgeting in production planning with Advanced Planning System (APS) tools for company supply chain. Indeed, in actual APS, operational and tactical plans do not integrate financial resources synchronisation, as described in figure: financial metrics are only translated in physical metrics such as stock level for example.

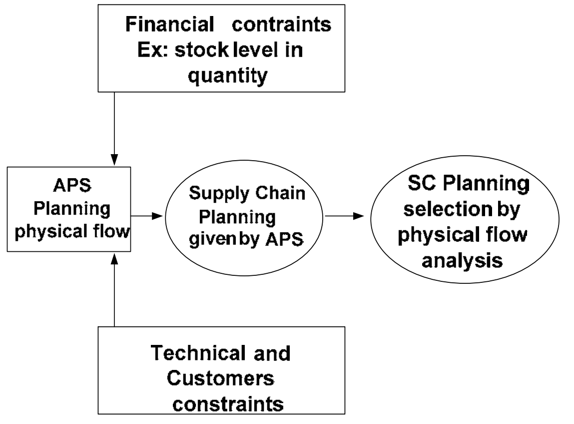

Fig. 1. Actual process of tactical planning selection in APS

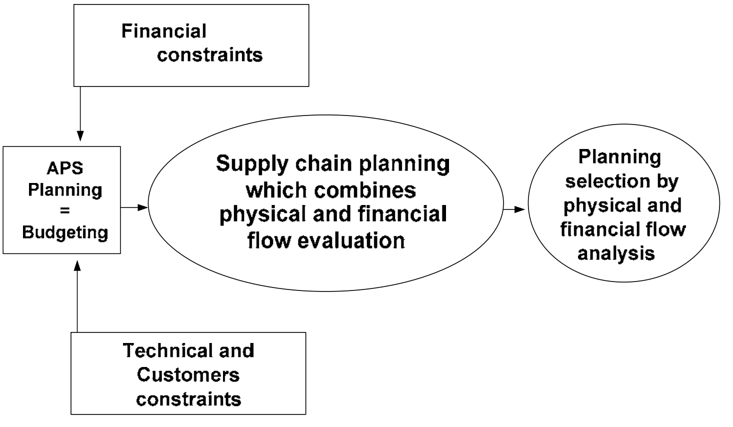

Fig. 2. Towards a planning selection in APS thanks to physical and financial flow evaluation

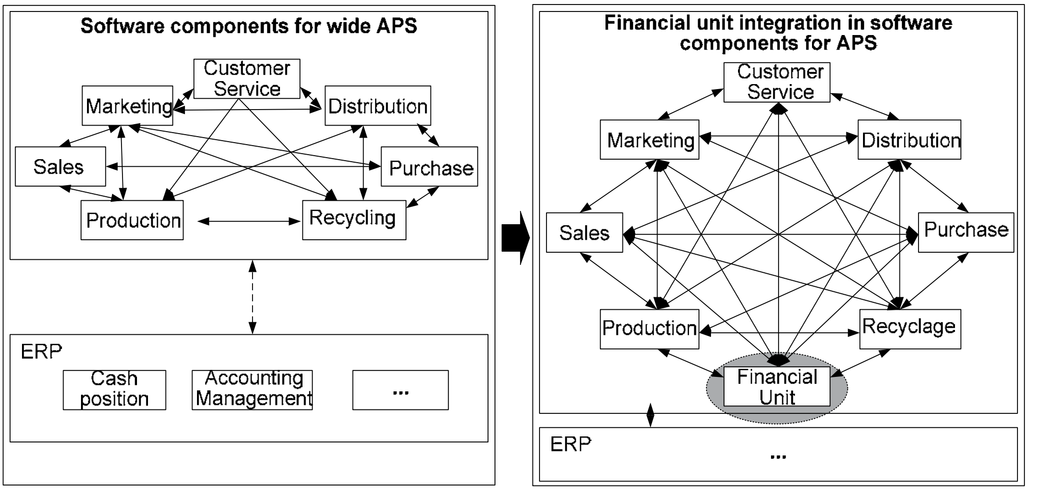

Fig. 3. Financial unit integration in software suite for supply chain management

This paper proposes to integrate financial metrics in APS. We assume that budgeting and planning financial and physical flows could be synchronised. This kind of synchronisation can be seen as a performance driver for supply chain management. By integrating financial parameters such as payments terms in Activity Based Costing models and coupling this type of model with computer models for planning, each production plan will be associated with a budget and with financial metrics.

The paper is organized as follows: next section present a brief state of the art about integrated decision making software for supply chain management. An interoperable and multi flow decision making tool software, called Advanced Budgeting System is proposed in section 3. Section 4 presents computational results based on the ABS used in a case study. Finally, some conclusions are given in section 5.

2. State of the art and problem description

Most part of the authors who propose to study financial flows in supply chain management focus on cost models such as Activity Based Costing. Activity Based Costing was introduced by Cooper (1991). If theoretical works are done on ABC modelling and supply chain management (Senechal and Tahon, 1998), (Hombourg, 2004), (Boons, 1998), (Bih Ru and Fredendal, 2002), very few works deals with ABC using in Supply Chain production planning evaluation. Connections of tactical production planning and ABC are presented by (Schneeweiss, 1998) and (Ozbaayrak et al., 2004). The aim of their work is to evaluate production strategies in flexible manufacturing system thanks to ABC tools, not to evaluate supply chain planning. ABC evaluation is not a financial flows evaluation because payment delay and depreciations are not taking into account: therefore, this evaluation only deals with costs and not cash management problem, which is a very important parameter in enterprise financial evaluation in tactical level.

The main objective of cash manager is to have enough cash to cover day-to-day operating expenses but also to have the fewest excess cash because it is not a productive asset. By having excess cash in account, a company loses the potential interest (an opportunity cost) generated by investing money in securities. This implies that firm has to maintain a balance between amount of cash sitting in account and cash invested in securities. Cash management problem was simply formulated by Baumol (1952) as an inventory problem assuming uncertainty (Miller and Orr, 1966). Two types of metrics are generally used to optimize financial flow: cash position which reveals the cash which is available in the end of a period and cash flow which reveals cash generation during a period. In a recent paper, (Badell et al., 2005) optimizes financial flow and cash position in the end of each period. To our knowledge, as shown in table 1, there are very few scientific works which integrate financial aspect and physical aspect in a simultaneous way operational, tactical and strategic planning for supply chain.

To conclude this section, table 2 presents a study (which is not exhaustive) which evaluates the most important APS software editors. For each APS, we study if financial flow is integrated with physical flows optimization. Note that some of the tested APS have links with ERP but these links do not integrate financial evaluation with planning. Moreover, discrete event simulation are not used by APS which only use optimization tools.

	Horizon level			Studied Flow	
Authors	Operational	Tactical	Strategic	Physical flow	Financial Flow
Badell et al. 2005		X		X	X
Baumol, 1952	X	X			X
Bertel et al., 2009	X			X	X
Brown and Haegler, 2004	X	X			X
Cattani and Souza, 2001	X	X			X
Comelli et al, 2008		X	X	X	X
Comelli et al 2009	X	X		X	X
Girlich, 2002	X	X			X
Graham and Harvey, 2001		X			X
Gul, 2001			X	X	X
Hendricks and Singhal, 2003			X	X	X
Inderfurth and Schefer, 1996	X				X
Miller and Orr, 1966	X	X			X
Orgler, 1969		X			X
Premachandra, 2003			X	X	X
Rink et al., 1999			X	X	X
Salameh et al., 2003			X	X	X
Vidal and Goetschlalx, 2001			X	X	X
Wang, 2002		X		X	X

Table 1. Cash management formulation and supply chain management: a state of the art

	Dataware House	Process Modelling	Physical flow Optimization	Budgetary Development	Discrete event Simulation
Not specialized tools ADEXA iCollaboration Suite ; ASPEN eSupply Chain Suite ; FUTURMASTER Futurmaster; ORACLE aps; PEOPLE SOFT SupplyChain Planning; SAP Advanced Planer and Optimization (APO); SYNQUEST One2One Solutions.	Not Specified	Yes	Yes	No	No
Specialized tools SIB Sextant; KEYRUS K@-prim; MC KESSON Evoluance SIAD...	Not Specified	Yes	Not specified	No	No

Table 2. APS functionalities

If supply chain managers want to plan and budget activities as a whole, they must use software which permits a real integration of supply chain informational, physical and financial flows. This kind of software does not actually exist. Next section proposes a software concept which takes into account physical and financial flows in decision making modelling.

3. Avanced Budgeting System proposal

It is worth noting that there is a need for general approach for both supply chain modelling and evaluation which combines data from physical, informational and financial flow in one type of software which is a global Advanced Planning Systems. This one allows solving supply chain planning problems with an integration of all the system flows. Advanced Budgeting System is the chosen name for this software concept. Supposing that the “budgeting” activity for financial flow is the equivalent of the planning activity for physical flow, an advanced budgeting system is defined as a coherent succession of software applications allowing optimization and evaluation of supply chain physical and financial flows. This software combines physical and financial flows for the whole chain as for an entity with strategic, tactical and operational levels. These various applications are connected to the information system of supply chain entities by a data warehouse which reprocesses heterogeneous data resulting from different software applications in order to combine prescriptive and descriptive models data. Usually, prescriptive models are used in APS for decision making (Dietrich, 1991): they are used to make a choice on the design, control or functioning of supply chain, while descriptive models make it possible to evaluate decision made by prescriptive model or directly by actors.

Figure 4 shows the ABS characteristics and the connexions between the various supply chain activities and flows.

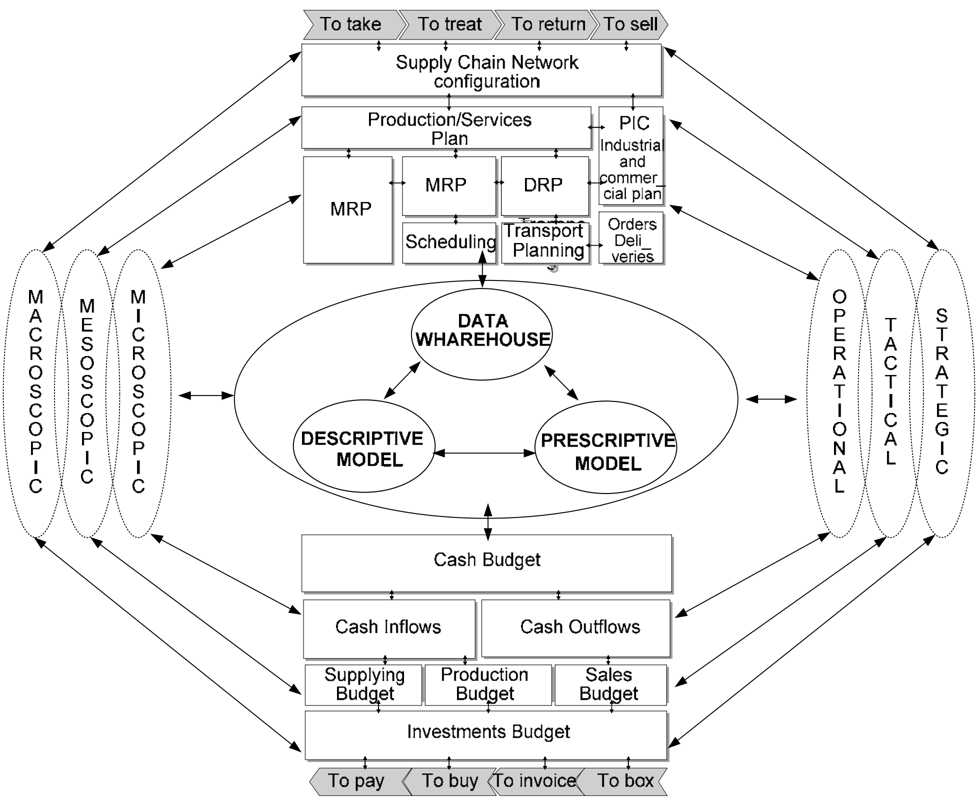

Fig. 4. Advanced Budgeting Context.

Technical and conceptual features of an ABS are given in table 3. If the context (figure 4) of an ABS use is the same than an APS , software functionalities integrate activities budgeting with planning. An ABS can be used for a complex system of the supply chain (a factory, a business unit…) as for the whole supply chain. ABS contains a decisional module which organises information for supply chain managers with balanced scorecards (Kaplan, 1992).

	Advanced Planning and Scheduling	Advanced Budgeting and Scheduling
Context	Internal and external Supply Chain	Internal and external Supply Chain
Functionalities		
Network Design	For physical flow	For physical and financial flows
Distribution (DRP)	For physical flow	For physical and financial flows
Production (PDP)	For physical flow	For physical and financial flows
Supplying (MRP)	For physical flow	For physical and financial flows
Scheduling and transport	For physical flow	For physical and financial flows
Decisional Tools Performance Measurement	Some physical flow metrics	Balanced Scorecard+ PREVA model (Comelli et al., 2008)
Connection with the chain entities information system	Not detailed	Data warehouses allowing collection of data and information from heterogeneous applications
Software components for decision making tools	Optimisation (Cplex) and heuristics	Coupling of optimisation/ simulation (prescriptive and descriptive models)
Collaborative Planning	Collaborative planning gives to the chain entities the quantity of products and services to be produced and delivered on short, medium and long term for a given customer satisfaction rate.	Collaborative planning gives to the chain entities the quantity of products and services to be produced and delivered on short, medium and long term which gives the highest level of value for Supply Chain entities.

Table 3. ABS characteristics.

Financial flow can be evaluate thanks to PREVA models (PREVA means PROcess EVAluation (Comelli et al., 2008)) which makes it possible to translate in a prospective and causal way the impact of physical flows in supply chain financial flows. PREVA gives the possibility, thanks to ABC models and cash flows models to evaluate supply chain running.

Collaborative plannings resulting from ABS allows, for a level of customer satisfaction to choose the solution / the planning which generates the most value for the supply chain.

A case study, which presents, thanks to PREVA approach improvement, the interest of ABS software is detailed in next section.

4. Avanced Budgeting System use

To illustrate the approach presented in previous sections, a industrial case study, adapted from a real industrial application done in Clermont Ferrand Computer Laboratory is presented in first paragraph. An example of an ABS which was built for this case study is given in paragraph 2. Scorecards and results are given in paragraph 3.

4.1 Case study presentation

The company supply chain, called M (a tyre manufacturer) is comprised of 6 Business Units, called B1, B2, B3, B4, B5, B6. Six families of product, called P1, P2, P3, P4, P5, P6 are manufactured in the system. Figure 5 presents the supply chain infrastructure.

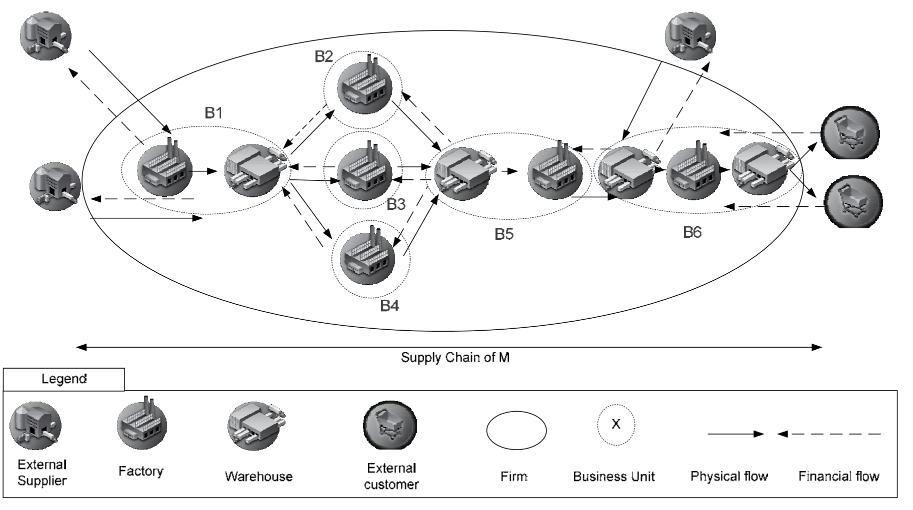

Fig. 5. Supply chain structure

This Company Supply Chain is shared in four steps. In first step, one business unit called B1 is considered. In step 2, B2, B3, B4 are working both together and have exactly the same structure. In step 3, product from B2, B3, B4 are manufactured in B5 on a special plateform. This type of plateform gives the product its name and its quality. In step 4, B6 products are prepared for european, asian, american markets. M logistic processes are as follows:

i. B1 is made up of a factory and a logistic platform in which products are stocked;
ii. B2 is made up of one factory;
iii. B3 is made up of one factory;
iv. B4 is made up of one factory;
v. B5 is made up of one logistic platform and one factory. Products from B2, B3, B4 are stocked in B5 logistic platform before being transformed in B5 factory;
vi. B6 is made up of two logistic platform and one factory. The first B6 logistic platform, which is implanted before B6 factory stocks products from B5 and from external

suppliers. The second B6 logistic platform, which is implanted after B6 factory stocks final products;

- Distribution Requirement Planning(DRP) is done by M supply chain manager; production planning of each supply chain Business Unit is done by collaborative planning. This internal collaborative planning is elaborated thanks to meetings and by exchange between M supply Chain Manager and each business unit supply chain managers.
- logistic processes in Business Unit are modelled with SCOR processes (Source, make, deliver) and specified with ARIS (figure 7).

Thanks to a modelling study which was done in collaboration with Business Unit costing managers and supply chain managers, cost drivers are determined for each supply chain process in each business unit. Table 4 details for each family process the associated cost driver, and the budgetary responsable. Note that this study is done for each level of granularity.

Business Unit	Process	Associated Cost driver	Process Responsable
BU1	Source	Supplier Number	BU 1 Supply Chain Manager
	Make	Production setup	BU 1 Supply Chain Manager
	Storage/Deliver	Delivered product quantity	M Supply Chain Manager
BU2	Source	Product type number	M Supply Chain Manager
	Make	Production setup	BU 2 Supply Chain Manager
	Deliver	Delivered product quantity	BU2 Supply Chain Manager
BU3	Source	Product type number	M Supply Chain Manager
	Make	Production setup	BU 3 Supply Chain Manager
	Deliver	Delivered product quantity	BU 3 Supply Chain Manager
BU4	Source	Product type number	M Supply Chain Manager
	Make	Production setup	BU 4 Supply Chain Manager
	Deliver	Delivered product quantity	BU 4 Supply Chain Manager
BU5	Source/Storage	Product type number	M Supply Chain Manager
	Make	Production setup	BU5 Supply Chain Manager
	Deliver	Delivered product quantity	BU5 Supply Chain Manager
BU6	Source /Storage	Product type number	M Supply Chain Manager
	Make	Production setup	BU6 Supply Chain Manager
	Storage/Deliver	Sold product quantity	M Supply Chain Manager
M Supply Chain	Plan DRP	Product type number	M supply Chain manager
	Plan Production Planning	Production setup	M supply Chain manager

Table 4. Cost Drivers and logistic processes in Supply Chain Business Unit

The major objective of this study is to compare two supply chain management strategies in order to elaborate a good collaborative supply chain planning:

- first strategy is called Pull strategy and consists in managing supply chain with a pull approach.
- second strategy is called Financial Pull strategy and consists in integrating financial constraint in product selection during supply chain planning elaboration.

The horizon level is 12 months, and the planning horizon level is the week. In order to compare these two supply chain strategies, ABS concept is implemented. Next paragraph presents the specificity of the action models (computers models) built for this case study, and last paragraph presents scorecards and metrics obtained thanks to the proposed approach.

4.2 ABS instance on M company supply chain

Considering the complexity of the case study, discrete event simulation was preferred to mathematical models for many reasons such as modelling constraints and computation time. Hence, simulation is used to reproduce supply chain working during 12 months. The specification of supply chain running thanks to ARIS modelling is translated in discrete event simulation computer model (figure 6).

Both plans were obtained from two dedicated heuristics which are integrated in the simulation model. Indeed, the difference between both planning results from the choice of manufactured products after each end of production lot on each factory. Production Plans given by to heuristics and simulations are then evaluated thanks to an instance of the financial analytical model. For each plan, a financial budget is then associated.

Figure 13 presents the ABS which is done for this case study.

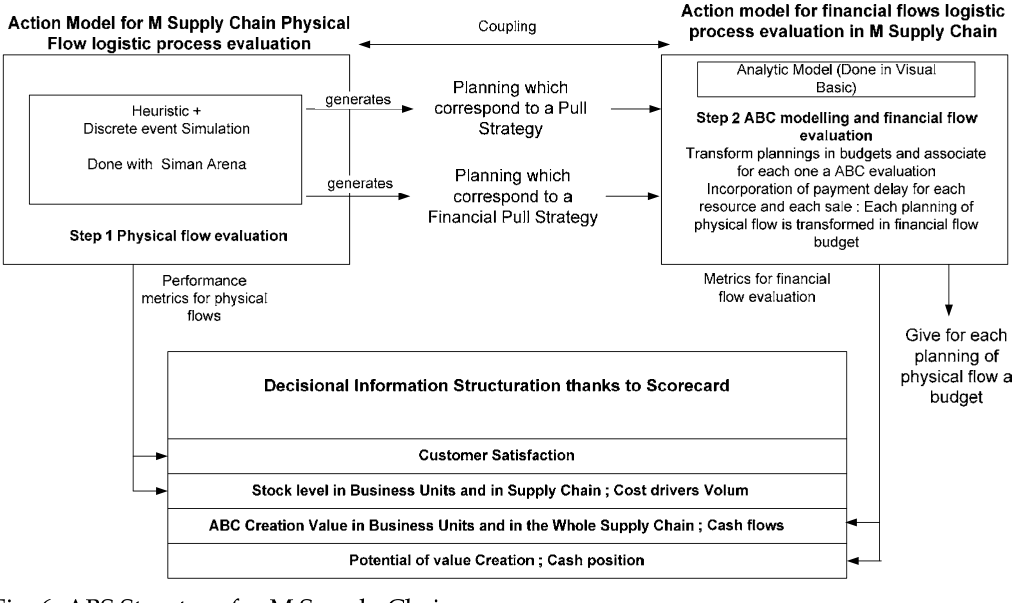

Fig. 6. ABS Structure for M Supply Chain.

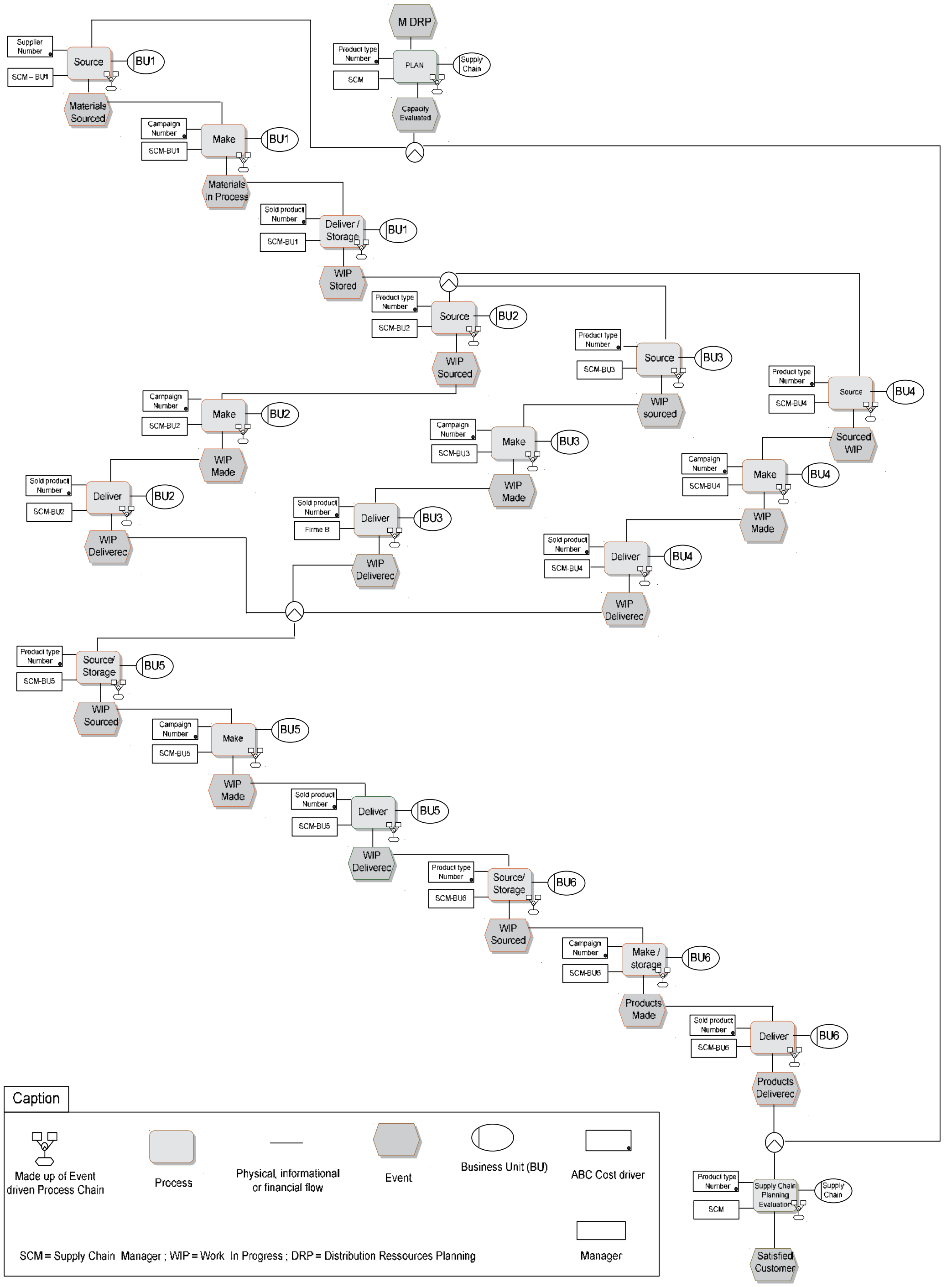

Fig. 7. Supply Chain specification

Both heuristics reproduce Supply Chain Managers behaviours in Business Unit.

The first one reproduces Supply Chain Managers behaviours in Business Units in order to build a planning with a pull strategy. This heuristic is a greedy algorithm which chooses the type of products which gets the least autonomy. The calculation of a parameter called "Autonomy" corresponds to the number of periods where customer demand can be satisfied with the actual stock level of finished products. This heuristic is used as a benchmark to evaluate other strategies of physical flows. This one is called pull strategy. Its description is given in algorithm 1.

```
    Initialization
 ProdType:=0                          // set the product chosen to 0
 AutonMin:=∞                          // assign the autonomy to infinity
    for i:=1 to n do                  // for each product i∈I
    Calculate Autonomy(i)             // calculate autonomy of product i
      if Autonomy(i)<AutoMin then     // if autonomy of product i is min
         AutoMin :=Autonomy(i)        // update AutoMin
         ProdType:=i                  // assign product chosen to i
      endif
    endfor
```

Algorithm 1. Heuristic for Pull Strategy

The second heuristic is similar to pull strategy but integrates financial constraints. Product selection process integrates financial preferences, and the product family which has the smallest payment term is firstly chosen. This one is called financial pull. Its description is given in algorithm 2.

Regards to these data, these strategies consist in prioritizing in each factory the family of products, which get the least autonomy. State of system is used as input data by two heuristics. Each heuristic takes into account finished products stock levels since these data allow estimating Supply Chain autonomy for each factory (autonomy i). A full strategy is thus reproduced along the Supply Chain.

These heuristics are implemented in a Discrete event Simulation model done with ARENA. Thanks to this action model, physical flow running is reproduced, and plans can be generated. Plans of physical flows gives:

- quantity of made product in each BU and in the whole Supply Chain;
- quantity of cost drivers used by each process in each BU and in the whole supply chain;
- quantity of products sold and stored in each BU and by the whole supply chain.

In a second time, these planning are evaluated by a second model. This second model combines information from physical flows planning with data given by supply Chain ERP. This financial computer model is done and linked to Discrete Event Simulation Model with Visual Basic. Both models reproduce financial flows running under supply chains management strategies and give physical and financial metrics.

```
Initialization
ProdType:=0                            // set the product chosen to 0
FinanType:=0                           // set the product payment term
                                       // chosen to 0
AutonMin:=∞                            // assign the autonomy to
                                       // infinity
  for i:=1 to n do                     // for each product i∈I
  Calculate Autonomy(i)                // calculate autonomy of
                                       // product i
   if  Autonomy(i)<AutoMin then        // if autonomy of product i is
                                       // min
    AutoMin :=Autonomy(i)              // update AutoMin
    ProdType:=i                        // assign product chosen to i
    FinanType:=PayTerm(i)              // assign product payment term
                                       // of the product i
   Endif
  endfor

  for j:=1 to n do                     // for each product i∈I
  Calculate Autonomy(j)                // calculate autonomy of
                                       // product i
   if  Autonomy(j)=AutoMin             // find another product with
    and ProdTerm(j)< FinanType then // the same autonomy and a
                                       // better product payment term
    FinanType:=PayTerm(i)              // assign product payment term
                                       // of the product i
    ProdType:=j                        // assign product chosen to i
   Endif
  Endfor
```

Algorithm 2. Heuristic for Financial Pull Strategy

4.3 ABS scorecards

The results for physical flows evaluation by the proposed approach after 12 periods of 1 month are given in table 5 and 6. As mentioned above the chosen model for this step is the simulation one. This model was developed with Arena 7.0 and the simulation run takes 3 minutes on a PC with 1.8 GHz processor and 256 Mo of RAM. The global model (which links physical and financial flows) takes ten minutes after 12 periods of 1 months.

The results presented above are given for the whole horizon time. Note that it is possible to detail them for each period. Results show that the closing stock level is better (in quantity) in strategy pull than in strategy financial pull. However, it is quite difficult for supply chain manager to choose the strategy since the demand satisfaction level is nearly the same as well as the number of production setups. Therefore, an evaluation of cash flow level and ABC level thanks to the ABS will help supply chain manager to have more information and by this way to take the right decision.

a) Physical flow evaluation in Financial Pull Strategy (on the whole period)

Products	P1	P2	P3	P4	P5	P6	Global SC
Quantity manufactured *1000	565	521	470	316	212	192	2276
Customer satisfaction	100	100	50	50	100	100	83
Number of production setups	26	21	25	19	17	17	125

b) Physical flow evaluation in Pull Strategy (on the whole planning period)

Products	P1	P2	P3	P4	P5	P6	Global SC
Quantity manufactured *1000	577	532	570	578	13	16	2286
Customer satisfaction	100	100	80	100	40	40	83
Number of production setups	26	21	25	19	17	17	125

Table 5. Physical flow evaluation

	Products in Financial Pull							Products in Pull						
Business Unit	P1	P2	P3	P4	P5	P6	Total	P1	P2	P3	P4	P5	P6	Total
BU1	1200	10000	9700	10000	800	800	32500	0	1600	0	1600	21000	18600	42800
BU2	No storage in BU2													
BU3	No storage in BU3													
BU4	No storage in BU4													
BU5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
BU6	5600	19900	5480	4900	3100	2900	41880	2000	17200	3580	2200	1300	600	26880
Global	6800	29900	15180	14900	3900	3700	74380	2000	18800	3580	3800	22300	19200	69680

Table 6. Stocks level (in quantity) in Business Unit at the end of the planning horizon

Same income statements are created for each business unit and for the global supply chain. The computations use the analytic model developed in section 2. All results are given in Euros. Note that Budgets could be given for each product in each business unit for each period.

It is very interesting to evaluate (as shown in section 3) the value creation (figure 8), cash flow level and cash position (figure 9), potential of value creation (table 7). Value creation evaluation gives manager the possibility to know which products create value and where (in which business unit) value is created and where value is destroyed because of planning. To conclude this section, table 8 gives final results and planning selection.

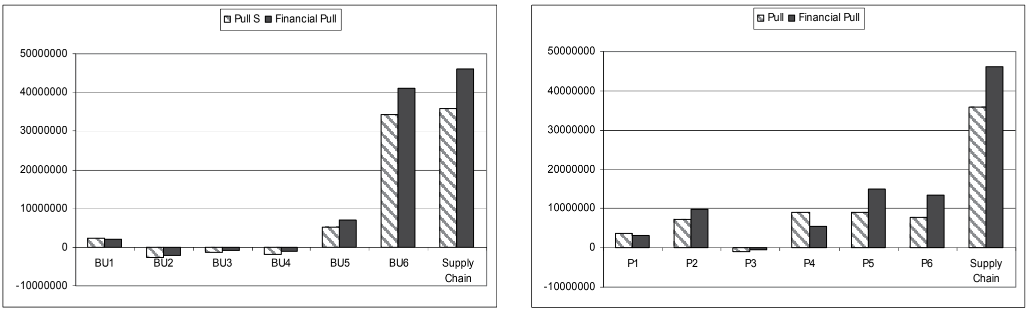

Fig. 8. Value Creation

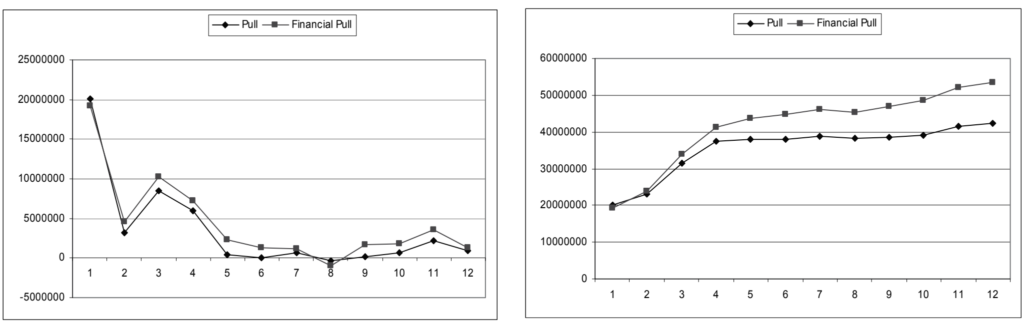

Fig. 9. Physical flow impact on financial flow: cash position and cash flow generated by different planning

In figure 8 and 9, note that the graph is very similar in period 1, 2, 3. The impact of planning strategy on financial flow is observable only three months after its beginning because of payment term, which is three months for main products P1 and P2 in this industrial case study.

	P1	P2	P3	P4	P5	P6	Global SC
Potential of Value Creation in Financial Pull	0	0	0	3859751	0	0	3859751
Potential of Value Creation in Pull	0	0	0	0	10347757	9740813	20088570

Table 7. Potential of value creation in strategy Financial Pull and in strategy Pull

	Financial Pull Strategy	Pull Strategy
Customer satisfaction	≈	≈
Stock level in quantity	-≈	+≈
Classical physical flows metrics gives very few differences: its very difficult for Supply Chain manager to select planning		
Value Creation	+	-
Cash flow	+	-
Cash position	+	-
; Potential of value Creation	+	-
Planning selection	**+**	
Thanks to ABS software, Supply Chain Manager is able to select planning with physical and financials parameters		

Table 8. Final result evaluation and planning selection

5. Conclusion

This paper proposes a global software concept for flows evaluation (physical and financials) in company supply chain. This software, called ABS for Advanced Budgeting System gives the possibility to associate planning and budgeting processes in Company Supply Chain. In case study, the financial model is coupled with simulation model. This choice, explained in section 4.2 will allow integrating stochastic phenomenon (such as demand variability, uncertain breakdown …) in order to study strategies robustness. Nevertheless, the proposed approach is generic and leaves the possibility to be used with mathematic models implemented in classical APS software. This approach was tested in an internal supply chain (a multinational company) and gives the possibility to select plans thanks to it. Of course, it improves the visibility of cost but the most important point in this approach is to show how physical flow impact is passed down to financial flow by taking into account payment terms. The proposed approach gives managers the possibility to select planning thanks to:

i. physical metrics (given by physical flows computers models);
ii. financial metrics (given by the generic financial flow model). This approach completes actual approach in operational, tactical and strategic planning selection.. This approach was only tested in tactical level. Since the approach is generic for logistic process in Supply Chain, it would be interesting to test it on other decisional levels such as operational or strategic level. Moreover, this approach, tested for logistic process evaluation in company supply chain could be used in others domains (services, health care systems…): it would be relevant to test it in such domains to see if the approach is enough generic or need to be adapted or re-conceived.

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2

Quantitative Models for Operational Risk to Implement Tobacco Supply Chain Strategies

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1. Introduction

Environmental issues are rapidly emerging as one of the most important topics for strategic manufacturing decisions. The scarcity of natural resources and the growing concern in the market for "tobacco" issues have forced executives to manage operations within an environmental perspective (Huang & Su, 2009). Growing public awareness and increasing government interest in the environment have induced many Chinese manufacturing enterprises to adopt programs aimed at improving the environmental performance of their operations (Dai & Su, 2009; Wang, Chen, & Xie, 2010). By bringing together existing contributions on strategic environmental management and performance measurement systems, the present paper aims to develop Dynamics Models for Tobacco Supply-Chain Management (DMTSCM) using super matrix, cause and effect diagrams, tree diagrams, and the analytical network process.

To provide quantitative decision tools for the tobacco supply chain, this chapter will introduce some mathematic methods to model the decision process of tobacco supply chain. Since the coordination is the key issue of supply chain management, to be more specific, we will introduce the coordination mechanism under risk-averse agent environment.

The rest of this chapter is divided into five major sections. The second section gives taxonomy of tobacco supply-chain strategies and highlights the critical factors of such strategies for a company's operations policy. The third section specifies quantitative model for a GSCM, while the fourth seeks how to structure critical factors hierarchically to support managers in the implementation of each tobacco supply-chain strategy. The fourth section describes how to quantify the effect of the factors on a GSCM and analyses how the suggested DMTSCM can be implemented in practice. The final section draws some

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conclusions from the suggested approach and indicates future directions for further environment-related research.

2. Literature review

The introduction of a tobacco supply-chain strategy is a very complex issue, since it presents a multi-dimensional impact on performance and often induces a significant modification in management procedures. In the light of these issues, it is important to analyze feasible patterns of strategic environmental behaviour, under which conditions these are a sustainable option and the implications on operations management.

In the light of the above issues, we distinguish between (see Tab. 1):

Strategy	Context	Characteristic
"evangelist" strategy	ethical objective and radical approach to environmental issues	Futurity(Godsell, Birtwistle, & van Hoek, 2010)
Pro-active tobacco strategy	"systemic" initiatives affecting the whole value chain and relationships with suppliers	High bargaining power of the company. Strategic perspective(Liwei, Yuchi, Jijiong, & Yingguang, 2009)
Responsive strategy	bargaining power vs. suppliers/shredders is low the regulators' pressures are low	High/low bargaining power of the company. Technical perspective (Joossens & Raw, 2008)
Re-active strategy	comply with environmental regulations or customers' environmental requirements (Chunming & Yingzi, 2008)	External oriented: High pressures from regulators and Technical perspective Market driven: High pressures of "tobacco" customers and Technical perspective
Unresponsive strategy	limited financial resources, passive pattern of environmental behaviour and delay "tobacco" programmes	High importance of cost based strategy (Juttner, Godsell, & Christopher, 2006)

Table 1. Main characteristics of the tobacco supply-chain strategies

First, we review the most related literature in supply chain coordination under risk-averse and tobacco supply-chain strategy briefly. Theoretical field has yielded plenty of literature on supply chain. Cachon(2003) offered a comprehensive review on supply chain contracts for coordination. Moreover, Taylor (2002), Cachon and Lariviere(2005)also have done this kind of research. In practical business, the agents of supply chain are often sensitive to risk, Seshedri(2000b) and Gan et al.(2004,2005) studied the supply coordination with risk-averse agents. As for the risk-averse, CVaR is shown to be a coherent risk measure and has better computational characteristics. Due to the advantage of CVaR, we will adopt CVaR criteria as the performance measure. Chen et al. (2003, 2009), Tomlin and Wang (2005), Tomlin and Wang (2005) and Gotoh and Takano (2007) adopted CVaR to measure risk.

As for the tobacco supply-chain strategy, (Godsell, Birtwistle, & van Hoek, 2010) have studied the ethical objective and radical approach to environmental issues. (Liwei, Yuchi, Jijiong, & Yingguang, 2009) researched show that "systemic" initiatives affect the whole value chain and relationships with suppliers considering High bargaining power of the company. (Joossens & Raw, 2008) studied bargaining power vs. suppliers/shredders issues from the technical perspective. (Chunming & Yingzi, 2008) investigated the Re-active strategy which includes external oriented: high pressures from regulators and technical perspective and market driven: High pressures of "tobacco" customers and Technical perspective. (Juttner, Godsell, & Christopher, 2006) studied the Unresponsive strategy about limited financial resources, passive pattern of environmental behaviour and delay "tobacco" programmes.

3. System dynamics models for tobacco supply-chain management

This section is a detailed discussion of the system dynamics modelling, which allows for simple representation of complex Cause-and-Effect Relationships. For the discussion that follows it is important to understand that it is the Levels (or state variables) that define the dynamics of a system. For the mathematically inclined we can introduce this in a more formal way. The following equations show the basic mathematical form of the DMTSCM.

$$measures[i]_t = \int_0^T levels[j]_t\,dt; \text{or } \frac{d}{dt} measures[i]_t = levels[j]_t \tag{1}$$

$$rates_t = levels_t dt = \int_0^T rates_t dt \quad \frac{d}{dt} levels_t \tag{2}$$

$$rates_t = \mathrm{g}(levels_t, aux_t, data_t, const) \tag{3}$$

$$aux_t = \mathrm{f}(levels_t, aux_t, data_t, const) \tag{4}$$

$$levels_0 = \mathrm{h}(levels_0, aux_0, data_0, const) \tag{5}$$

In these equations g, h, and f are arbitrary, nonlinear, potentially time varying, vector-valued functions. Equation (1) represents the evolution of the system over time, equation (3) the computation of the rates determining that evolution, equation (4) the intermediate results necessary to compute the rates, and equation (5) the initialization of the system.

4. Research objectives and methodology

The objective of the research adopted under the heading of Dynamics Models for Tobacco Supply-Chain Management (DMTSCM) was to identify tools and techniques that would facilitate:

- Identification of factors affecting Environmental Performance,
- Identification of the relationship between factors affecting Environmental Performance,
- Quantification of these relationships on one another, and on the overall performance of the supply processes, and

- Establishment of 'What if' analysis on process performance and strategy selection.

The six steps of the approach were developed as a result of the DMTSCM methodology implementation as depicted in Fig. 1. The details of this approach have been explained through a case study in Section 5.

The flow variables represent the flows in the system (i.e. remanufacturing rate), which result from the decision-making process. Below, we define the model variables (stock, smoothed stock and flow) converters and constants and cost parameters, their explanation, where necessary, and their units. We chose to keep a nomenclature consistent with the commercial software package that we employed; thus for the variable names we use terms with underscore since this is the requirement of the software package (it does not accept spaces). The stock variables in order that they appear in the tobacco supplying processes are the following:

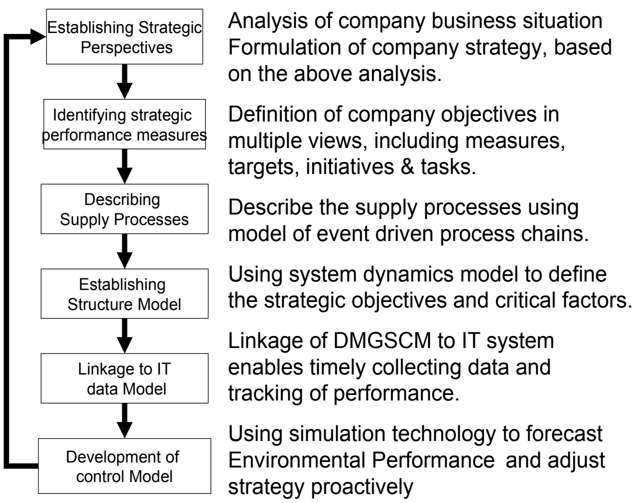

Fig. 1. DMTSCM Methodology Implementation

- Raw_Materials: inventory of raw materials [items].
- Serviceable_Inventory: on-hand inventory of new and remanufactured products [items].
- Distributors_Inventory: on-hand inventory of the distributor [items].
- Collected_Products: the inventory of collected reused products [items].

The smoothed stock variables are:

- Expected_Distributors_Orders: forecast of distributor's orders using exponential smoothing with smoothing factor a_DI [items/day].
- Expected_Demand: demand forecast using exponential smoothing with smoothing factor a_D [items/day].
- Expected_Remanufacturing_Rate: forecast of remanufacturer rate using exponential smoothing with smoothing factor a_RR [items/day].
- Expected_Used_Products: forecast of used products obtained using exponential smoothing with smoothing factor a_UP [items/day].

Constants, converters are:

- CC_Discrepancy: Discrepancy between desired and actual collection capacity [items/day].
- CC_Expansion_Rate: Collection capacity expansion rate [items/day/day].
- DI_Adj_Time: Distributor's inventory adjustment time [days].
- DI_Cover_Time: Distributor's inventory cover time [days].

4.1 Cause-effect diagram

The structure of a system in DMTSCM methodology is captured by cause-effect diagrams. A cause-effect diagram represents the major feedback mechanisms. These mechanisms are either negative feedback (balancing) or positive feedback (reinforcing) loops. A negative feedback loop exhibits goal-seeking behavior: after a disturbance, the system seeks to return to an equilibrium situation. In a positive feedback loop an initial disturbance leads to further change, suggesting the presence of an unstable equilibrium. Cause-effect diagrams play two important roles in DMTSCM methodologies. First, during model development, they serve as preliminary sketches of causal hypotheses and secondly, they can simplify the representation of a model.

The first step of our analysis is to capture the relationships among the system operations in a DMTSCM manner and to construct the appropriate cause-effect diagram. depicts the cause-effect diagram of the system under study which includes both the forward and the reverse supplying processes. To improve appearance and distinction among the variables, we removed underscores from the variable names and changed the letter style according to the variable type. Specifically, stock variables are written in capital letters, the smoothed stock variables are written in small italics and the flow variables are written in small plain letters. These variables may be quantitative, such as levels of inventories and capacities, or qualitative, such as failure mechanisms.

4.2 Mathematical formulation

The next step of DMTSCM methodology includes the development of the mathematical model, also presented as a cause-effect diagram that captures the model structure and the interrelationships among the variables. The cause-effect diagram is easily translated to a system of differential equations, which is then solved via simulation.

The cause-effect diagram is a graphical representation of the mathematical model. The embedded mathematical equations are divided into two main categories: the stock equations, defining the accumulations within the system through the time integrals of the net flow rates, and the rate equations, defining the flows among the stocks as functions of time. In the remaining of this section, we present selected formulations related to important model assumptions.

The equations related to collection tobacco supplying policy are the following:

$$\mathit{Desired\_CC}(t) = \mathrm{DELAYINF}(\mathit{Used\_Products}, \mathit{a\_CC}, 1, \mathit{Used\_Products}) \quad (6)$$

$$\mathit{Collection\_Capacity}(0) = 0 \quad (7)$$

$$Collection\_Capacity(\mathrm{t}+\mathrm{dt}) = Collection\_Capacity(\mathrm{t}) + \mathrm{dt} * CC\_Adding\_Rate, \quad (8)$$

$$CC\_Adding\_Rate = \mathrm{DELAYMTR}(CC\_Expansion\_Rate, 24, 3, 0), \quad (9)$$

$$CC\_Discrepancy = \mathrm{PULSE}(Desired\_CC * Collection\_Capacity, 50, P_c), \quad (10)$$

$$CC\_Expansion\_Rate = \max(K_c * CC\_Discrepancy, 0), \quad (11)$$

Desired_CC is a first order exponential smoothing of Used_Products with smoothing coefficient a_CC. Its initial value is the initial value of Used_Products. Collection_Capacity begins at zero and changes following CC_Adding_Rate, which is a delayed capacity expansion decision (CC_Expansion_Rate) with an average delay time of 24 time units, an order of delay equal to 3 and initial value equal to zero at t = 0. CC_Expansion_Rate is proportional to the CC_Discrepancy between the desired and actual collection capacity, multiplied by Kc. The pulse function determines when the first decision is made (50 time units) and the review period Pc. Similar equations dictate the tobacco supplying policy.

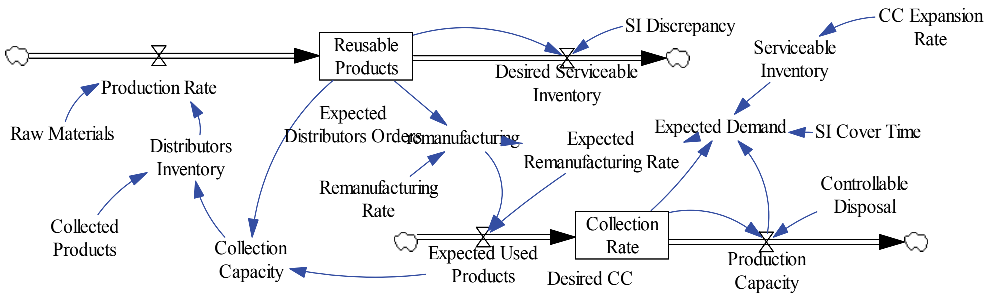

Fig. 2. Cause-effect diagram of the tobacco supplying processes

The total profit per period is given from:

$$Total\_Profit\_per\_Period = Total\_Revenue\_per\_Period - Total\_Cost\_per\_Period, \quad (12)$$

Where

$$Total\_Cost\_per\_Period = Investment\_Cost + Operational\_Cost + Penalty\_Cost, \quad (13)$$

$$Total\_Revenue\_per\_Period = Sales * Price, \quad (14)$$

$$\begin{aligned} Investment\_Cost = {} & (CC\_Expansion\_rate)^{0.6} * Col\_Cap\_Construction\_Cost \\ & + (RC\_Expansion\_rate)^{0.6} * Rem\_Cap\_Construction\_Cost, \end{aligned} \quad (15)$$

$$\begin{aligned} Operational\_Cost = {} & Collection\_Rate * Collection\_Cost + Production\_Rate \\ & * Production\_Cost + Reusable\_Products * Holding\_Cost \\ & + Sales * DI\_Transportation\_Cost + Distributors\_Inventory \\ & * DI\_Holding\_Cost + Shipments\_to\_Distributor * \\ & SI\_Transportation\_Cost + Serviceable\_Inventory * SI\_Holding\_Cost, \end{aligned} \quad (16)$$

4.3 Supply chain coordination with quantity-flexibility contract under CvaR

In this subsection, considering a supply chain comprises a risk-neutral supplier and a risk-averse retailer where the supplier's product is sold via the retailer to end consumers. We present a Stackelberg game in which the supplier is the leader and the retailer is the follower. Here, the retailer adopts CVaR as its performance measure. The definition of η-CVaR for an inventory policy μ is (see Rockafellar and Uryasev, 2000, 2002; and Pflug, 2006)

$$\eta\text{-CVaR}(g(\mu, D)) = \max_{v \in R} \left\{ v + \frac{1}{\eta} \mathrm{E}[\min(g(\mu, D) - v, 0)] \right\} \tag{17}$$

Where E is the expectation operator, and $\eta \in (0, 1]$ denotes the degree of risk-aversion of the decision-maker (the smaller η is, the more risk-averse the decision-maker is).

Market demand for the product is a stochastic variable D, and the cumulative distribution function (cdf) of D is F(·). We let the marginal production cost of the manufacturer be c and the salvage value per unit of unsold product is s. Let w be the wholesale price and r be the retailer's retail price. To avoid trivial, we assume that $s<c<r$. Before production, the supplier offers a supply contract under which the retailer decides the order quantity Q if he agrees the contract. Only once order is allowed because of long production setup lead time (see e.g., Cachon (2004)).

According to Cachon (2003), LEI YANG (2009), given a quantity-flexibility contract, the supplier charges w per unit purchased and then compensate the retailer for unsold losses. Namely, the retailer receives $(w - s)\min(I, \delta Q)$ from the supplier when selling season is over, where I is the amount of leftover inventory, Q is the order quantity and $\delta \in [0, 1]$ is a contract parameter indicating that the retailer may return up to δQ units for unsold items for a full refund. With the quantity-flexibility contract the transfer payment the transfer payment can be written as

$$T(Q, w, \delta) = wQ - (w - s)\left[(Q - D)^+ - ((1 - \delta)Q - D)^+\right] \tag{18}$$

To be specific, expression (18) can be rewritten as

$$T(Q, w, \delta) = \begin{cases} wQ & \text{if } Q \le D; \\ wQ - (w - s)(Q - D) & \text{if } (1 - \delta)Q \le D < Q; \\ wQ - (w - s)\delta Q & \text{if } (1 - \delta)Q > D. \end{cases} \tag{19}$$

And then the retailer's profit can be expressed as

$$\begin{aligned} \pi_r(Q, w, \delta) &= r\min(Q, D) + s(Q - D)^+ - T(Q, w, \delta) \\ &= (r - s)[Q - (Q - D)^+] \\ &\quad - (w - s)[Q - (Q - D)^+ + ((1 - \delta)Q - D)^+]. \end{aligned} \tag{20}$$

Consider the set of quantity flexibility contracts (w, δ) with η_r -CVaR: the retailer pays wholesale price w(δ) for unit product, where

$$w(\delta) = s + \frac{(r - s)(1 - F(Q^*)/\eta_r)}{1 + [(1-\delta)F((1-\delta)Q^*) - F(Q^*)]/\eta_r} \ \ with\ \delta \in (\hat{\delta}, 1], \tag{21}$$

Where $\hat{\delta}$ is the unique solution to $E[\pi_r(Q^*, w(\delta), \delta)] = E[\pi_{sc}(Q^*)]$. The quantity flexibility contract can induce the retailer to order a quantity at Q^*; that is to say, these contracts can fully coordinate the supply chain. The quantity-flexibility contract shares a part of demand risk by providing the retailer refund on a portion of the retailer's leftover inventory.

For more detailed proof of (21), see (LEI YANG et al., 2009).

5. Illustrative case

After the State Tobacco reform and several decades of development of the tobacco industry, market competition becoming increasingly fierce, various brands of tobacco companies have become the focus of the competition, the cigarette brand development strategy become the key to survival and development of cigarettes industrial enterprises.

Since 2000, senior management has been committed to a reduction in the environmental impact resulting from production activities, and product usage. In terms of operational policy, such an interest in "tobacco" issues has given rise to two major programmes: (1) The F1 program, specifically aimed at improving the environmental performance of the supply processes; (2) The F2 program, which focuses on the introduction of new environmentally friendly cigarettes.

The implementation of the above initiative results in the modification of design, process efficiency and volume indices (see Table 2). Specifically, the take-back of bumpers leads to a reduction in the purchase of plastic raw materials and energy consumption (30 per cent with respect to traditional plants), since the fluff resulting from the grinding of cigarette bodies is cleaner.

		Planned value	**Reported measure**
	Time for production	5 hours	4.5 hours
	Time for disassembling	7.8 hours	6.6 hours
	No. of different materials in the product	14	19
Volume index	Quantity of recovered plastics	6.346 tons	8.650 tons
	SOx	423 tons	532 tons
	NOx	312 tons	395 tons
Process efficiency	Electrical energy	345,000 Mwh	430,000 Mwh
	Oil	1,383 tons	2,250 tons
	COD	25,500 tons	23,000 tons
	Sulphates	168,000 tons	269,500 tons

Table 2. Measures expressing a company's impact on the state of natural resources

From a financial perspective (see Table 3), the program affects expenditure related to the internal efficiency of operations, e.g. the reduction of energy, raw materials and environmental regulations related costs (regarding both waste water and solid wastes), as well as other operating costs associated to the take back and recycling of bumpers, higher labor costs to implement the recycling process internally, and increased expense for the recycling process itself. In addition, the introduction of new cigarettes produced an increase in volume (50,000 units).

	Forecast Value (RMB)	**Reported measure (RMB)**
Revenue		
Total Revenue per Period	4,450,000,000	4,645,000,000
Total Cost per Period		
Total Profit per Period	65,500,000,000	67,450,000,000
Operational Cost	38,150,000,000	37,650,000,000
Energy costs	7,640,000,000	75,527,000,000
Other environmental costs		
Recycling costs	835,720,000	828,780,000
Costs related to environmental regulations	693,400,000	793,300,000

Table 3. The economic items affected by the initiative

In the light of the above analysis, it can be concluded that the company respected its own targets: indeed, the increase in actual labour costs over standard costs is only marginal and, above all, the result of the growth in production volumes.

The above discussion highlights that there are significant differences in the deployment and assessment of a pro-active or a re-active tobacco supply-chain strategy. In particular, both the design of the GSCM and the gathering of data present different operating problems which depend on the adopted pattern of environmental behaviour.

In general terms, the design of an effective GSCM is more complex within pro-active companies than within re-active organizations. It must be noted that the assessment of a pro-active tobacco supply-chain strategy requires identification of physical and economic indicators which well describe a company's potential environment-related sources of competitive advantage. This implies significant changes in the traditional systems adopted to monitor the evolution of environmental performance. Indeed, the latter were usually designed to verify compliance with existing regulations. A re-active tobacco supply-chain strategy simply demands verification of whether environmental performance of the company's products and/or processes are consistent with the stakeholders', i.e. regulators' and/or customers', requirements. The implementation of the suggested approach in FA (the re-active firm) did not in fact require the definition of new measures, as the company's GSCM already considered compliance indicators.

It is evident that, apart from managers' skills and the effectiveness of the information system, the deployment of innovation-based tobacco supply-chain strategies (evangelist, pro-active and responsive) is more complex than passive patterns of environmental behavior. A key point in the effective assessment of innovative environmental policies is the identification of measures clarifying how the company positions itself with respect to competitors, and how the adopted programmes affect the company's profitability. In this respect, a growing body of literature highlights that the failure of some ambitious environmental strategies is a direct consequence of an incorrect selection of the indicators to be used in the GSCM.

6. Concluding remarks

The suggested framework is an effective tool for operations managers wishing to design GSCMs. The operational guidelines on PMS architecture and the appropriate measurement techniques provide support in devising performance indicators that best suit the intended tobacco supply-chain strategy. An important benefit gained from the DMTSCM approach is that the interaction of the factors can be clearly identified and expressed in quantitative terms. This identification will bring us one step forward in understanding the dynamic behavior of factors affecting Environmental Performance.

This chapter extends the concept of supply chain coordination in risk-averse environments, specifically, we consider a supply chain with one risk-neutral supplier and one risk-averse retailer where the retailer takes CVaR as his performance measure. And we find that the supply chain can also be coordinated under properly designed contracts. Furthermore, the problem of supply chain coordination in risk-neutral setting is a special case of ours. Our results extend the supply chain coordination to the risk-averse setting. By analytic optimal solutions obtained in this chapter, the proposed coordinating policies can be easily implemented when the retailer is risk-averse. Supply chain coordination in risk-averse setting is a quite important issue in academic and practice. We all know that CVaR is a conservative risk measure, another possible extension is that the retailer takes mean-variance as his performance measure. When both the supplier and the retailer are risk-averse, can we still find proper contracts to coordinate the supply chain? This will be another topic of our further research.

Moreover, the approach can be used in a "dynamic perspective", i.e. to analyze whether to change the adopted pattern of environmental behavior from a passive/re-active to a pro-active strategic attitude. In operational terms, this implies that a re-active firm has to design a GSCM which includes indicators highlighting how the company's economic value may change with the introduction of innovation-based environmental strategies.

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Critical Factors Affecting Supply Chain Management: A Case Study in the US Pallet Industry

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1. Introduction

Supply chain management is applied by companies across the globe due to its demonstrated results such as delivery time reduction, improved financial performance, greater customer satisfaction, building trust among suppliers, and others. According to D'Amours, Ronnqvist, and Weintraub (2008), companies resort to supply chain practices to improve their performance. Thus, it is important to first understand how their supply chains work. Figure 1 shows a generalized supply chain in the forest products industry.

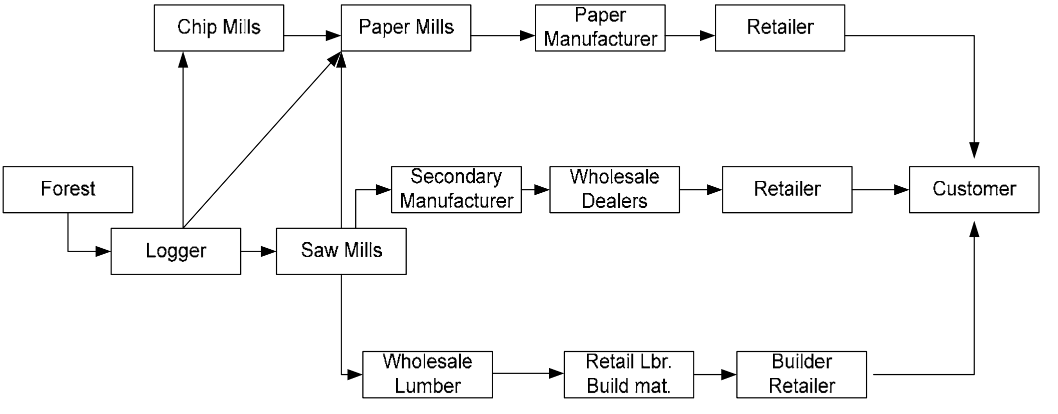

Fig. 1. Forest and wood products supply chain (Campbell and Kazan, 2008)

Figure 2 illustrates another example of the steps in a supply chain for wood pallet manufacturing industries. This process begins with logging operations, logs are then sent to the sawmill where cants and/or pallet parts are sent to the wood pallet manufacturer (pallet operations). Lastly, once wood pallets are manufactured, they are sent to a distributor or directly to the final customer.

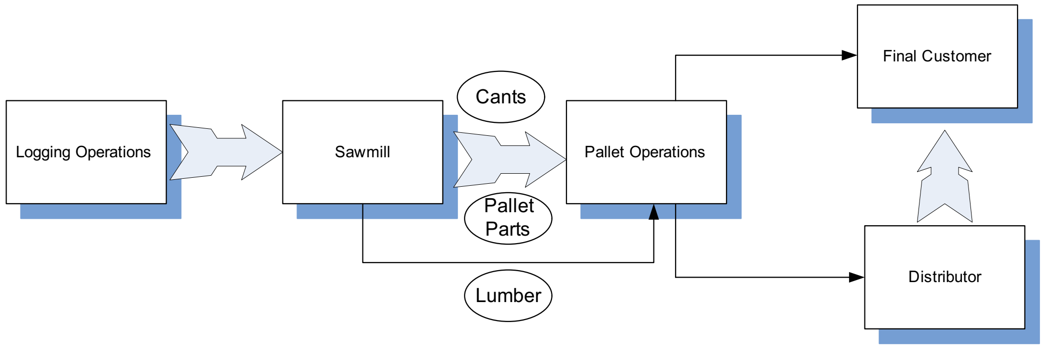

Fig. 2. Hypothesized wood pallet manufacturing process

2. Identification of Supply Chain Management factors

In order to understand how a supply chain works, it is important to identify the factors affecting supply chain management. The identification of these factors has been based on previous work by Li (2002), and Quesada and Meneses (2010). The following sections show generic supply chain management factors and sub-factors that might affect supply chain management activities.

2.1 Environmental uncertainty

Environmental uncertainty refers to the environmental issues in the product chain (Dwivedi and Butcher, 2009). Ettlie and Reza (1992) described this as the unexpected changes of customer, supplier, competitor, and technology. It was said by Yusuf (1995) that government support plays an important role for business success. Paulraj and Chen (2007a) mentioned that environmental uncertainty is an important factor in the realization of strategic supply management plans. The increase of outsourcing activities in the industry had augmented the awareness of the importance of strategic supply management, which leads to better relationship among organizations. Under this factor, three sub-factors were identified: environment, government support, and uncertainty aspects from overseas.

2.1.1 Company environment

This sub-factor is related to the company's relationship with suppliers and their level of trust and commitment. Company environment is also related to the company's expectations of quality, on time delivery, competition in the sector, and the level of rivalry among firms. In order to respond effectively to demand, companies realize that imports are a good option for obtaining flexibility in response, even though working with countries from overseas implies working with uncertainty (Wu, 2006). According to a study carried out by Ambrose et al. (2010), uncertainty negatively affects company performance. But this can be reduced if a strategic relationship with critical suppliers is established (Chen et al., 2004). Thus, companies need to implement new strategies that allow them to deal with environmental uncertainties in the supply chain (Wu, 2006) in order to perform in a proficient manner.

2.1.2 Government support

The level of support that the company receives from the government when importing raw materials or products from overseas or using domestic materials. It includes the use of norms, regulations, policies, and advice for the sector. The research conducted by Elzarka et al., (2011) describes how government can make a series of reforms to encourage exportats by increasing manufacturing sector's competitiveness in the international market through logistics competency. The increase of international trade for acquiring resources from other countries introduces complicated matters such as language barriers, transportation, transportation costs, exchange rates, tariffs, and administrative practices (Quayle, 2006).

2.1.3 Uncertainty aspects from overseas

When requiring the outsourcing of raw materials or products, it is important to acknowledge the existence of environmental factors such as political uncertainties in other countries that can increase risk for suppliers, provoke decisions of no investment, change business strategies, and in general influence business decisions. Social uncertainties such as religion, environment, language, cultural issues, limitations of communication (Bhattacharyya et al., 2010) and also the technology used in other countries might interfere with supply chain planning and function (Bized, 2007).

2.2 Information technology

Telecommunications and computer technology allow all the actors in the supply chain to communicate among each other. The use of information technology allows suppliers, manufacturers, distributors, retailers, and customers to reduce lead time, paperwork, and other unnecessary activities. It is also mentioned that managers will experience considerable advantages with its use such as the flow of information in a coordinated manner, access to information and data interchange, improved customer and supplier relationships, and inventory management not only at the national level but also internationally (Handfield and Nichols, 1999). Also the advantages will include supply contracts via internet, distribution of strategies, outsourcing and procurement (Simchi-Levi et al., 2003). All companies are looking for cost and lead time reductions with the purpose of improving the level of service but also to enhance inter-organizational relationships (Humphreys et al. 2001).

A study carried out by Tim (2007) states that through the use of communication tools, such as the web sites, industrial organizations can build value in their supply chain relationships. According to Turner (1993), another key for supply chain management success is the use of planning tools. He also mentions that without the use of information systems, companies cannot handle costs, offer superior customer service and lead in logistics performance. Turner (1993) indicates that firms cannot effectively manage cost, offer high customer service, and become leaders in supply chain management without the incorporation of top-of-the-line information technologies. Li (2001) identified 14 such information technology tools, among them electronic data interchange (EDI), enterprise resource planning (ERP), internet, and extranets. Li grouped these tools into three groups in terms of their primary purpose: communication tools, resource planning tools, and supply chain management tools. Given this classification, two subfactors are considered in this research: communication and planning tools.

2.2.1 Communication tools

Communication tools are used to facilitate data transfer and communication between the trading parts and this might include EDI, electronic fund transfer (EFT), intranet, internet, and extranet (Li 2002). Electronic Data Interchange (EDI) is used for procurement (purchase orders, order status, and order follow-up). EDI serves as electronic catalogs for customers who can get information, dimensions, and cost about a specific product. EFT provides trading partners with an effective way to transfer funds from one account to another through a value added network (VAN) or the internet. Intranets are corporate local area networks (LAN) or wide area networks (WAN) that communicate through the internet and are secured by firewalls. Usually this type of communication tool is used inside a corporation that features different locations. On the other hand, extranet allows business to communicate and share business with external collaborators with a certain degree of security and privacy. Another type of communication tool is the internet, a uniform interface that allows global communication with the use of browsers (Bowersox et al., 2007). According to O'Neill (2008) the advances in information technology have made communication tools easier for users, allowing its presence in components to extend in the supply chain. Another significant communication tool is the internet based information and communication technology (ICT), mentioned by Tan et al. (2009). This study suggested that the use of ICT is a strategic communication tool that improves the organization's competitiveness, allowing cost reduction and permitting the company's effectiveness.

2.2.2 Planning tools

Supply chain management planning tools are intended to integrate the resource planning activities in a firm or organization. Some of the most common planning tools are: material requirment planning (MRP), manufacturing resources planning (MRPII), and Enterprise Resource Planning (ERP). A MRP is a tool that allows an organization to schedule production activities to meet specific deadlines based on the bill of materials, inventory levels, and master production schedule. An improvement of MRP tools is MRPII which integrates manufacturing capabilities and capacities with the benefits of MRP. An ERP tool allows the organization to integrate all processing information tasks related to all processes in the value chain. This is usually a single system that might include order management, inventory fulfillment, production planning, financial planning, and customer service in a company. It is the backbone of the logistic systems for a variety of firms (Bowersox et al., 2007).

Some other IT tools exist that can be used to execute or manage the various activities and relationships in the entire supply chain (Kumar 2001). These may include: data warehouse (DW), vendor managed inventory (VMI), distribution requirement planning (DRP), and customer service management (CRM).

2.3 Supply chain relationships

Supply chain relationships play an important role in achieving the firm's goals. The coordination and integration of activities with suppliers and understanding of customer's needs results in greater benefits for companies. According to Fraza (2000), supply chain management is directly related to relationship management, which includes suppliers and customers. Strategic supplier partnerships and customer relationships are main components in the supply chain management practices (Li et al., 2005), leading to information sharing, which is one of the five pillars in achieving a solid supply chain relationship (Lalonde, 1998). Two sub-factors are considered in the model relationship with suppliers and customers.

2.3.1 Relationships with suppliers

Companies are inclined to work with different suppliers in different ways. It is important that the relationship with suppliers satisfies their company needs. Hines (2004) mentioned that in commodity products, it is common to find an adversarial relationship mainly based on price between buyer and supplier. This type of relationship with suppliers does not allow for cost reduction in the supply chain. It may be beneficial to network the supplier, to develop partnerships and alliances that will benefit both partners. This could be based on production, personal, and or symbolic networking, that will turn on strategic alliances (Hines, 2004), allowing the information sharing, risk sharing, obtaining mutual benefits and coordinating plans, permitting the improvement of the supply chain.

2.3.2 Relationships with customers

The global markets offer a variety of products of different quality and cost. As a result, companies are always competing and trying to reduce costs and improve quality. According to Burguess (1998) and Hoek (1999), customers look for more choices, better service, higher quality, and faster delivery. The relationship with customers has turned a strategic issue for today's companies.

2.4 Value-added process (manufacturing)

Value-added products can be commodity processes or products that already exist; you only have to use smart modifications and apply them. According to Bishop (1990), value-added is defined as "*adding those manufacturing or service steps to a commodity product, which the customer perceives as increasing its value*". Customers always want to pay the cost that they think is correct, and if they get something additional to the product, they got value-added. Two factors are significant when we talk about value-added: flexibility and quality. And, as stated by Benetto, Becker and Welfring (2009), production processes contribute to improved value-added.

For example, Dramm (undated) affirms that the forest products industry is mainly focused on acquiring the highest value throughout the manufacturing process at the lowest cost, improving efficiency, quality, and productivity. Thus, it is important to include the production system as a part of the value-added process.

2.4.1 Flexibility

The complex markets, fierce competition and fast changes in demand require that companies be ready to react promptly to customers' needs. Flexibility can be understood as the ability to react and adapt quickly to changes in the market due to an increase or decrease of customers' requirements, accelerating or decelerating the manufacturing processes when it is requested. Bowersox, Closs, and Cooper (2007) mention that a logistical competency of a firm can be measured by how well it is able to adapt to unpredictable situations.

2.4.2 Quality

Quality is not a bonus for the customer; it is expected. Quality is also important for the acceptance of a product. High costs, low productivity, and loss of market share are directly related to poor quality (Dramm, undated). Quality is meeting or exceeding the expectations of your customer (Bishop, 1990). This could be achieved, for example, by the use of quality metrics, which improves the production system (Juran, 1988). Achieving better efficiency, quality and productivity, and acquiring the highest value of a product at lower cost will improve the business performance of a company.

2.4.3 Production system

A study made in the automotive glass business showed how changing the industrial structure of the production system adds value to processes, which will help to expand their business future (Just-Auto, 2010). This value-added could be achieved by reducing activity time, cost processes, and identifying bottlenecks that will improve the production processes. As a result, it will give value-added to the products (Mehta, 2009).

2.5 Supply Chain Management performance (SCM)

SCM performance is defined as the operational excellence to deliver leading customer experience (Simchi-Levi et al., 2003). Beamon (1999) mentions some features present in effective performance measurement systems and these include the following: inclusiveness (measurement of all pertinent aspects), universality (allows for comparison under various operating conditions), measurability (data required are measurable), and consistency (measures consistent with organization goals). Also, the strategic goals include key elements such as the measurement of resources (generally cost), output (generally customer responsiveness) and flexibility. Stevens (1990) states that to build up an integrated supply chain requires the management of material flow from three perspectives: strategic, tactical, and operational. From these perspectives, the use of systems, facilities, and people must be seen as a whole and work in a coordinated manner. He also mentions that a company can measure the supply chain performance by inventory level, service level, throughput efficiency, supplier performance, and cost. Lear-Olimpi (1999) also stated that logistics play an important role in pursuing supply chain excellence which will lead to improved business performance (Lear-Olimpi, 1999). Another critical sub-factor of successful supply chain management is the analysis of the supplier market (Purchasing, 2007). An important point according to Canbolat, Gupta, Matera and Chelst (2008) is outsourcing, which is significant in the supply chain management for the opportunities and risks that it offers. Then, this factor comprises four sub-factors logistics, supplier markets, supplier performance, and materials sourcing.

2.5.1 Logistics

Logistics is defined by Bowersox, Closs, and Cooper as "*the responsibility to design and administer systems to control movement and geographical positioning of raw materials, work-in-*

process, and finished inventories at the lowest total cost" (Bowersox et al., 2007). The research of Autry, Zacharia and Lamb (2008) establishes that logistics must be focused on the coordination and collaboration of activities, logistics social responsibility, strategic distribution planning, and technology and information systems.

2.5.2 Supplier markets

According to Yushan and Cavusgil (2006), changes in the market create sensible companies regarding firm-supplier relationship. For manufacturers it is more important to build supplier's trust and to rely on suppliers, focusing on customer orientation, competitor orientation, and inter-functional coordination. The current competitive environment makes manufacturers aware of the need to reduce costs and to develop new products quickly. This is when supplier's expertise plays an important role. Superior supply chain management requires significant information with respect to supplier markets. Implementation of strategies in the supply chain will make the precious firm-supplier relationship difficult to copy by competition (Eltantawy, 2005).

2.5.3 Supplier performance

When looking for successful supplier performance, it is important to emphasize relationship quality. Researchers such as Walter, Kaufman, and Palmatier, propose relationship quality as a "multi-dimensional construct consisting of trust, satisfaction, and commitment." Steward, Wu, and Hartley (2010) consider factors such as product quality; responsiveness to requests for change; sales, service and/or technical support; total value received; and overall cost performance as a measurement of supply chain performance. They also found that "supplier performance is higher when the supply manager perceives trust and satisfaction on the part of the supplier's account executive."

2.5.4 Material sourcing

Companies in any manufacturing sector are always looking for low-cost raw material, domestic or imported. With the objective of improving their competitive advantage, some of them see importing as an appealing option. As there are some advantages when importing resources, such as lower labor cost and lower cost of resources, there are also some disadvantages that companies have to take into account when evaluating whether or not to work with offshore companies. Importing raw materials, components or products increases the dependence on suppliers (Lockamy and McCormack, 2010), and some risks are identified such as culture, language, foreign exchange rate, regulations, quality, political and economic stability, and transportation delays (Canbolat et al., 2008).

2.6 Business management

Business management consists of leading, planning, organizing, monitoring and controlling all the involved actors and activities in a company to achieve goals and objectives. It is described by Ford and Mouzas (2010) as "*the process of managing networking between companies*". Fast changes in customer demand, globalization of markets, and changing technology require companies to focus their efforts on improving competitiveness, trying to achieve customer's satisfaction through adding more value to their products (Hung, 2010).

Thus, improving business process performance is critical for business management (Linzalone, 2008). Also, process strategy is used to improve manufacturing performance, and as result business performance (Thomas et al., 2008).

Marketing strategy is viewed by managers as a tool for improvement of their financial returns (Peterson, 1989). And innovation should be seen as part of business management, allowing the implementation of new processes, products, and services to respond promptly to customers' requirements (Leavy, 2010).

2.6.1 Process strategy

Process strategies are utilized by companies to improve their manufacturing performance and as a result business performance (Thomas et al., 2008). Sultan (2006) states that process strategy management requires the identification of objectives, the creation of policies and assignation of resources for the plan's implementation.

2.6.2 Process performance

Companies are expected to provide superior quality at low cost. To achieve these goals, they have to look for tools and strategies that help them obtain high process performance. Rework rate, defect rate, and inventory turnover rate are measures of process performance (Pakdil, 2010).

2.6.3 Marketing strategy

Marketing strategy is defined "*as an organization's integrated pattern of decisions that specify its crucial choices concerning products, markets, marketing activities and marketing resources in the creation, communication and/or delivery of products that offer value to customers in exchanges with the organization and thereby enables the organization to achieve specific objectives*" (Varadarajan, 2010).

Managers are always confronting the problem of how to implement marketing strategies in the company. It might be better to increase advertising, to create and invest in loyalty programs, and to improve product or service quality by focusing on financial returns of marketing (Rust et al., 2004).

2.6.4 Innovation

Verhees and Meulenberg (2004) mention that innovation is the creation of a new product and the process of acceptation and implementation of the new product. There are three levels at which innovation can be studied: the sectorial, regional, and project level. According to Meeus and Oerlemans (2000) innovation allows companies to growth and survive in the complex markets. Also, according to the Organization for Economic Co-Operation and Development (2005) innovation is defined as "*the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organizations, or external relations.*" Another definition of innovation was done by Schramm (2008) as "*The design, invention, development, and/or implementation of new or altered products, services, processes, systems, organizational structures, or business models for the purpose of creating new value for customers and financial returns for the firm.*"

2.7 Customer satisfaction

The customer's perception is not always the same as the product manufacturer's perception. Customers may give more value to low cost, on time delivery, delivery date certainty, or receiving a customized product (Simchi-Levi et al., 2003). According to Kurata and Num (2010), manufacturers and retailers are always looking for practical after-sales policies that will permit them to enhance customer satisfaction levels. Furthermore, an analysis conducted by Ou, Liu, Hung and Yen (2010) showed that customer-firm-supplier relationship management improves operational performance and customer satisfaction. Based on this, a sub-factor customer service is identified.

2.7.1 Customer service

The goal of the companies is to give customers the best service in an efficient and effective manner (Handfield and Nichols, 1999), without forgetting about information such as product description, product availability, order status, shipping dates, and assisting them in all what they need (Lambert and Cooper, 2000). Quayle (2006) states that customer service is defined by demand forecasting, service levels, order processing, parts/service support, and aftermarket operations.

3. Validation of factors affecting Supply Chain Management

Once factors affecting supply chain management activities have been defined, it is necessary to test the relationships among those factors. For this test, the wood pallet industry sector was selected. Wood pallets are utilized during transportation of materials, from raw materials to finished products. Their importance has grown through the years; especially with globalization. Pallet and container manufacturing is a significant part of the wood products sector in the U.S., representing an average of 5.8% of the total value of shipments, and 11.1% of participation in the wood products sector employment, from 2000 through 2008. Also, the value of product shipments (domestic production) has grown from about $5 billion dollars to $7 billion over the investigated 9-year period. The top wood pallet importers were France, Canada, and China. Even though imports have stayed almost constant throughout those years, it is necessary to look for other potential sources of wood pallet materials not only in the U.S., but also in other countries. The United States produce approximately 13%, of roundwood followed by India and China with around 9% each, and Brazil with approximately 7% of the world's roundwood. Information about the type of wood pallet material imports is limited in the literature. Also it is important to add that competition for raw material has increased. According to the RISI'S Wood Biomass Markets (2010) wood pallet manufacturers are currently competing for wood fiber with alternative energy markets, who receivesubsidies from the Biomass Crop Assistance Program (BCAP).

3.1 Hypothesis development and testing procedures

The SCM model to be tested in the wood pallet industry sector is shown in Figure 3. The constructs, hypothesis, and items were designed using the previous review of factors affecting SCM. The literature reviewed supports the factors previously mentioned, and hypotheses need to be established in order to test their significance with regression analysis. In this case we are focusing on six hypotheses which would positively or negatively affect the three main factors: supply chain management performance, business management, and customer satisfaction. For better understanding, a detailed explanation of the relationship between factors is given here: environmental uncertainties, information technology, supply chain relationship, and value-added process are affecting supply chain management. Then, supply chain management directly affects business management, which as a consequence, affects customer satisfaction. Also the hypothesized arrows represent the relationship (positive or negative) between factors. In the following paragraphs a detail of the hypotheses is shown.

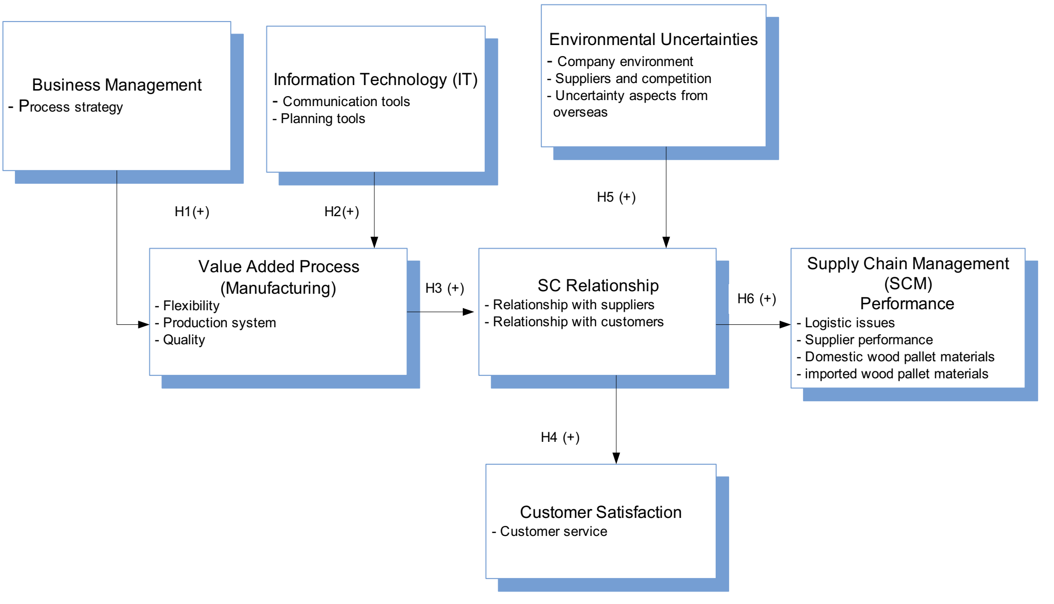

Fig. 3. Factors affecting supply chain management

Hypothesis 1 (H_1): Environmental uncertainties negatively affect supply chain management performance

The uncertainty of a business environment has many sources, including the wide variety of customer's needs. Environmental uncertainties are related to how hard it is to precisely foresee the future (Lee et al., 2009). According to Sung and Hsu (2009) supply chain performance can be influenced by environmental uncertainties, which can allow deciding about significant aggressive factors to take into account and weigh in for the formulation of a successful competitive strategy. This leads to the hypothesis:

H_1: Environmental uncertainties negatively affect Supply Chain Management Performance

Hypothesis 2 (H_2): Information Technology positively affects Supply Chain Management Performance

The use of information technology has turned companies need to utilize information technology to remain competitive. Its use in the supply chain allows transparency and more efficient collaboration. The global advancement of information technology allows companies to coordinate activities, to share information in real-time, and to put into practice electronic commerce and supply chain technology (Patterson et al., 2003). This leads to the hypothesis:

H_2: Information Technology positively affects Supply Chain Management Performance

Hypothesis 3 (H_3): Supply Chain Relationship positively affects Supply Chain Management Performance

According to Sheridan (1998), information technology is only one part of a successful supply chain management. The need to establish good supply chain relationships with internal and external members, from suppliers to customers, should be based on trust and information sharing. This leads to the hypothesis:

H_3: Supply Chain Relationship positively affects Supply Chain Management Performance

Hypothesis 4 (H_4): Value-Added Process (Manufacturing) positively affects Supply Chain Management Performance

Jones and Womack (2002) proposed the reduction of non-value-added activities at a supply chain level, because excessive inventories, transportation, and inefficient information flow are major drivers for supply chain inefficiencies. Thus, companies should reduce non-value adding processes; this will improve customer satisfaction, which is the ultimate goal of supply chain management (Lambert and Cooper, 2000). This leads to the hypothesis:

H_4: Value-Added Processes (Manufacturing) positively affect Supply Chain Management Performance

Hypothesis 5 (H_5): Supply Chain Management Performance positively affects Business Performance

There is ample support in the research for the link between supply chain management practices and business management performance (Berry et al., 1999; Mason-Jones and Towill, 1997; Towill, 1996b). Some benefits mentioned in the literature are reduced lead times, inventories and costs, and improved customer satisfaction. This leads to the hypothesis:

H_5: Supply Chain Management Performance positively affects Business Performance

Hypothesis 6 (H_6): Business Management positively affects Customer Satisfaction

Perceived quality and customer expectations are the inputs for achieving customer satisfaction. Customers focus on product value and product quality (Terblanche, 2006). According to Huber and Pallas (2006) the success formula is that all processes must be customer-oriented. Managers are always concerned about the customer's behavior, so they are always looking for strategies, methodologies, creating new products that will help the company to achieve customer satisfaction. This leads to the hypothesis:

H_6: Business Management positively affects Customer Satisfaction

To purify and test the internal reliability of the data obtained from the survey firms, Cronbach's alpha and factor analysis were used as suggested by Durham (1975), DeVellis (1991), Stevens (2002), and Field and Miles (2010). After data was purified and validated, factor scores were calculated using the method of sum by factor (DiStefano et al., 2009) to be used in multiple regression analysis. The regression model describes and assesses the relationship between a dependent variable and one or more independent variables

(Chatterjee, 2006). A general linear model is used for multiple regression models, where response Y is related to a set of qualitative independent variables. The general lineal model has the following structure (Ott, 2001):

$$Y = B_0 + B_1X_{11} + B_2X_2 + \ldots\ldots\ldots. + B_\kappa X_{i\kappa} + \xi$$

Then, the main relationships between dependent and independent variables can be seen below:

- $VAPM = b_0 + b_1BM + b_2IT + \xi$
- $SCR = b_0 + b_1VAPM + b_2EU + \xi$
- $CS = b_0 + b_1SCR + \xi$
- $SCMP = b_0 + b_1SCR + \xi$

Where:

b_0 = Intersection, b_1, and b_2 = Regression coefficients, and ξ = Regression error
SCMP = Supply Chain Management Performance
BM = Business Management
CS = Customer Satisfaction
EU = Environmental Uncertainties
IT = Information Technology
SCR = Supply Chain Relationship
VAPM = Value-Added Process

3.2 Survey implementation

A pre-test is an indispensable part of the research process when carrying out a research (Hunt et al., 1982). According to Churchill (1979), the questionnaire development process has to include a pre-test. Therefore, this was conducted to evaluate the questionnaire developed in previous steps to find potential inconsistencies or errors, questions that need clarifications, and get expert's feedback to improve the research instrument, as suggested by Dillman (2000). A representative from a major trade publication, entrepreneurs, and professors reviewed the questionnaire and provided their feedback, which was used to improve the initial version of the questionnaire.

The questionnaires were sent to 1,500 companies in the US pallet industry to test the model. Once the questionnaires were returned, different inferential statistical methods were used to validate the model. Questionnaires were accompanied by a cover letter explaining the purpose of the survey and the potential benefits for the industry, and the questionnaire contained a prepaid return postage code. Two questionnaires were mailed to all companies, with a four week-separation between each mailing (Cossio, 2007; Dillman, 2000). Questionnaires were mailed during the fall of 2010. After the second mailing, a non-respondent bias assessment was conducted. The purpose of the non-response bias was to determine if there were significant differences between respondents and non-respondents. The methodology for the non-response bias compared early and late respondents; this practice is based on the assumption that there is a continuum in the likelihood to return a questionnaire from high for early respondents, to zero for non-respondents (Dalecki et al., 1993; Etter and Perneger, 1997b; Lahaut et al., 2003). Three company characteristics were selected for the non-response bias analysis: number of employees, revenue, and pallet production output.

All the responses were coded and entered into electronic spreadsheets. The statistical analysis was carried out using spreadsheet software for processing the data and presenting results, and statistical tests were carried out using SAS® and SPSS® statistical software. Excel was used to perform most of the charts elaborated during the research. Mann-Whitney test and Chi-square were used to analyze non-respondents bias, the former for interval data and the latter for categorical data.

3.3 Model testing results

Results show that there are relatively strong associations between the proposed factors as explained in the hypothesis. Table 1 shows the P values for the hypothesis test. For instance, supply chain relationships (SCR) have a positive effect on Customer Satisfaction (CS). This has been asserted in the literature by several authors. For example, Fynes et al (2005) found association between the quality of supply chain relationships and customer satisfaction, chiefly through the improvement of conformance and design quality. Improvement in customer satisfaction from supply chain collaboration can originate from several sources. For example, customer satisfaction is more likely if customers are more actively involved in the product development process or when defining order specifications (e.g., sawmills developing “custom grades” specific for pallets). Another way in which collaboration leads to customer satisfaction is when an industrial customers (e.g. pallet manufacturer) actively participates in improving the supplier’s (sawmill) internal processes (e.g., sharing improvement methodologies or even sharing costs of improvement programs).

Hypothesis	Description of Hypothesis	Model Equation	P value
H_1	Business Management (BM) positively affects Value-Added Process (VAPM)	$VAPM = b_0 + b_1BM + b_2IT + \xi$	<.0001
H_2	Information Technology (IT) positively affects Value-Added Process (Manufacturing) (VAPM)		
H_3	Value-Added Process (VAPM) positively affects Supply Chain Relationship (SCR)	$SCR = b_0 + b_1VAPM + b_2EU + \xi$	<.0001
H_5	Environmental Uncertainties (EU) positively affects Supply Chain Relationship (SCR)		
H_4	Supply Chain Relationship (SCR) positively affects Customer Satisfaction (CS)	$CS = b_0 + b_1SCR + \xi$	<.0001
H_6	Supply Chain Relationship (SCR) positively affects SCM Performance (SCMP)	$SCMP = b_0 + b_1SCR + \xi$	0.0064

Table 1. Results of model validation

Also, it was shown that Information technology (IT) has a positive effect on value-added process (VAPM). Information technology can be a powerful tool when reducing inventory (non-value adding) and improving supply chain responsiveness (value-adding). Sanders and Premus (2005) had proven the positive relationship between Information Technology capability and collaboration and company performance, as measured by, among other items, costs reduction and time performance improvement.

Value-added processes (VAPM) and supply chain relationships (SCR) are related as well (see Table 1) and line up with previous research results. Stiess (2010) for instance, supports that information sharing helps to reduce wasteful activities, specifically improving material flows and reducing inventories. Wikner et al (1991) demonstrated that high levels of information sharing result in reduced "demand amplification", which is directly related to unnecessary inventory levels throughout the supply chain.

3.4 Practical implications

These results, although specific to a certain industry sector, can help manufacturers to have a better understanding of their supply chain management practices. Findings provide a theoretical framework for supply chain management by identifying and testing seven factors. Manufacturers could achieve improvements in supply chain performance through the effective management of critical items and factors identified in the research. Industry support organization can use the results from this research to better design technical assistance and educational programs for the wood pallet manufacturing sector.

Manufacturers should focus on the effective management of value-added process (manufacturing) since it was demonstrated that they directly affect the supply chain relationships, and as a consequence to supply chain management performance.

Manufacturers should be aware of how critical it is to communicate, and to plan jointly with suppliers. Increasing the importance of supply chain relationships and understanding the significance of this concept will increase customer satisfaction. Practitioners must realize that the flow of information in a coordinated manner, access to information and data interchangegreatly improve customer and supplier relationship. This identifies information technology as a potential area for improvement.

Manufacturers should also be aware that fast changes in customer demand, globalization of markets, and changing of technology require companies to focus their efforts on improving competitiveness by trying to achieve customer satisfaction through adding more value to their products. The implementation of process strategies will improve manufacturing performance and supply chain management performance.

4. Prioritizing success factors

The previous section identified and tested a model for supply chain management that includes seven factors. However, as the company moves forward to improve their supply chain management activities, it is important to identify which of the seven are the most critical factors that need to be improved in order to lead the firm to an overall success. In this section the authors developed a procedure to help practitioners to identify which of the previous seven factors have the highest priority.

4.1 Critical success factors

Daniel (1961) was perhaps the first one to mention critical success factors. In his paper on management of crisis in information systems Daniel pointed out that a company information system must be discriminating and selective. It should focus on “success factors”. Daniel also says that in most industries there should be three to six critical success factors that determine success. Anthony, Dearden and Vancil (1972), in their work on the design of management control systems emphasized three musts for any such system:

"*The control system must be tailored to the specific industry in which the company operates and to the specific strategies that it has adopted; it must identify the critical success factors that should receive careful and continuous management attention if the company is to be successful; and it must highlight performance with respect to those key variables in reports to all levels of management*."

Perhaps the most important contributions came from Rockart (1979) who argued that critical success factors are a key for development of information systems. Rockart’s research was focused on developing a methodology for determining critical success factors. Rockart put together the ideas of Daniel, Anthony, Dearden and Vancil. Rockart suggests that every firm will have different critical success factors depending on firm’s structure, competitive strategy, industry position and geographic location, environmental factors, and time factors. Rockart’s (1979) original CSF methodology consisted of the following steps:

1. Three to six hour session to explain the method.
2. CSF method focuses on individual managers and on each manager’s current information needs.
3. Interviews conducted in a minimum of two separate sessions.
   a. Session 1: Executive goals are recorded and CSF that underlie the goals are discussed. Interrelationships of the CSF and the goals are then talked about for further clarification and for determination of which CSF should be combined, eliminated or restated. At initial look at measures is also taken in this first interview.
   b. Session 2: Review results from session 1. Analyst will sharpen CSF and think about them.

Boynton and Zmud (1984) cited three main weakness of the CSF method. The first one has to do with the belief that the method is difficult to use. The second weakness is related to the bias introduced during the interview process. However; Munro (1983) showed that two independent analyses yielded similar results and no bias was found. The third weakness was pointed out by Davis (1979) who criticized the use of the CSF approach because it relied on managers’ responses. Given these three main limitations, Boynton and Zmud stated that:

“It is not clear to what extent limitations such as these imperil the use of the CSF method. Research results and case experiences of applying CSF should eventually provide a better understanding of such issues.”

Boynton and Zmud also suggest that there are two key strengths of the CSF method. First, the CSF method generates user acceptance at the senior management level, and second; the CSF facilitates a structured, top-down analysis or planning process.

Dickinson 1984 states in his research that CSF has been mainly studied for Management Information Systems (MIS). However, Munro and Wheeler (1980) suggest that CSF can be used to direct an organization's efforts in developing strategic plans besides applications in MIS. This implies that CSF can be used in a company to help achieve high performance.

Later,Kaplan and Norton (1992) accomplished what Munro and Wheeler suggested earlier - using the CSF methodology beyond the MIS scope. Kaplan and Norton described a procedure to define performance measures and CSF based on companies' strategic objectives called the balanced scoreboard procedure (BSP). BSP allows managers to look at business from four important perspectives: customers, internal, innovation and learning, and financial. As described by Kaplan and Norton (1993), the balanced scoreboard procedure consists of the following steps:

1. Preparation: Define the Scoreboard Business Unit for which a scoreboard is appropriate.
2. Interviews: First round. Senior managers receive background on the balanced scoreboard procedure, as well as documents that describe the company's vision, mission and strategy. Obtain input on tentative proposals for the scoreboard.
3. Developing the scoreboard: Top management team is brought in to develop the scoreboard. The following question is addressed: If I succeed in my vision and strategy, how will my performance differ for shareholders (customers), for internal business processes, for my ability to innovative, grow, and improve?
4. Review. Interviews with senior managers and top management to discuss further improvement of the scoreboard.
5. Implementation: Linking the scoreboard to the company databases and information systems, communicating the balanced scoreboard to the organization and facilitating the development of second-level metrics for decentralized units.

The main advantage of Kaplan and Norton BSP is that it integrates CSF with strategic objectives in a simple manner. For the BSP to be successful, the firm involved must have previously defined vision, mission and strategic objectives. Baetz and Bart (1996) defined a mission as a tool for formulating and implementing an organization's strategy. Lucas (1998) stated that a vision is necessary to trace a company's future. On the same subject, Leuthesser and Kohli (1997) mentioned that mission and vision statements are the ways in which a corporation reveals its philosophy and strategy, and Kaplan and Norton (2000) write how important it is to make sure the company strategy is understood by the entire organization in order to be successful.

Measuring whether the CSF achieved satisfactory levels of performance is an important part of this strategic process. Kaplan and Norton's (1992) BSP also provides a framework that translates company's strategic objectives into a coherent set of performance measures. Kanji (2002) also made contribution to the identification process of performance measures considering CSF. Kanji's methods show how the organization should measure performance considering both the internal processes and shareholder input. He used the Balanced Scoreboard Procedure from Kaplan and Norton as the base of his methodology. Moreover, his contribution consists of identifying specific variables when measuring performance and how those variables are related to each other.

As Kanji (2002) suggested, identification of the most important process is also a critical part when defining CSF and performance measures.

4.2 Methodology to prioritize factors in Supply Chain Management

Benchmarking in the manufacturing sector is always a difficult task to achieve for reasons such as confidentiality, time concerns, and targeted processes (what to benchmark). Most of the time the decision on what to benchmark comes directly from the top manager's point of view and that decision is arbitrarily made. There are no planning/research tools to help managers in making this decision by considering vision, mission, CSF, and key internal business processes. As was discussed in the previous section, there are methodologies that help determine CSF (Rockar 1979), to identify key performance measures (BSP of Kaplan and Norton 1992), and to prioritize what should be done first (AHP procedure and House of Quality). However, integration among those tools and procedures is necessary at this point when managers may not be certain which business process is the most critical one for the company, especially if a benchmarking exercise is on the firm horizon.

The objective of this section is to develop a methodology for determining key internal business processes firm critical success factors. This methodology should enable a company to:

1. Determine CSF and key performance measures by using Kaplan and Norton's BSP method based on vision, mission and strategic objectives statements.
2. Prioritize most important CSF according to rating scores such as cost savings, necessary improvement, and own discretion.
3. Relate CSF with internal business processes based on "strength of relationship" in order to define the most critical internal processes.
4. Compare possible differences in the perception of CSF and strategic objectives among different managing levels (higher-level managers vs. lower-level managers).

CSF to be determined should be based on each company's mission and vision as well as strategic statements. Kaplan and Norton (1996) discussed the importance of having a strategic management system to establish short and long-term goals. The balanced scoreboard procedure fits well for this purpose since mission and vision statements are translated into four dimensions that are broken down into measurable parameters in order to determine whether the firm is achieving its goals. With this in mind, the balanced scoreboard will be the starting point for prioritizing internal business processes.

Once top executives/managers have defined CSF and their key performance measures, an adaptation of the House of Quality (HOQ) (Hauser and Clausing 1988) matrix will be used (Figure 4) to prioritize CSF by importance, necessary improvement level, and cost leverage. Due to time restrictions, the urging situation of companies under study, and scope of the project; the prioritization matrix method (explained earlier) will be used to rank companies' CSF instead of the AHP procedure. In the same prioritization tool, top firm's representatives will also be asked to indicate how strong or weak is the relationship of their respective CSF to a predefined group of internal business processes (Figure 4). The mathematical description to prioritize CSF is described as follows:

$$\sum_{j=1}^{N} X_j(a_i + b_i + c_i)\text{, where i=1,2,3,..,CF} \tag{1}$$

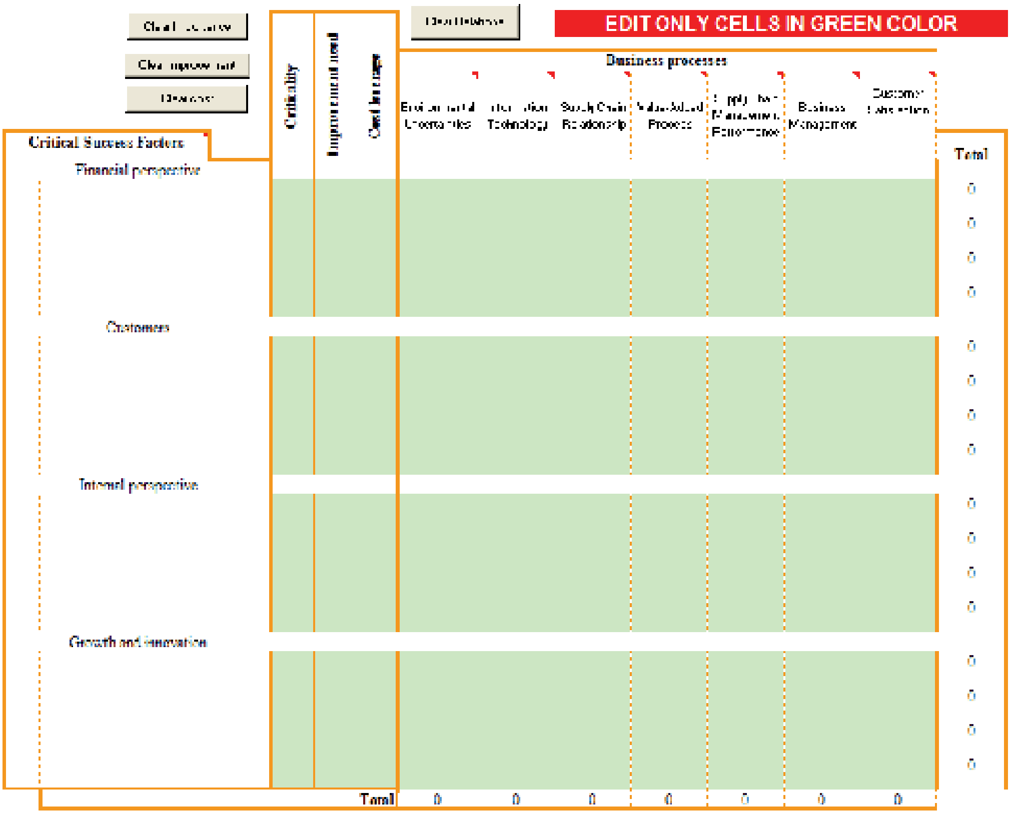

Fig. 4. Tool to prioritize SCM factors.

Definitions:

N: Number of business processes being evaluated.

X: Relationship of critical success factors with business process. Possible values are:

0 No relationship
1 Weak/possible relationship
3 Medium/moderate relationship
6 Strong relationship

a: Criticality of the critical success factor. Possible values are:

1 Low priority
3 Medium priority
6 High priority

b: If the critical success factors need improvement or not. Possible values are:

0 None needed
3 Needed

c: Cost leverage, meaning that if improvement is required then this would mean cost reduction. Possible values are:

0 No savings
1 Savings.

CF: Number of critical success factors to evaluate.

And the mathematical expression for prioritizing the internal business processes is:

$$\sum_{i=1}^{CF} X_i (a_i + b_i + c_i) \quad (2)$$

Definitions for Equation 2 are the same as for Equation 1.

This tool was applied to furniture industries in order to validate it. Companies were selected based on their ranking in the 300 Furniture Design and Manufacturing (FDM) ranking (Plantz 2003). Only furniture companies with plants or headquarters in Indiana were considered due to traveling, logistics and cost issues. Three companies agreed to participate in the study, two from the office furniture and one from the kitchen cabinet sector.

Prior to the initial face-to-face meeting, a project description was sent to the participating companies addressed to either the plant manager or the president/CEO. Next, a company visit was scheduled and divided into three sessions:

1. An executive meeting with the top executives or company president to explain the methodology to be followed (1-2 hours). The prioritization procedure was explained to the firm executives. Once the exercise was explained, an electronic version of the BSP and the prioritization tool was given to them.
2. A manufacturing plant tour guided by the respective process owners (2-3 hours).
3. A closing meeting to clarify the methodology and questions addressed during the plant tour (1/2-1 hour).

The application of the prioritizing tool was very useful to help managers to identify the critical success factors they should focus on. One weakness of this methodology is that it draws results based on perceptions that are not exactly representative of the real world. Munro (1983) commented on this apparent weakness of the CSF method and came to the conclusion that outcomes were very similar when comparing two case studies performed on the same population. It was evident that at the end, top-executives and managers were able to identify CSF, key performance measures, and most critical factors related to SCM.

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4

A Potential Study of HUA–IT Market Aiming as a Collection and Distribution Center of Agricultural Products in Southern of Thailand

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1. Introduction

Due to shrinkage of economic situation of the South, government and private agencies has collaborated to solve the problem that focused on productivity improvement in the agricultural sector in order to aid farmers, who are main proportion of people in Thailand. The sector that was directly involved in this mission is the agricultural central market. It, which is a governmental agency, has a role to support farmers and buyers in providing a place where agricultural products can be traded according to standards of quality and price. Agricultural central market has vital roles such creating opportunities for marketing activities, increasing efficiency or decreasing logistics costs of agricultural products, minimizing losses and risks from collecting and distributing products, and strengthening the standards of Thai agricultural products. Market System Promotion and Development Division, which is under Department of Internal Trade, Ministry of Commerce has authority and responsibility in supporting private sector to establish and manage central market under the support of province and the department. There are three categories of the central market in Thailand, which are paddy and crops central market, fruit and vegetable central market, and marine central market; which are located nationwide, totally 76 markets under promotion. Especially, fruit and vegetable markets are located in the North 7 markets, in the Northwest 4 markets, in the Central 5 markets, and in the South 4 markets.

Business process along the supply chain of central market starts from harvesting and collecting agricultural products from farms, and transporting to central market, which may be intermediary market or distribution market. And from central market, products are distributed to destinations, where depending on types of consumers, which may be domestic or international. Each market has the same common problems such preservation after post-harvest, cold storage, packaging, inefficient transportation, ineffective distribution, etc. In order to strengthen the mission of central market, continual improvement is absolutely inevitable. Such in this research, it was focused on fruit and vegetable central market, named Hua-It Market, located in Nakon Si Thammarat Province, as shown in Figure 1 below. Hua-It Market has an important role in helping to produce jobs and incomes for the populace of Nakon Si Thammarat, and other provinces in the South. Therefore Department of Internal Trade Office of Nakon Si Thammarat desired to remodel Hua-it Market into a collection and distribution center of agricultural products in the southern Thailand in order to strengthen the regional economy.

Fig. 1. Geographic Location of Hua-It Market, Nakhon Si Thammarat
(Source: http://en.wikipedia.org/wiki/File:Thailand_map_CIA.png)

Key functions assigned to Hua-It Market as a collection and distribution center are such (1) being a center for the classification of agricultural products, serving as product quality grading, packaging, storage, product quality preserving, testing for plant diseases and insects, testing for contaminants and toxic residues, or in Thailand can be called as "Agricultural Quality Grading Center (AGQC)", (2) promoting collaboration among members for trading in Hua-It Market, (3) supporting an export to Singapore, Malaysia, Indonesia, and Middle East, and (4) reducing the logistics costs along Hua-It supply chain. To achieve the mission, two questions came up in the following.

The first question in this research, "whether or not, Hua-It Market has potential enough to be a collection and distribution center for the southern Thailand, along the requirements of Office of Internal Trade, Nakhon Si Thammarat". Becoming as a center for collecting and distributing agricultural products of the southern Thailand, it depends on various factors.

All these factors are affecting the costs incurred in collecting and distributing agricultural products from upstream to downstream, thus the studies to assess the potential of Hua-It Market to be as a collection and distribution center for the southern Thailand are crucial from the perspective of the logistics and supply chain management.

And the second question in the study, which is successive from the first question, "To aim to be the collection and distribution center of agricultural products for the southern Thailand, what are the strategies for Hua-It Market?" Consequently, in this research will focus on formulating strategies in order to propose to Department of Internal Trade Office of Nakhon Si Thammarat. These strategies will be assessed from the viewpoint of logistics and supply chain management, resulting from analysis of Hua-It's potential.

Therefore, this research was studied to analyze the potential of Hua-It Market aiming towards to be a collection and distribution center for the southern Thailand. Analysis framework was made under the concept of logistics and supply chain management, which aimed to study the relationships of each logistics activities along the Hua-It supply chain and costs incurred in each process of the supply chain. Data collected from area-based were applied in developing supply chain models for the sake of analyzing the potential of the supply chain, which can help to profoundly comprehend the processes and characteristics of Hua-It Market, and strategy analysis of Hua-It Market as a collection and distribution center. The contribution of research results can be the prototype for other fruit and vegetables central markets under promotion of Department of Internal Trade, which aim to improve their status. Furthermore, the formulated strategies in this research also may be valuable, and the developed models in this research can clearly convey the thoughts, which have linkage with Hua-It strategies. Finally, it represents the applicability of operation research technique to the real world problem.

As previously mentioned the problem statements, objectives of research can be stated as four main thrusts: (1) to study and survey logistics and supply chain system of Hua-It Market, also including with infrastructures, goods inflow and outflow, numbers of farmers and customers involved in supply chain, routes of incoming and outgoing goods; (2) to develop supply chain models of Hua-It Market; (3) to study and assess potential of Hua-It Market aiming to be a collection and distribution center of agricultural product in southern of Thailand and nearby countries, which are Singapore, Malaysia, Indonesia, and Middle East; (4) to formulate strategies for Hua-It Market in fitting itself to be a collection and distribution center, and propose to Nakon Si Thammarat Province and Department of Internal Trade Office of Nakon Si Thammarat.

2. Literatures review

Campbell presented hub location problems, which have important applications in transportation systems. He proposed integer programming formulations for four types of discrete hub locations problem, which are analogous to four fundamental types of discrete facility location problems. These hub problems are the p-hub median problem, the uncapacitated hub location problem, the p-hub center problems, and the hub covering problems. (Campbell, 1994)

Beamon studied supply chain design and analysis, focusing on models and methods. This work intends to review the past research works in the field of supply chain modeling and to propose the future work in this field. The study summarized that supply chain is a collection of business processes under various stakeholders, including suppliers, manufacturers, distributors, and retailers. In supply chain, there are two fundamental activities (1) production planning and inventory control arising in the upstream of supply chain, (2) distribution and logistics processes occurring in the downstream. And supply chain model can be classified as (1) deterministic analytical models, (2) stochastic analytical models, (3) economic models, and (4) simulation models. The decision variables related to supply chain models also differentiate to various kinds such as production patterns, production schedules, inventory levels, distribution channels, etc. (Beamon, 1998)

Lertkrai studied the structure and the dynamic of Hua-It Market, Nakhon Si Thammarat, under the field of economic anthropology based on the concept of the social dynamic, the concept of dialectic, and theory of culture. The study began by reviewing the documents, and field surveying. It was found out that originally Hua-it was just the place for bus stopping before entering the city. But in these buses there were loading up of vegetables so the merchants just came to buy these products for selling. Later, Mr. Suporn Intharavichian prepared his own land and founded as a market for trading among sellers and buyers. And this market gradually grew up since then. (Lertkrai, 2000)

Fernie and Staines studied an understanding of European grocery supply chain. This research is survey oriented in order to acquire data and use them as input for planning supply chain management of grocery products in the future. The study started from downstream of supply chain or retailers, and tracing back to manufacturers. The studied variables were categorized into three groups, namely trading structure, physical characteristics, economic and social structures, totally eighteen variables. The surveyed samples were (1) consumers in 10 countries in Europe; (2) major retailers in Europe, including Metro, Rewe, Tengelmann, Aldi, Carrefour, etc; (3) major manufacturers such as Unilever, Nestle, Philip Morris, Heineken, etc. From the study, they found out that the trading between supply chain members through computer system help in cost reduction and facilitating partnerships among supply chain. (Fernie and Staines, 2001)

Poorpongsakorn studied an analysis management system of fresh fruits and processed fruits in the east of Thailand in order to obtain the approach in organizing and managing the market and distribution system. The objectives of this study are (1) to study trend and future consumption, export, and production of these three fruits, which are durian, mangosteen, and rambutan, (2) to analyze trend of price and volatility in price of fruits, (3) to survey and assess the fruit market system and marketing margin, etc. In this study, it was found out that the main problem of production and marketing system of fruits affecting the income of farmers and exporters was that the price of products had been decreased or remained stable while production costs had been increased. Therefore strategic management of fresh fruits and processed fruits in the east should focus on the farmers and the exporters such quality improvement of marketing management system or development of production system and modern marketing system focusing on fruits value added. (Poorpongsakorn, 2005)

Cochran and Ramanujam conducted a research about carrier mode logistics optimization of inbound supply chain for electronics industry. The problem statement is about that physical flow and information flow from manufacturer to factory experienced with problem in the relatively high cost. Thus it outsourced third party logistics provider to operate the transportation activity. By selecting the carrier was very complicated, thus the indicator that helped the company in making a decision was the total cost reduction. Factors affected the cost influencing in selecting third party logistics providers were packaging sizes, packaging styles, etc. In this research proposed the method of selection third party logistics providers based on numerical programming. (Cochran and Ramanujam, 2006)

Campo and Beghin studied dairy food consumption, supply, and policy in Japan. The study surveyed and interviewed Japanese entrepreneur, also studied the secondary data obtained from the economic history of Japan. Demands of dairy products in the past were used to forecast the current and future demands of products. The study found out that dairy market has received attention since after World War II. And the factors that affected consumer demand were the economy, society, and culture, including consumer needs. (Campo and Beghin, 2006)

3. Research methodology

The concept underlying in this study is gap analysis. Between Hua-It Market and reference site, which is a market where is considered as best practice of a collection and distribution center, performance indicators were compared. In addition, these indicators were developed and analyzed from the viewpoint of logistics and supply chain management. Since market is the place where facilitates the trading between vendors and buyers and market system is a system comprising of many components which are interrelated in nature. Thus examining such system like market from viewpoint of logistics and supply chain concept, it will be very helpful. In conducting research, the methodology can be represented in the following stages.

3.1 Preliminary survey of background information of Hua-It and reference site

In this stage, a preliminary survey of current status of Hua-It Market was made in order to develop performance indicators and to use as guideline for designing the questionnaire. From preliminary survey data, such information were applied for the development of various indicators related to the points in this study such being a center for the classification of agricultural products, collaboration among members for trading in Hua-It Market, logistics costs, etc. The questionnaire developed is divided in three parts as follows (1) general inquiries, (2) performance indicators of market, and (3) opinion and suggestion. Furthermore, the questionnaire was tested for validity and reliability before it was exercised.

3.2 Field data collection of Hua-It and reference site

In this step the following data were collected from fields, which are Hua-It Market and reference site: (1) demand, (2) supply, (3) inbound and outbound physical flows, (4) infrastructures, (5) routes from origin to destination, and (6) logistics costs. The questionnaire developed in 3.1 is a main tool used in field data collection. And sampling method applied was a stratified random sampling and in each stratum, simple random sampling was used. Besides questionnaire, deep interview was applied to.

3.3 Gap analysis between Hua-It and reference site

A study of "AS-IS" status of Hua-It market and "TO-BE" status of a collection and distribution center, which is considered from a reference site market that has best practices, was made in this step. From previous data collection, an analysis was made in this stage in order to investigate the discrepancy between Hua-It and reference site. Or it can be said that the analysis aims to justify the "AS-IS" status of Hua-It Market and the "TO-BE" status of reference market. And observation of the variation between Hua-It and reference site was made. The result from this investigation is gap, which will be used as input in the next stage.

3.4 Strategies formulation

After the gaps between Hua-It Market and reference market was indicated, the challenge is how these gaps can be reduced or eliminated. To fulfil such question, strategies are compulsory for Hua-It Market in aiming toward a collection and distribution center. Thus strategy formulation is the mission in this stage.

Internal Factors	Weight (1)	Rating (2)	Weighted Score (3)=(1)*(2)	Comments
Strengthes				
S1………………..	0.15	5.00	0.75	
S2………………..	0.05	3.00	0.15	
S3………………..	......	......	......	
....	......	......	......	
Weaknesses				
W1……………….	......	......	......	
W2……………….	......	......	......	
....	......	......	......	
Total	1.00			
External Factors	**Weight (1)**	**Rating (2)**	**Weighted Score (3)=(1)*(2)**	**Comments**
Opportunities				
O1………………..	0.10	3.00	0.30	
O2………………..	0.03	4.00	0.12	
....	......	......	......	
Threats				
T1……………….	......	......	......	
T2……………….	......	......	......	
....	......	......	......	
Total	1.00			

Table 1. Calculation of Weighted Scores

Stages of formulating strategy can be concisely explained as follows. (1) Analyze the strengths (S), weaknesses (W), opportunities (O), and threats (T) of Hua-It Market by using data from field survey with questionnaire, from brainstorming among all those stakeholders of Hua-It, and from Nakhon Si Thammarat Province's strategy. Both strengths and weaknesses are considered as internal factors, while opportunities and threats are deemed as external factors. (2) Prioritize S, W, O, T, by using Likert's Scale 1-5, which 1 is the least important and 5 is the most important. And evaluate the weight given to each S, W, O, and T, which the minimum weight is 0.0 and the maximum weight is 1.0. The weight of internal factors, which are S and W, is equal to 1.0, the weight of external factors, which are O and T, is equal to 1.0, as well. Then multiply priority rating with the weight given, the result is weighted score of each factor. This step can be shown in Table 1. (3) Select S, W, O, and T with the highest weighted score which are accounted for eighty percent of all the factors to match up in term of the matrix. This is commonly known as TOWS Matrix Diagram in order to determine the strategies. An example of TOWS Matrix Diagram can be shown in Table 2 below. From this diagram, the strategy can be seen from different perspectives. (4) Summarize the obtained strategies from previous step, and then unite the similar strategies as one.

Internal Factors / **External Factors**	**Strengthes** **S1……………** **S2……………** **S3……………**	**Weaknesses** **W1……………** **W2……………** **W3……………**
Opportunities O1…………… O2…………… O3……………	 SO1…………… SO2…………… SO3……………	 WO1…………… WO2…………… WO3……………
Threats T1…………… T2…………… T3……………	 ST1…………… ST2…………… ST3……………	 WT1…………… WT2…………… WT3……………

Table 2. TOWS Matrix Diagram

3.5 Supply chain models development

When the strategies for Hua-It Market were formulated, conveying the idea behind the strategies, which is abstract, to concrete is indispensable. There are numerous ways to achieve this requirement. In this research, quantitative modeling was selected. These developed supply chain models demonstrate the characteristics of supply chain system in accordance with the proposed strategies. Then the strategies coupling with the supply chain models can be effortlessly comprehensible for the decision makers.

4. Research results

In this section, it presents the results from research, which can be divided into three main sections. Section one illustrates the supply chain structure of Hua-It Market, including the costs involved in supply chain of Hua-It activities. In section two, the formulated strategies for Hua-It market to be used as a guide for aiming to a collection and distribution center of agricultural products, will be introduced. And in last section, the supply chain models which are relevant and consistent to the strategies in section two will be proposed. Discussion in details of each section can be found in the following.

4.1 Supply chain structure

To understand the overview of Hua-It market, the necessity to prepare supply chain structure is very crucial. Supply chain structure of Hua-It Market is illustrated in Figure 2. From this figure, it can be seen all the members involved, also logistics activities and non-logistics activities occurred, in supply chain of Hua-It Market. In addition, logistics costs of each activity in supply chain were investigated in order to quantify the total systemwide cost of supply chain. Also it is illustrated the all costs relevant to logistics activities and non-logistics activities in Figure 3.

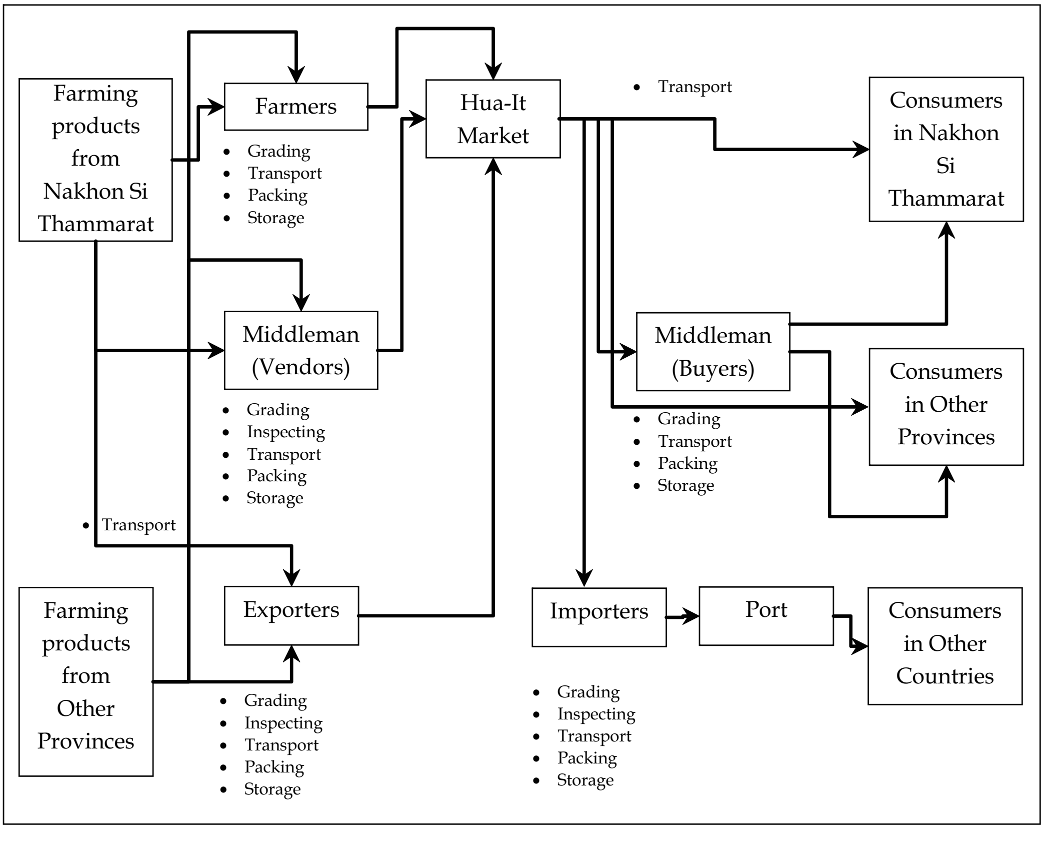

Fig. 2. Supply Chain Structure of Hua-It Market

From Figure 2, members in Hua-It supply chain can be divided into two main clusters, which are vendors and buyers. Furthermore, vendor cluster can also be categorized as farmer, middleman, and exporter. And buyer cluster, they are classified to be consumer, middleman, and importer. As well as, it can be notified that upstream of Hua-It Market starts off from two sources. One is from inside the Nakhon Si Thammarat and another is from other provinces where are outside. About eighty percent of products are from outside Nakhon Si Thammarat province. Before products are transported to Hua-It, they are transshipped through farmers, middleman (vendors), or exporters. For majority group of vendors of Hua-It, they are middleman, followed by exporter, and farmer, respectively. And from Hua-It, products are transshipped through middleman (buyers) or importers, to downstream of supply chain, who are consumers in Nakhon Si Thammarat, other provinces, or other countries. Nevertheless, there also is direct linkage from Hua-It to consumers in Nakhon Si Thammarat, without middleman. As well as, majority group of buyers of Hua-It, they are middleman, followed by consumer, and importer, respectively. Destinations of products mainly are in the southern of Thailand.

Also logistics activities, such transportation, packing, storage, and non-logistics activities, such grading, inspecting, at each stage of each member of supply chain are illustrated. These activities are contributing to the total systemwide cost in the following Figure 3.

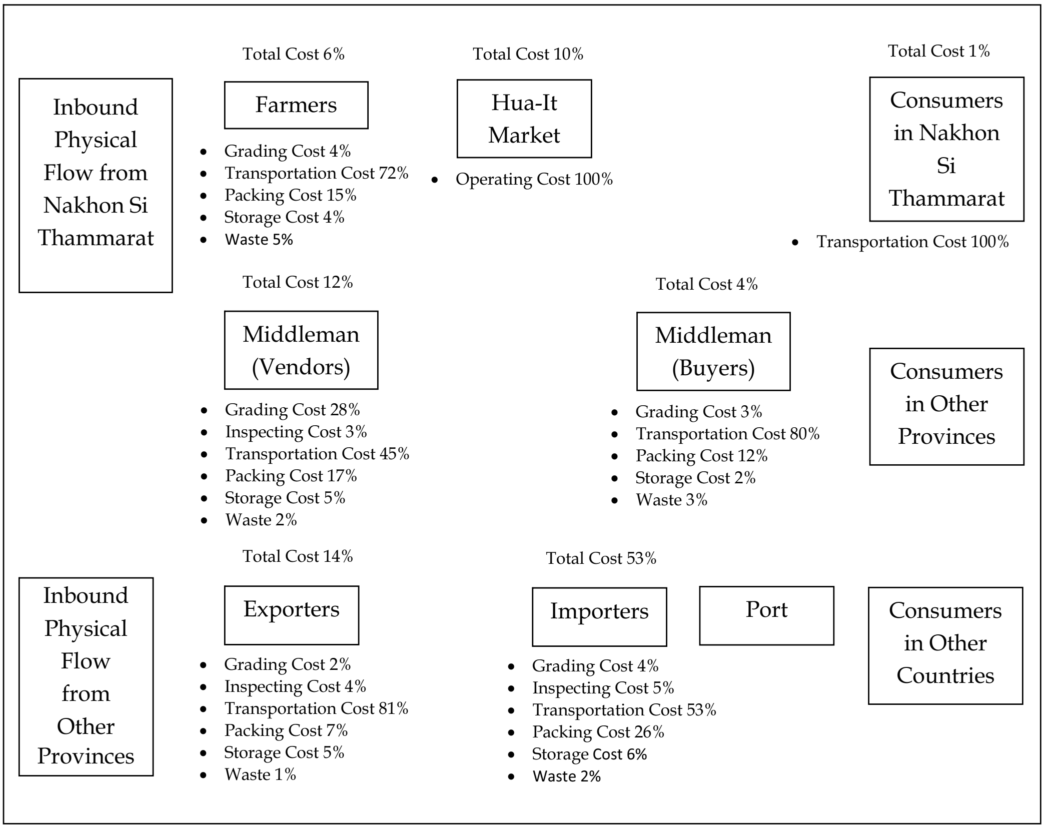

Fig. 3. Total Systemwide Cost of Hua-It Market Supply Chain

From Figure 3, it can be seen different types of costs involved in total systemwide cost of Hua-It supply chain. These costs are categorized as following activity based costing concept. When considering in details, it found out that the greatest percentage of costs of vendors, no matter who they are farmer, middleman, or exporter, is from transportation cost. Since most Hua-It's products are from out of Nakhon Si Thammarat Province and there is no collaboration among members in supply chain. Also the same characteristic for the buyer side, the transportation cost still is a great part of the total systemwide cost of supply chain. Since most products have been sold to nearby provinces where are not far from Hua-It, but transportation activities have not been collaborated thus it made the transportation cost is outstandingly high.

4.2 Strategies formulation

In this section, it presents the strategy formulation for Hua-It which the data used were from three main sources, which are primary data from field survey, primary data from brainstorming, and secondary data from government agencies. The formulating strategy process was previously explained in section 3.4. Illustrations of calculation of weighted scores can be represented in the following Table 3.

Internal Strategic Factors	Weight	Rating	Weighted Scores
Strengths (S)			
1. Hua-It is widely known for its vendors and buyers who trade in market for a long time.	0.0850	4.2400	0.3604
2. Hua-It is a unique symbol of Nakhon Si Thammarat.	0.0950	3.6000	0.3420
3. Hua-It has the advantage in location since it is located on a main road to the city.	0.0858	3.6000	0.3089
4. Vendors and buyers in market have strong relationship with mutual dependence like a large family.	0.0700	3.5000	0.2450
5. There are varieties of products according to the requirements of consumers.	0.0408	3.8400	0.1567

Table 3. Example of Calculation of Weighted Scores

From Table 3, it is illustration of calculating of weighted scores for the strengths. The same procedure was repeated for W, O, and T. Then all of them were selected from weighted scores to match up in TOWS Matrix Diagram. Afterward the results from matching in TOWS are strategies which are various perspectives such SO, WO, ST, and WT strategy type. The idea behind each type of strategy can be summarized as follows. SO strategy type will figure an approach for the operation by using the organization strengths, which are internal factors to take advantage from the opportunities, which are external factors. WO strategy type will improve the weaknesses in the organization by taking advantage from the opportunities. ST strategy type will use the strengths of the organization to avoid or lessen the impacts occurred from the threats from external factors. And WT strategy type is defensive tactics aiming to minimize the organization weaknesses and to avoid the threats from outside. Examples of SO, WO, ST, and WT strategy type can be illustrated Table 4 below.

Finally from different types of strategies will be blended as one for Hua-It. The following Table 5 illustrates the strategies for Hua-It Market. After obtaining the strategies, then each strategy was developed in the components, including objectives, indicators, targets, action plans, and departments or sectors who are responsible for or involved in each strategy.

Strategy Type	Strategy
SO	Finding business alliances
SO	Encouraging and developing integration
WO	Increasing area utilization to accommodate future development
WO	Preparing standardization in organization both technical and management aspects
ST	Strengthening of the agricultural sector
ST	Being a leader in product variety
WT	Structuring the organization systematically
WT	Developing organization information system

Table 4. Example of Strategies of Each Type

No.	Strategy
1	Aiming to be the Agricultural Quality Grading Center (AGQC) for agricultural products
2	Building collaboration with all relevant members throughout Hua-It supply chain in order to optimize the efficiency of agricultural management
3	Encouraging and developing of consolidation to focus on decreasing transportation cost
4	Developing of Hua-It Market's infrastructure for supporting the growth in future
5	Encouraging and developing of export system
6	Developing of information system to link all relevant members throughout Hua-It supply chain

Table 5. Strategies of Hua-It Market

From Table 5, let discuss some of strategies in details. Such in strategy no. 1, it gives the direction for Hua-It to aim to be AGQC, which the main functions are grading the product quality, packaging, storage, preserving quality during transportation, testing for plant diseases and insects, and testing for contaminants and toxic residues. The facts that found out from field survey are reference site market allocated the importance to grading product quality and testing for contaminants and toxic residues. At the reference market, there is agreement between the vendor and the market about grading product before shipping to market. In addition, at the reference market, it has its own laboratory that it will take products sampling from vendors and test for contaminants and toxic residues. While at Hua-It, these testing activities are outsourced to third party service provider. This can make high difference in term of costs. Thus if Hua-It aims to be a collection and distribution center, it cannot avoid these activities with any reason.

Strategy no.2 recommends Hua-It supply chain has to encourage the collaboration among members because it can improve the efficiency of agricultural management. The reason behind this strategy can be pointed out from survey. At reference market, the vendor, especially farmers, have banded together to sell to the market. Such the farmers who are from the same district will gather in the same car. This is simply the example of collaboration since this action is the main concept in logistics and supply chain management. Thus it can be imagined if this strategy can be accomplished, Hua-It supply chain can deliver more value with lower cost, which means high efficiency. Teaming up with strategy no.6, collaboration will not be completed unless there are information systems. Since information systems are the driver, which can increase the efficiency while can increase supply chain responsiveness at the same time.

Strategy no. 3 focuses on decreasing transportation cost. It is very obvious in Figure 3 that transportation costs of Hua-it supply chain, either incoming flows or outgoing flows are relatively high among other activities in the same supply chain. Furthermore, when compared with the reference market, Hua-It transportation costs also higher. The reasons from the fact are that transportation activities in Hua-it, either inbound or outbound hardly do together. Especially the middleman who is buyers, it occurs. Even the destinations of Hua-It's product are in the south, which are not far from Hua-It. Yet the transportation without consolidation can severely increase the cost. Thus in this strategy absolutely recommend Hua-It should encourage the consolidation, and the result from achieving this strategy will reveal in the next section.

4.3 Supply chain model

Supply chain models in this research have been developed with the purpose of linkage to the strategies in order to convey the ideas behind of these strategies, which are abstract to concrete. In addition, models can be used to measure performance of the market as a collection and distribution of agricultural products. The models were developed from quantitative data collected in a systematic method. There are three models represented in this section. First model is gravity location model relevant to the first strategy, which is aiming to be the center for the classification quality of agricultural products. Second model is hub and spokes model with cost related to third strategy. And the last model is about generalized network model with the objective of minimization total systemwide cost of supply chain.

4.3.1 Gravity location model

Gravity location model is a model that point to the coordinates or location for establishing the facility, where guarantee the minimization of transportation cost from sources of farming products to Hua-It and from Hua-It to consumers. This model is applied in order to ascertain that the current location of Hua-It Market is proper for being the collection and distribution center. Since Hua-It has been found since 1986, thus relocation of market is quite impossible. Therefore the gravity location model has been adopted to confirm its potential. The objective function of gravity location model and the optimum solution can be illustrated in equation (1), (2), and (3), respectively.

$$\text{Min } TC = \sum_{n=1}^{k} d_n D_n F_n \tag{1}$$

$$x' = \frac{\sum_{n=1}^{k} \frac{D_n F_n x_n}{d_n}}{\sum_{n=1}^{k} \frac{D_n F_n}{d_n}} \tag{2}$$

$$y' = \frac{\sum_{n=1}^{k} \frac{D_n F_n y_n}{d_n}}{\sum_{n=1}^{k} \frac{D_n F_n}{d_n}} \tag{3}$$

where TC = total transportation cost,

d_n = $\sqrt{(x-x_n)^2+(y-y_n)^2}$ (distance to location n)

D_n = quantity to be shipped between Hua-It and source or consumer n,

F_n = cost of transportation one kilogram of farming product for one kilometer between Hua-It and either source or consumer n,

x_n, y_n = coordinate location of either a source of products or consumer n,

x', y' = optimum facility location.

Result from the gravity location model is indicated that the optimum location should be located at the coordinate (x′= 590.06, y′= 960.80), where is Tambon Ka Roa, Amphur Nob Pi Tam, Nakhon Si Thammarat Province, which is farther than the current location of Hua-It about 30-35 kilometers, as shown in Figure 4.

Fig. 4. Optimum Location from Gravity Location Model
(Source: maps.google.co.th)

Total transportation cost incurred if Hua-It is located at the optimum location is 16,173,363 baht/month, while if it is located at the current location, the cost of transportation is 16,245,283 baht/month. It is found that the transportation cost decreases 71,920 baht/month or 0.44 percent. From this result, it can be notified that the difference of transportation cost between optimum location and current location only 0.44 percent which can be considered not significantly different. This result can confirm to the potential of Hua-It's current location that it is suitable for locating the collection and distribution center for the southern of Thailand. In addition, in the past, at its current location, it was a gas station and nearby the main road through the city. It is also a meeting point of vendors who brought farming products to sell in the city. Sometimes, they also traded to each other. That's the market activities happened. So this can prove the wisdom of the founder of Hua-It market in choosing the right location.

4.3.2 Hub and Spokes model with cost

Hub and spokes model with cost is a model that represents the minimum of total cost in establishing the collection points for incoming products and the distribution points for outgoing products. In this model, two main components of costs were considered, which are transportation cost and fixed cost of establishing collection or distribution points. This model is applied in order to illustrate the idea behind the third strategy that is promoting and developing of consolidation to focus on decreasing transportation cost. The objective function and the constraints of hub and spoke model can be illustrated in equation (4), (5), (6), (7) and (8), respectively.

$$\text{Min } TC = \sum_{i=1}^{m}\sum_{j=1}^{n} V_i R_i d_{ij} x_{ij} + \sum_{j=1}^{n} F_j y_j \tag{4}$$

$$\sum_{j=1}^{n} x_{ij} = 1 \quad \text{for all } i \tag{5}$$

$$x_{ij} \le y_j \tag{6}$$

$$\sum_{j=1}^{n} y_j = p \tag{7}$$

$$x_{ij}, y_j = \{0,1\} \tag{8}$$

where TC = total cost of establishing collection points or distribution points,
F_j = fixed cost of establishing either a collection point or a distribution point,
i = node of either a source of products or a consumer,
j = node of either a collection point or a distribution point,
V_i = quantity of goods to be transported either from a source of products or to a consumer,
R_i = transportation rate either from a source of products or to a consumer,
d_{ij} = distance between a source of products and a collection point or between a distribution point and a consumer,
p = numbers of collection points or distribution points,

x_{ij} = 1 when there's a shipment from a source to a collection point or from a distribution point to a consumer, otherwise x_{ij} = 0,

y_j = 1 when a collection point or a distribution point is established at node j, otherwise y_j = 0.

Interpretation of model can be clearly made in the following. Equation (4) denotes the total cost in establishing collection points or distribution points, comprising of the variable cost and the fixed cost. The variable cost mainly in this model is transportation cost, while the fixed cost can be regarded as investment cost of setting up that collection point or distribution point. Equation (5) denotes either from a source i^{th} of product must be shipped to single collection point j^{th} , only, or a consumer i^{th} in market must be received from single distribution point j^{th} , only. Equation (6) denotes either from a source i^{th} of product must be shipped to a collection point j^{th} , which is open, only, or a consumer i^{th} in market must be received from a distribution point j^{th} , which is open, only. Equation (7) denotes numbers of collection points or distribution points to be open. And equation (8) indicates that all decision variables are binary integer number.

Solutions from this model can be categorized into two sets, which are establishing collections points for incoming products and establishing distribution points for outgoing products. Detail of the solution set from establishing collection points is expressed as follows. A criterion for choosing the place to launch a collection point is the distance from Hua-It Market. In Nakhon Si Thammarat Province, it is assigned one collection point within radius of 50 kilometers. But there will be one collection point within radius of 200 kilometers for other areas, which are outside Nakhon Si Thammarat. From this criterion, there are 10 collection points, where can be launched. And then comparison for the right amount of collection points that should be opened is made through the mathematical model.

From Figure 5, it can be said that number of collection points that will minimize total cost of establishment are two points and the total cost will be 11,289,960 baht/month. While if there are no collection points, the total cost will be 18,774,430 baht/month. Thus total cost will be cut down by 7,484,470 baht/month or 39.87 percentages. The solution from hub and spokes model recommended that two collection points should be launched in two districts, where one is in Nakhon Si Thammarat, located in the southern Thailand, and another is in Ratchaburi, located in the central Thailand. Each point will be a collection center of incoming products which are from various districts. And when considering it in detail, the collection point in Nakhon Si Thammarat will receive incoming products from the sources where are widely in the southern area. And the collection point in Ratchaburi will collect the products, which are from the northern, northeastern, eastern, and central of Thailand.

And detail of the solution set from establishing distribution points is discussed in the following. A criterion for choosing the place to launch a distribution point is also the distance from Hua-It Market. In Nakhon Si Thammarat Province, it is assigned one distribution point within radius of 50 kilometers. But there will be one distribution point for every 100 kilometers radius from Hua-It for other areas, which are outside Nakhon Si Thammarat. Likewise the case of collection point, there are 6 distribution points, where can be launched from this criterion. And then comparison for the right amount of distribution points that should be opened is proved by the mathematical model.

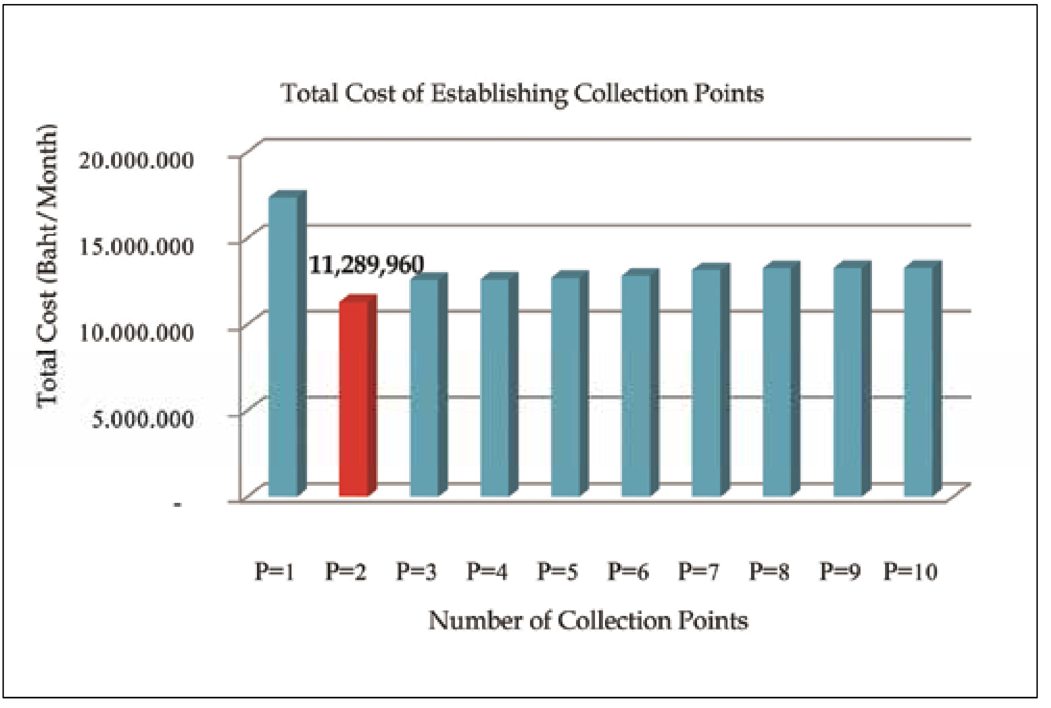

Fig. 5. Total Cost Comparison among Different Number of Collection Points

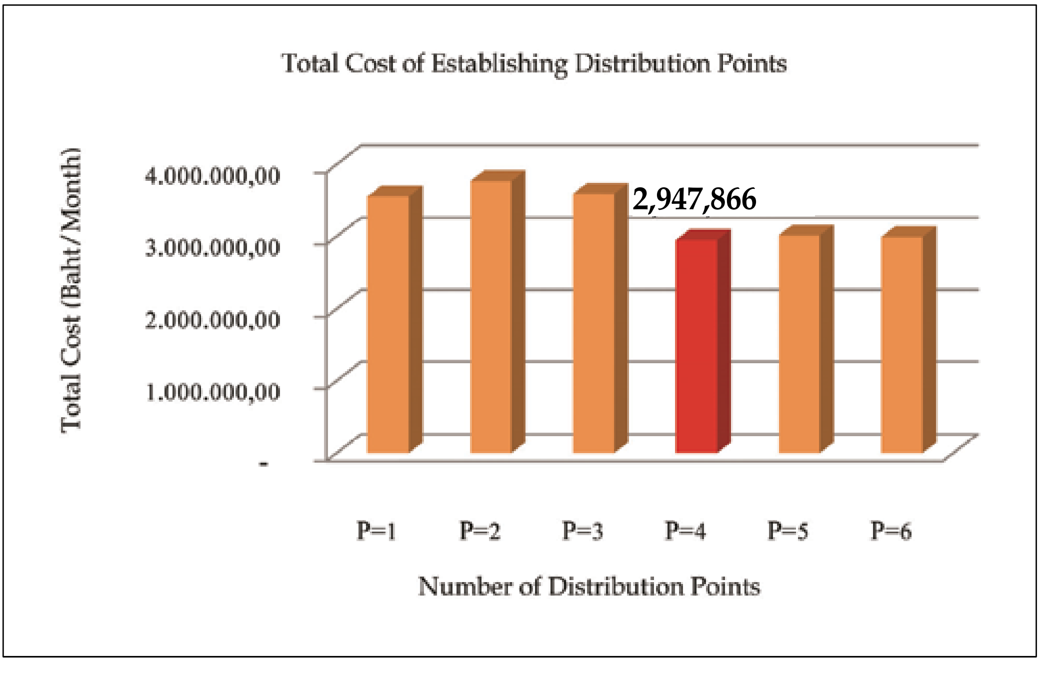

Fig. 6. Total Cost Comparison among Different Number of Distribution Points

From Figure 6, it can be declared that numbers of distribution points that will minimize total cost of establishment are four points and the total cost will be 2,947,866 baht/month. While if there are no distribution points, the total cost will be 5,520,335 baht/month. Thus total cost will be cut down by 2,572,469 baht/month or 46.60 percentages. The solution from hub and spokes model recommended that four distribution points should be launched in four districts, where are in Nakhon Si Thammarat, Phattalung, Phang-Nga, and Yala, all located in the southern Thailand. Each point should be launched a distribution center of outgoing products to consumers who are widely spread in numerous districts where all are in the southern Thailand.

In addition, when considering the whole inbound and outbound together by having collection points and distribution points, the transportation costs incurred is 14,237,826 baht/month. While if there are no collection points and distribution points, the transportation costs will be 24,294,765 baht/month. It means the transportation costs can be cut down by 10,056,939 baht/month or 41.40 percentages. The results from this model are indicated that promoting and developing of consolidation among inbound and outbound parties of Hua-It supply chain are required in order to decrease transportation cost which will effect to the total systemwide cost of supply chain.

4.3.3 Generalized network model

Generalized network model is a model that represents the physical flow of product from upstream to downstream, with the objective of minimizing the total systemwide cost of supply chain. In this research, fifteen products accounted for 80 percent of the total product which have the highest trading volume, were studied. These products include vegetables, which are cabbage, pumpkin, cassava, cucumber, gourd, chili, lemon, and fruits which are watermelon, mango, orange, jackfruit, pineapple, pomelo, and banana. This model will reflect the total systemwide cost of each product flowing from sources to consumers in Hua-It supply chain. Components of costs that taken into this model, include production cost, grading cost, packaging cost, inspection cost, transportation cost, storage cost, and cost from product waste. This model is applied in this research in order to support the second strategy that is building collaboration with all relevant members throughout Hua-It supply chain in order to optimize the efficiency of agricultural management. Because the efficiency can be measured by output divided by input, which is cost, thus recognizing the total systemwide cost will be very informative in viewpoint of agricultural management.

Flow structures of each product, mentioned previously, in Hua-It Market can be categorized into three patterns. First structure is products have sourced from other districts, where are not in the south. Second is products have sourced in the south, only. And third structure is products have sourced from both in the south and not in the south. Flow diagrams relevant to all three structures can be illustrated in Figure 7, Figure 8, and Figure 9, respectively.

In this manuscript will represent the network model of the third flow structure as follows. The formulated objective function and the constraints of the generalized network model can be illustrated in equation (9) - (16), respectively.

$$\text{Min } z = \sum_{i=1}^{n}\sum_{j=1}^{o} c_{ij}x_{ij} + \sum_{i=1}^{n}\sum_{k=1}^{p} c_{ik}x_{ik} + \sum_{j=1}^{o}\sum_{k=1}^{p} c_{jk}x_{jk} + \sum_{k=1}^{p}\sum_{l=1}^{q} c_{kl}x_{kl} \tag{9}$$

$$\sum_{j=1}^{o} x_{ij} \le S_i \quad \text{for} \quad i = 1,2,3,\ldots,n \tag{10}$$

$$\sum_{i=1}^{n} x_{ij} - \sum_{k=1}^{p} x_{jk} \ge 0 \quad \text{for} \quad j = 1,2,3,\ldots,o \tag{11}$$

$$\sum_{k=1}^{p} x_{jk} \le T_j \quad \text{for} \quad j = 1,2,3,\ldots,o \tag{12}$$

$$\left(\sum_{i=1}^{n} x_{ik} + \sum_{j=1}^{o} x_{jk} \right) - \sum_{l=1}^{q} x_{kl} \ge 0 \quad \text{for} \quad k = 1,2,3,\ldots,p \tag{13}$$

$$\sum_{l=1}^{q} x_{kl} \le U_k \quad \text{for} \quad k = 1,2,3,\ldots,p \tag{14}$$

$$\sum_{k=1}^{p} x_{kl} = D_l \quad \text{for} \quad l = 1,2,3,\ldots,q \tag{15}$$

$$x_{ij}, x_{ik}, x_{jk}, x_{kl} \ge 0 \tag{16}$$

where i = node (district) where is the source of product, starting from 1 to n,
j = node (district) where is the collection of product, starting from 1 to o,
k = node (district) where is the location of market, starting from 1 to p, generally, but in this case k =1 denoting Hua-It Market,
l = node (district) where is the consumer of product, starting from 1 to q,
S_i = supply capacity at source (district) i,
T_j = capacity at collection node (district) j,
U_k = capacity at Hua-It Market,
D_l = demand at consumer node (district) l,
x_{ij} = quantity of product flows from source i to collection j,
x_{ik} = quantity of product flows from source i to Hua-It Market,
x_{jk} = quantity of product flows from collection j to Hua-It Market,
x_{kl} = quantity of product flows from Hua-It Market to consumer l,
c_{ij} = total cost per unit of product flowing from source i to collection j,
c_{ik} = total cost per unit of product flowing from source i to Hua-It Market,
c_{jk} = total cost per unit of product flowing from collection j to Hua-It Market,
c_{kl} = total cost per unit of product flowing from Hua-It Market to consumer l.

Interpretation of model can be clarified as follows. Equation (9) denotes objective function with aiming to minimize the total systemwide cost of Hua-It supply chain, starting from sources of products i, collection j, Hua-It market, and finishing at consumers l. Equation (10) denotes quantity of product flows from source i to collection j shall not exceed supply capacity at source (district) i. Equation (11) denotes quantity of product flows from collection j to Hua-It Market must not exceed the amount received from quantity of product flows from source i to collection j. Equation (12) denotes quantity of product

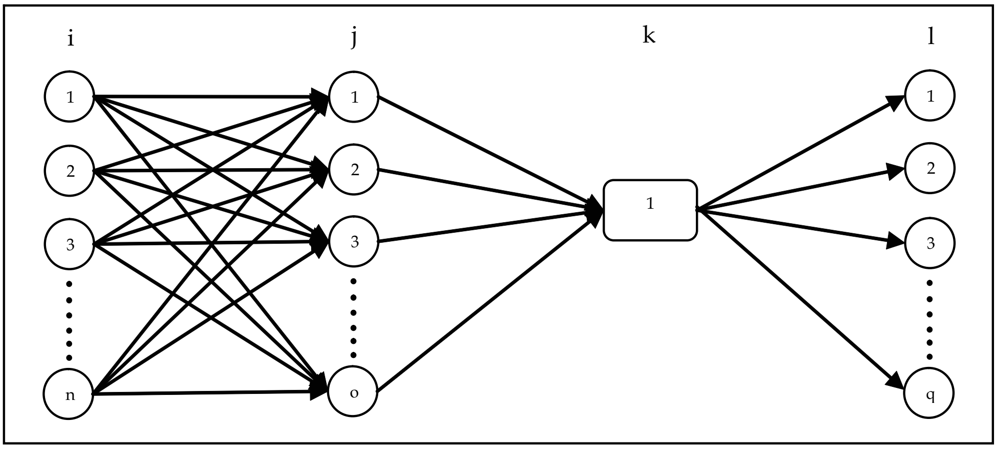

Fig. 7. Flow Structure Pattern I

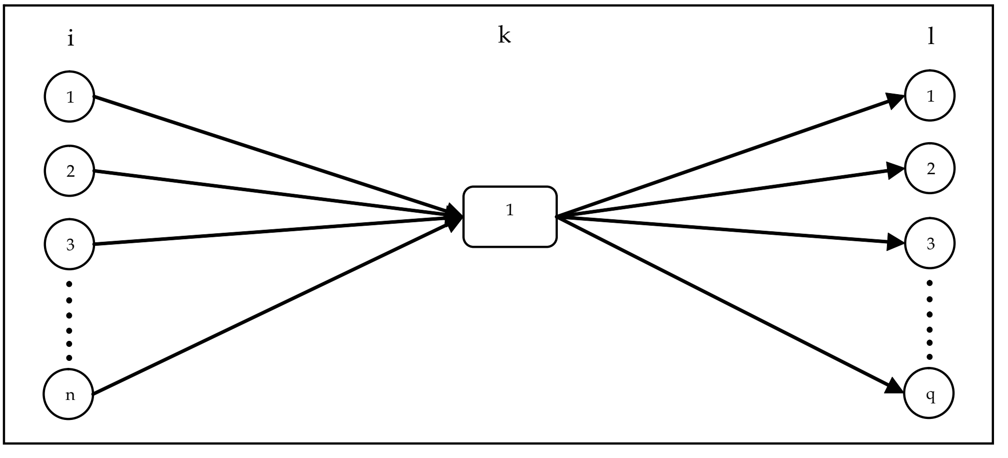

Fig. 8. Flow Structure Pattern II

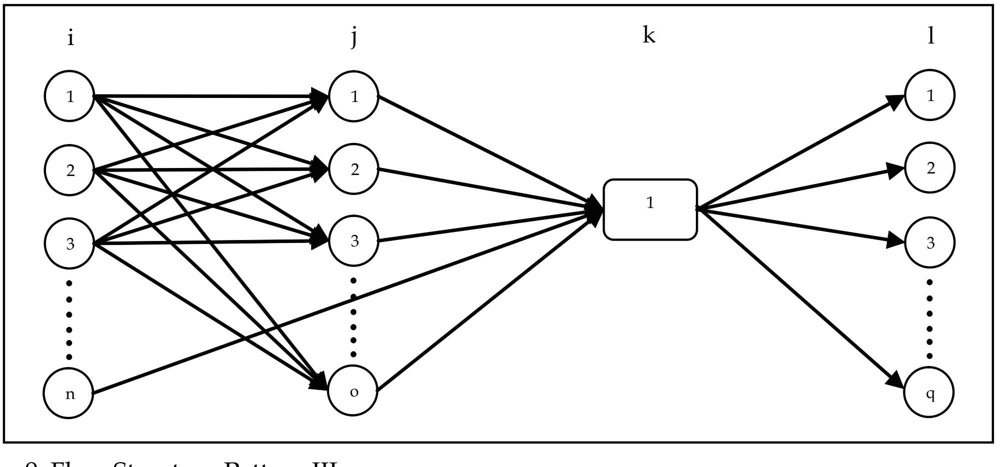

Fig. 9. Flow Structure Pattern III

flows from collection j to Hua-It Market shall not exceed capacity at collection node (district) j. Equation (13) denotes quantity of product flows from Hua-It Market to consumer l must not exceed the amount received from quantity of product flows from source i plus quantity of product flows from collection j. Equation (14) denotes quantity of product flows from Hua-It Market to consumer l shall not exceed capacity of Hua-It Market. Equation (15) denotes quantity of product flows from Hua-It Market to consumer l must be equal demand at consumer node (district) l. And equation (16) indicates that all decision variables are real number that greater than zero.

Results obtained from the generalized network model are the total systemwide cost of each product and quantity flows between node to node in Hua-It supply chain. Illustration of result can be demonstrated in the following figure.

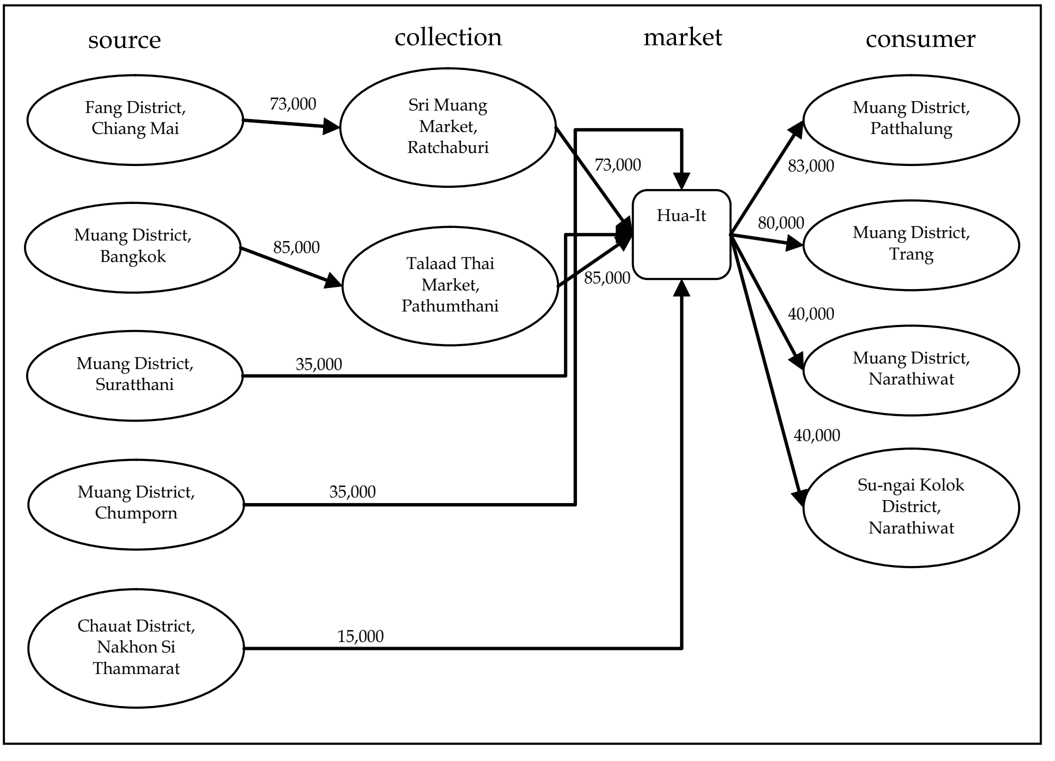

Fig. 10. Flow Structure of Orange, unit is kilograms/month

From Figure 10, the model searches through the supply chain network and provide the optimal flow from one node to another node. It can be seen the flow quantities of product from upstream to downstream in Hua-It supply chain. Costs incurred in this system include production cost, grading cost, packaging cost, inspection cost, transportation cost, storage cost, and cost from product waste. And the total systemwide cost of this product is 1,253,720 baht/month. Absolutely by modeling the supply chain of all fifteen products, it can be identified the total costs of each product, also flow quantities. Thus this model will be served as a decision making tool in selecting and matching the source of the products and the location of markets with the guarantee of minimizing total systemwide cost.

5. Conclusion and future research

In this research was focused on a potentiality study of Hua-It Market at Nakhon Si Thammarat Province, located in the south of Thailand. It intended to investigate whether or not Hua-It Market has potential enough to be a collection and distribution center for the southern Thailand along the requirements of Department of Internal Trade such being an "Agricultural Quality Grading Center (AGQC)", promoting collaboration among members in Hua-It supply chain, or reducing logistics costs along supply chain. Underlying research concept was gap analysis along logistics and supply chain management viewpoint. It aimed to clarify the relationships of processes in Hua-It supply chain, comprising of logistics activities and non-logistics activities, also cost incurred in the supply chain. It is following that collected data were exploited in the strategy development for Hua-It aiming to an agricultural collection and distribution center. Finally, supply chain modeling was carried out. These developed models supported the preparation of strategies and the analysis of supply chain performance.

The results of the research were the Hua-It's strategies which were evaluated under logistics and supply chain management viewpoint through the developed supply chain models. Each strategy clearly specified objective, indicators, targets, and action plan associated with the stakeholders. Since some strategies are required to demonstrate what actual performance will happen if the strategy is implemented? Thus the models can demonstrate the effect that is expected to turn out. The models applied and developed in the research were gravity location model, hub and spoke model with cost, and generalized network model. Each model was focused on logistics cost components, especially transportation cost which had high contribution to total systemwide cost of supply chain. Costs such production cost, grading cost, packaging cost, inspection cost, storage cost, and cost from product waste also integrated to the models, as well.

Key success factors for Hua-It Market in aiming to be a collection and distribution center for the southern Thailand obtained from this research can be stated as follows. (1) The development of market to be an agricultural quality grading center, which is responsible for grading the product quality, packaging, storage, preserving quality during transportation, testing for plant diseases and insects, and testing for contaminants and toxic residues. (2) The encouragement of collaboration among vendors and buyers for trading in market. (3) The improvement of market's infrastructures. (4) The encouragement and development of exporting system to Singapore, Malaysia, Indonesia, and the Middle East countries. (5) The operations in market with the minimum total systemwide cost. (6) The improvement of quality and cultivation standards of fruits and vegetables so that products can satisfy market needs and consumers tastes. (7) The founding of service centers for facilitating farmers operations. (8) The encouragement of farmers to abide by Good Agricultural Practice (GAP).

To fulfill the transformation of Hua-It Market to a collection and distribution center for the southern Thailand, it counts on the competency of market executives to manage the operations efficiently. Nevertheless, it also relies on the cooperation among related agencies, both public and private sectors. Particularly, the public sectors must perform as coordinators, urge, promote, and encourage as well so that the collaboration among Hua-It supply chain can take place, ultimately, in order to achieve the mission of a collection and distribution center for the south of Thailand.

For future research is an extension from this study. Department of Internal trade, Ministry of Commerce wishes for launching distribution center for agricultural product in four regions of Thailand in order to strengthen the domestic trade system and alleviate the price fluctuation of agricultural product. The question such where are the optimum locations for each distribution center in each region? What is the capacity of each distribution center? How these four distribution centers can collaborate? Or which kind of products should flow from or to which distribution center, etc? This kind of problem constantly emerges in the supply chain management field and it challenges for supply chain practitioners, at all times.

6. Acknowledgment

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Part 2

Supply Chain Optimization and Development

5

Small Block of Supplier Shares Improve Trust Performance in Supply Chain Relationship

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1. Introduction

By advent and development of globalization concept in economy, companies and firms around the world have entered a new era of competitive market. Sustaining in this new competitive market demands a paradigm shift in dealing with business processes within and among organizations and companies. The severe competition in new markets is driven by advances and improvements in industrial technology, increased globalization, achievements in information availability, and creative business designs (Metzner, 2004). Companies are constantly striving to redesign their processes for dealing with their suppliers and customers, to dictate their differentiator values and gain higher market share. In the late 1980s a Japanese word penetrated into business world, called Keiretsu (Miyashita & Russel, 1994). Keiretsu is recognized by networks of inter-connected firms which hold stable shares of each other and developed around a main bank (McGuire & Dow, 2009). Japanese organizations are characterized by two important forms of linkages: horizontal keiretsu and vertical keiretsu. A horizontal keiretsu is consisted of very large companies which work under close relations with a main bank and linked with each other through reciprocal shareholding, trading, and etc. These companies usually work in different segments and differ in their field of business. Mitsubishi Group of companies is a famous example of a horizontal keiretsu. A vertical or pyramid keiretsu consists of a very large company (usually a manufacturer) such as Toyota and hundreds of small companies subordinate to it. These subordinate companies usually serve as a supplier for main manufacturer.

Because of achievements that leading companies like Toyota, Honda, Nissan, Hitachi, Sony, and etc attain through vertical relationship with their suppliers and subordinates within their vertical keiretsu, other global companies outside Japan like GM, Xerox, Boeing, Motorola, Volkswagen, Porsche, DuPont, Swisscom, and etc, have tried to implement same concept in their business networks (Miyashita & Russel, 1994) (Guth, Nikiforakis, & Norman, 2007) (McMillan, 1994).

The effectiveness of the Japanese keiretsu characterized by informal but strict cooperation and inter-connected members, changes the business climate, these changes made many companies outside Japan embarked new types of inter-organizational relationships based on both economical (shareholding) and social (trust) criteria (Handfield & Bechtel, 2002).

Investing in a supplier through acquiring a small block of its share (5-10%) by the manufacturer can be considered as a as a favourable devotion to their relationship (Guth, Nikiforakis, & Norman, 2007). It has also that a firm's trust in their supply chain partner is highly associated with bilateral specific asset investments, like shareholding, in supply chain partnership mentioned (Suh & Kwon, 2006).

Many manufacturers consider buying of their suppliers' share as a financial tool to improve flow of information and materials between both parties. The factor that has been largely overlooked is the effect of shareholding on trust performance between suppliers and manufacturers (Emberson & Storey, 2006). The trust makes companies strive to exceed the minimal requirement of a relationship. It is matter of concern to know whether shareholding has any effect on informal inter-organizational factors like trust and whether shareholding can improve trust performance between firms.

It is of paramount importance for managers to consider ways in which to improve their firm's inter-organizational supply chain relationships. Supply chain performance is based on a high level of trust among supply chain partners. The shareholding between manufacturers and suppliers is one of new approach to improve supply chain performance and also inter-organizational supply chain relationship.

The objectives of this chapter are to evaluate and analyse level of trust between manufacturer and supplier as well as to evaluate the effect of holding small block of supplier's shares by manufacturer on trust between them. Finally the authors will provide a propose framework to improve supplier-manufacturer relationships.

2. Background study

Cooper et al,(1997) suggest a conceptual framework of supply chain management. This framework involves three interrelated element: supply chain structure, business processes, management components (Figure 1).

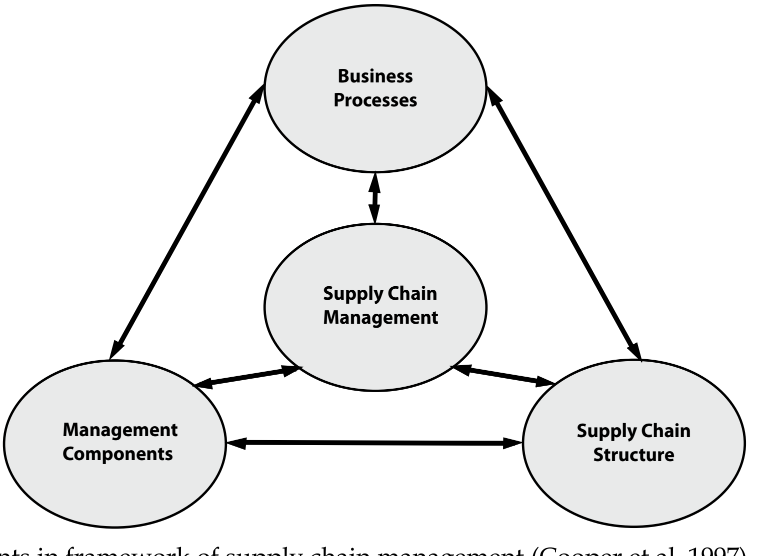

Fig. 1. Elements in framework of supply chain management (Cooper et al, 1997)

Vertical Keiretsu

Keiretsu are established and commonly recognised networks of Japanese firms. Japanese industrial organization has long been characterized by two important form of inter-corporate linkages. Historically, horizontal keiretsu dominated the industrial landscape of Japan. Complementing this horizontal keiretsu is vertical keiretsu usually organized around a major industrial firm and its buyers and suppliers. Vertical keiretsu appear during 1950s as solution for Japanese companies in dealing with scarce financing sources for expansion of their production (Edwards & Samimi, 1997). In contrast to the symmetrical shareholding in horizontal keiretsu, shareholding in vertical keiretsu is not reciprocal and suppliers hold small (if any) in their core manufacturer. The core manufacturer usually invests holds share in first tier, concurrently encourages them to buy shares in second tier suppliers (McGuire & Dow, 2009). This pyramidal nature of shareholding links all companies in the group in a way in which the core company even might be unaware of number of its affiliates (Miyashita & Russel, 1994), (Figure 2).

Participating in these kinds of affiliates usually have breakthrough for both the whole group and the individual members. The individual members are provided with a stable target and market for their products and even might be provided with technical, financial, and managerial supports from the core company. On the other hand, the core company prefer to hold greater ownership in more dedicated affiliates and suppliers. These mutual benefits induce both parties to work toward long-term relationship by offering lower costs and higher quality (McGuire & Dow, 2009). Cross-shareholding also could facilitate flow of information among group members and stability of their relationships which could result in a mutual moralized trading relationship in which both sides consider it as an obligation and try to support it (McMillan, 1994).

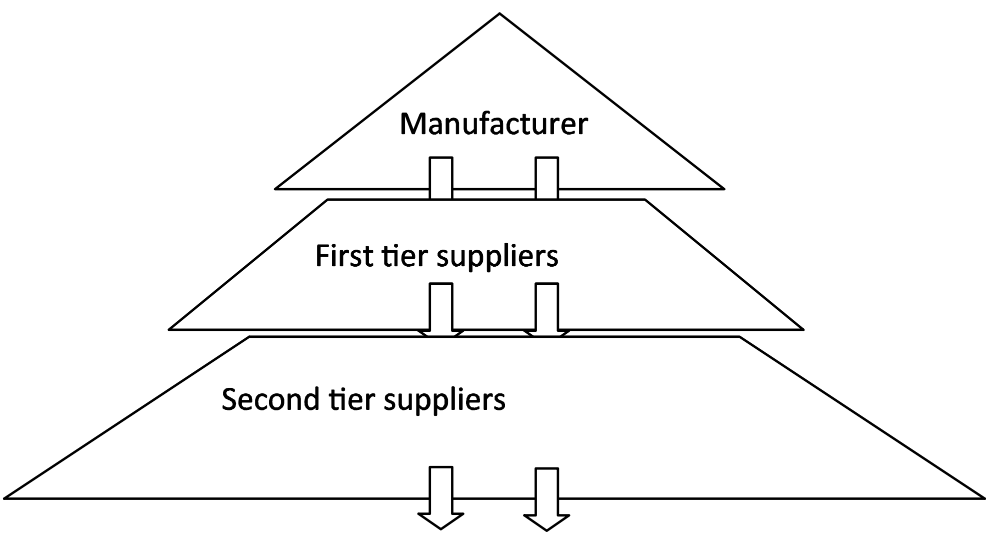

Fig. 2. Pyramidal structure of vertical keiretsu with unknown numbers of tiers

Its mentioned (McMillan, 1994), what make this system keep working, is not repeated transactions but rather it is culture. The mutual relations formed between firms create personal relationships between managers and individuals of both parties. These personal relationships create mutual commitments and bonds of trust between the individuals and relatively between firms. These mutual obligations vary with size of the companies and amount of shareholdings. Tight relationships empowered by Japan's culture in maintaining lifetime employment have caused companies in the keiretsu be group-oriented and work for benefits of the whole group and even sacrifice their own advantages. With the Japanese tradition of loyalty within a hierarchy, with a lifetime employment system, opportunism is a lesser danger because if you treated someone badly by taking advantage of him for immediate profit, it won't be forgotten (Miyashita & Russel, 1994). Trust is an inseparable factor in this system.

In a vertical keiretsu, companies show their commitment to their counterparts by holding shares at a level that doesn't give them direct decision power. Closer scrutiny reveals, this partial ownership helps companies within group to improve their managerial and production processes. Through many supportive advices, companies received in numerous consulting sessions with their affiliates smooth the flow of information in the group. The core company easily gives demand information to its affiliated suppliers and information smoothly flow the group, based on a trust that has been created among them. by providing a forum for discussion, the keiretsu can help solve the coordination problem of achieving an efficient equilibrium. And by providing a mechanism for keeping track of any opportunistic behaviour by either subcontractors or procuring firms, the keiretsu provides a disincentive to such behaviour. Opportunism may be a lesser danger in Japan because of the explicit encouragement, and actual prevalence in the Japanese economy of what one might call moralized trading relationships of mutual goodwill. The stability of the relation is the key. Both sides recognize an obligation to try to maintain it (McMillan, 1994).

3. Methodology

The role of shareholding on trust performance components (capability, commitment, consistency, willingness to invest, willingness to examine assumptions, and willingness to risk) were investigated. Based on the influential components of trust performance, six hypotheses were defined. Samples were gathered using questionnaires. The questionnaire were involved two part; the first part was related to general information of responding companies and the second part was involved 29 questions regarding different factors of trust performance. Linear regression and ANOVA were used to analyze the data in order to investigate whether or not the collected data support the hypotheses.

The questionnaire was developed to evaluate trust between supplier and manufacturer based on two assumptions, prior acquiring the supplier's share and after acquiring supplier's share by manufacturer. Based on Hacker and Willard (2002), trust assessment is categorized into two main groups. However, these two main criteria are not measured directly. Rather than, these main criteria are broken down into six sub-criteria. They are explained in the below. For each value contrasting descriptions are considered to stimulate the respondent's thinking about trust. A seven point interval scale is used (from 1 to 7) in which "1" shows the description on the left depicts the relationship more properly and "7" indicates the description on the right side is paired with relationship. If neither shows a perfect match, the respondent can use other scale between two extremes to express what he/she think. The sub-criteria for "Trustworthiness"including:

- Capability

- Commitment
- Consistency
- Willingness to invest
- Willingness to examine assumptions
- Willingness to risk

Data were collected via survey from manufacturers of Middle East country. A survey methodology is chosen because it is the most efficient of collecting large number of respondents.

The survey was designed to be conducted in one stage. Respondents are requested to focus on a key-input supplier. When the manufacturer has more than one supply chain partner, the respondent is asked to consider the one that has the most impact on their business (Suh & Kwon, 2006). The survey was filled by respondents in interview like sessions. The respondents were requested to respond to the same questions in the stage one but by assumption that they have acquired a minority block (5 to 10%) of the supplier's shares. The respondents were told that this amount of shares practical are considered as non-voting shares and give no decision power to acquirer firm (Guth *et al.* 2007). In addition, respondents were asked to respond to question about the size of their company, their working sector and products.

3.1 Measures

Six items is used to calculated trust performance: capability (6 questions), commitment (4 questions), consistency (4 questions), willingness to invest (5 questions), willingness to examine assumptions (4 questions), willingness to risk (6 questions). Firstly, the total score for each item were entered in cumulative score column by adding the relative score for each question. Then the cumulative scores were divided by number of questions in that in that item to obtain an average for each component that matched our 1-7 scale, the resulting scores were entered in fraction column in Appendix B. Finally, by adding all the fraction score for all items and dividing it by the number of items (6 items) trust were calculated for each case. The measures for trust performance calculation were adapted from (Hacker & Willard, 2002).

3.2 Testing hypothesis

There are two aspects to consistency. The first aspect has to do with the match between words and deeds. In short, do they "walk the talk". The second aspect has to do with consistency over time, "Do they walk the talk every time". This is especially important in relationships in which the company may not have explicitly stated its intentions. In other words, suppliers may not have heard my talk. They have only my actions as evidence of my consistencies and will watch to see that my behaviour is steady over time.

H1. There is a positive relationship between the perceived level of consistency and trust

Commitment is a two-forked proposition. Commitment must be present in two different arenas. First, commitment toward each other as companies within the relationship must exist. Believing that another company has your best interests at heart and prepared to back you up in difficult times is one aspect of commitment. But also important in building trust is the shared commitment to a cause or goal. Understanding that common objectives and common values sets exist deepen the relationship. Because you "know how the other company thinks" and their thinking is in line with yours, you can trust their decisions.

H2. There is a positive relationship between the perceived level of commitment and trust

The third component of trust deals with another's ability to produce results or to meet our performance expectations. In other word "does the supplier have the skills to get the job done, does this supplier have the experience to perform well". Choosing suppliers based on their consistency or commitment alone may set up for the disappointment if the capability of those suppliers cannot be trusted.

H3. There is a positive relationship between the perceived level of capability and trust

Building trust requires effort and focus. By clarifying with whom and to what degree you intend to build trust you can increase the speed and likelihood for strong and purposeful relationships. As our interdependence with suppliers increases, however, the optimal level for trust increases proportionally. When two or more supplier's fates are linked, when doing a job requires more than just your own effort, there is a need to develop a trusting relationship in order to efficiently and effectively achieve your common goal.

H4. There is a positive relationship between the perceived level of willingness to invest and trust

Our assumptions about how the world operates form the foundation of our individual beliefs and values. And our beliefs and value are what allow us to make choices and prioritize our decisions. In any given situation, our experiences and our biases help us determine whether to move forward with trust or withdraw in distrust.

H5. There is a positive relationship between the perceived level of willingness to examine assumptions and trust

The most important component in our trust calculation is risk. It's what we measure our investment against, and it's what colors our assumptions and predisposition to trust. Without risk, no trust is gained.

H6. There is a positive relationship between the perceived level of willingness to risk and trust

3.3 Data analysis by using P-values

The p-value or calculated probability is the estimated probability of rejecting the null hypothesis (H_0) of this study question when that hypothesis is true. The term significance level is used to refer to a pre-chosen probability and the term "P value" is used to indicate a probability that you calculate after a given study. The alternative hypothesis (H_1) is the opposite of null hypothesis.

If your P-value is less than the chosen significance level then it is possible to reject the null hypothesis i.e. accept that our sample gives reasonable evidence to support the alternative hypothesis.

The choice of significance level at which you reject H0 is arbitrary. Conventionally the 5% (less than 1 in 20 chance of being wrong), 1% and 0.1% ($P<0.005$, 0.01 and 0.001) level have been used. These numbers can give a false sense of security. What we can do is try to optimise all stage of our research to minimise source of uncertainty. When presenting P-values, it is helpful to use the asterisk rating system as well as quoting the P value:

$$P<0.05$$

$$P<0.01$$

$$P<0.001$$

Most authors refer to significant as $P<0.05$ and statistically significant at $P<0.01$ and statistically highly significant as $P<0.001$.

4. Results and discussion

Linear regression analyses were conducted for study. Table 1; summarize the results of the regression analysis.

Dependent variable	Adjusted R^2	Independent variable	F-value	P-value
Trust	0.076	Consistency	4.853	0.032
	0.1296	Commitment	7.99	0.0069
	0.140	Capability	8.62	0.0052
	-0.0189	Willingness to invest	0.1560	0.6947
	-0.0189	Willingness to examine assumptions	0.1297	0.7204
	0.0624	Willingness to risk	4.1274	0.0480

All of the coefficients estimates are highly significant at $p<0.001$; statistically significant at $p<0.01$; and significant at $p<0.05$

Table 1. Summary of regression results

In the first regression analysis trust was the dependent variable, and independent variable was consistency. Consistency (H1, $p<0.05$) affects the perception of the trust between the manufacturer and its supplier.

The second regression analysis was run with trust as the dependent variable and commitment as the independent variable. The result revealed that commitment (H2, $p<0.01$) is a good predictor of perceived trust between supply chain partners.

In the third regression trust was dependent variable and capability was independent variable. Like commitment, capability (H3, $p<0.01$) was also a good predictor of trust between partners.

The fourth regression was conducted in which trust was as dependent variable and willingness to invest was independent variable. The result revealed, willingness to invest (H4, $p>0.05$) does not influence trust performance between manufacturer and supplier.

In the fifth regression we got the same result as the fourth regression. In this stage, trust was the dependent variable and willingness to examine assumption was the independent variable. The result disclosed that willingness to examine assumptions (H5, $p>0.05$) has no influence on the trust performance.

The last regression was carried out by the trust as the dependent variable and willingness to risk as the independent variable. The result showed that willingness to risk (H6, $p<0.05$) is good predictor of perceived trust between supply chain partners. However, willingness to risk does not to seem to be very significant predictor of trust. Table 2 summarize the results of the analysis.

Hypotheses	Results
H1. There is a positive relationship between the perceived level of consistency and trust	Supported
H2. There is a positive relationship between the perceived level of commitment and trust	Supported
H3. There is a positive relationship between the perceived level of capability and trust	Supported
H4. There is a positive relationship between the perceived level of willingness to invest and trust	Not supported
H5. There is a positive relationship between the perceived level of willingness to examine assumptions and trust	Not supported
H6. There is a positive relationship between the perceived level of willingness to risk and trust	Supported

Table 2. Summary of hypothesis testing

Four out of the six hypotheses were fully supported. Based on this study, the perceived level of factors like commitment, capability, consistency and also willingness to risk towards supplier could improve as the result of shareholding by manufacturer. On the other hand analysis showed us the shareholding has no influence on the perceived level of willingness to examine assumptions and willingness to invest and also on the relative level of trust between manufacturer and its supplier.

The analysis was also conducted for comparison between the current perceived levels of trust by manufacturer, the perceived levels of needed trust that manufacturer thought should exist and the calculated trust. The calculated trust is a factor which obtained from adding the given rate to all the trust performance variable (consistency, commitment, capability, willingness to examine different assumptions, willingness to risk) and then dividing the cumulative rate by number of categories for each variable (29 items). The product is the calculated trust of the perceived level of trust acquired from shareholding by manufacturer. The simultaneous comparison of all three resulted trust (existing trust, calculated trust, needed trust) is demonstrated in Figure 3. The mean for each these factors also are presented in Table 3.

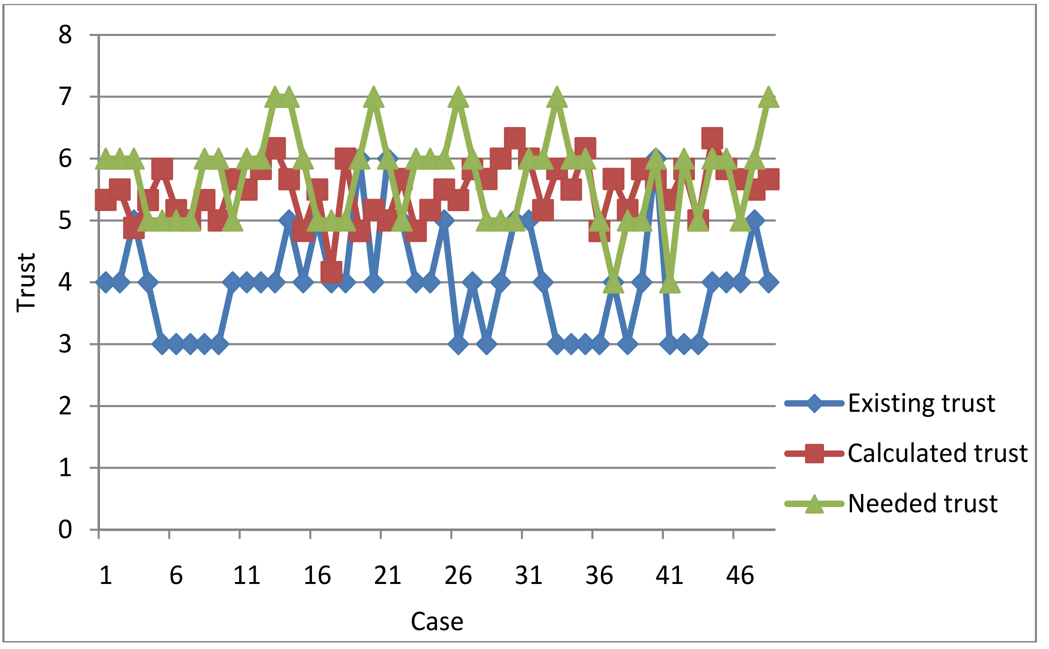

Fig. 3. Comparison of resulted levels of trust

	Existing trust	Calculated trust	Needed trust
Mean	3.979	5.480	6.222

Table 3. Mean amounts for results

Since there is a growing recognition that modern competition is between supply chains rather than between firms (Ketchen & Guinipero, 2004), it is of paramount importance for managers to consider ways in which to improve their firm's inter-organizational supply chain relationships. Supply chain performance is based on a high level of trust among supply chain partners (Kwon & Suh, 2004). Trust simulates a relational bond between suppliers and customers which facilitates the establishment of productive collaborations. Therefore managers look for way in which they can increase the level of trust in their supply chain partners.

This study was based on this perception that manufacturer and supplier can improve their inter-organizational relationship by using shareholding conceprt. Studies (McMillan, 1994) have shown companies show their commitment to their counterparts by holding shares at a level that doesn't give them direct decision power. Closer scrutiny reveals, this partial ownership helps companies within group to improve their managerial and production processes and trust performance between them. Through many supportive advices, companies received in numerous consulting sessions with their affiliates smooth the flow of information in the group and improve the perceived level of trust. The core company easily gives demand information to its affiliated suppliers and information smoothly flow the group, based on a trust that has been created among them. by providing a forum for discussion, the shareholding can help solve the coordination problem of achieving an efficient equilibrium. Opportunism may be a lesser danger in these companies because of the explicit encouragement, and actual prevalence in the both firms environment of what one might call moralized trading relationships of mutual goodwill. The stability of the relation is the key. Both sides recognize an obligation to try to maintain it (McMillan, 1994).

5. Conclusion

This study shows that holding small block of key-player supplier by the manufacturer can significantly improve the perception that manufacturer has about its supplier's consistency, commitment, capability, willingness to risk. But on the other hand, this study shows shareholding has no influence on the perception of willingness to examine assumptions and also willingness to invest. One factor that might be influential in current case and shouldn't be undermined is the organizational culture of Iranian manager. As Yeganeh (Yeganeh & Su, 2007) said, masculinity and uncertainty avoidance are two main characteristics of Iran managerial culture and it make managers always have other alternatives in his mind and also make Iranian managers unwilling to make invest in their suppliers. These two factors might be in congruent with our results in this study. This study shows that shareholding might not to lead to higher level of trust resulted from higher level of perceived willingness to examine assumptions and also willingness to invest.

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6

Reverse Logistics and the Role of Fourth Party Logistics Provider

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1. Introduction

Conventional supply chain perspectives consider a set of processes, driven by customer demand, that convey goods from suppliers through manufacturers and distributors to the final customers. However, this is not where the story ends. Physical goods do not simply vanish once they have reached the customer. Nor does the value incorporated in them. Therefore, many goods move beyond the conventional supply chain horizon, thereby triggering additional business transactions: used products are sold on secondary markets; outdated products are upgraded to meet latest standards again; failed components are repaired to serve as spare parts; unsold stock is salvaged; reusable packaging is returned and refilled; used products are recycled into raw materials again.

The set of processes that accommodate these goods flows, which can often be interpreted as running 'upstream' in a conventional supply chain scheme, is known as *reverse logistics.* The OECD (2003) acknowledges that "Reverse logistics need to be developed. The imminent need in many countries to reduce, reuse and recycle waste will only become feasible with a transport system which carries used and returned goods for reuse and recycling (reversed logistics) in a cost-effective manner."'The main reasons to become active in reverse logistics are different: environmental laws, economic benefits and the growing environmental consciousness of consumers. The result is an increase on reverse logistics activities on a whole range of industries, from the transport sector, consumer electronics, press and media to textiles and clothing, to mention just a few. As in the U.S., effective management of reverse logistics is still emerging in Europe and more and more firms now realize that the reverse logistics is a business process by itself and needs core competency to successfully manage it. As firms develop core competency in the fulfillment process, the core competency on the reverse logistics too may be difficult to attain for the same firm. Fortunately, there are specialized firms in the market now that have already developed core competency in many of the business processes involving reverse logistics, and are rapidly becoming the preferred outsourcing alternatives for the firms.

2. Reverse logistics: Definition

Reverse logistics (RL), a relatively new research direction in the area of supply chain management and logistics has gained increasing attention from academics and practitioners

Council of Logistics Management	*"...the term often used to refer to the role of logistics in recycling, waste disposal, and management of hazardous materials; a broader perspective includes all relating to logistics activities carried out in source reduction, recycling, substitution, reuse of materials and disposal."*
Pohlen and Farris (1992)	*"...the movement of goods from a consumer towards a producer in a channel of distribution."*
Kopicky et al. (1993)	*"Reverse Logistics is a broad term referring to the logistics management and disposing of hazardous or non-hazardous waste from packaging and products. It includes reverse distribution which causes goods and information to flow in the opposite direction of normal logistics activities."*
Kroon (1995)	*"are the logistic management skills and activities involved in reducing, managing and disposing of hazardous or non-hazardous waste from packaging and products. It includes reverse distribution, which causes goods and information to flow in the opposite direction from normal logistic activities".*
Fleischmann et al. (1997)	*"a process which encompasses the logistics activities all the way from used products no longer required by the user to products again usable in a market".*
Krikke (1998)	*"is the collection, transportation, storage and processing of discarded products".*
Dowlatshahi (2000)	*"a process in which a manufacturer systematically accepts previously shipped products or parts from the point for consumption for possible recycling, remanufacturing, or disposal".*
Guide et al.(2000)	*"the task of recovering discarded products (cores); it may include packaging and shipping materials and backhauling them to a central collection point for either recycling or remanufacturing".*
Rogers and Tibben-Lembke (1999)	*"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 proper disposal."*
European Working Group on Reverse Logistics (RevLog)	*"The process of planning, implementing and controlling flows of raw materials, in process inventory,and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal" .*

Table 1. Definitions of Reverse Logistics

(Blumberg, 1999; Carter and Ellram, 1998; Dowlatshahi, 2000; Rogers and Tibben-Lembke, 1999, 2001, 2002; Schwartz, 2000; Stock, 1998, 2001; Thierry et al., 1995, Van Hoek, 1999).Despite the popularity of the term reverse logistics, both in academia and practice, there remains considerable confusion as to its meaning. Such ambiguity suggests a need to examine the phenomena of RL more closely in order to clearly define the term and concept, to identify those factors that contribute to effective RL, and to suggest how the adoption of a RL approach can affect corporate strategy and performance.

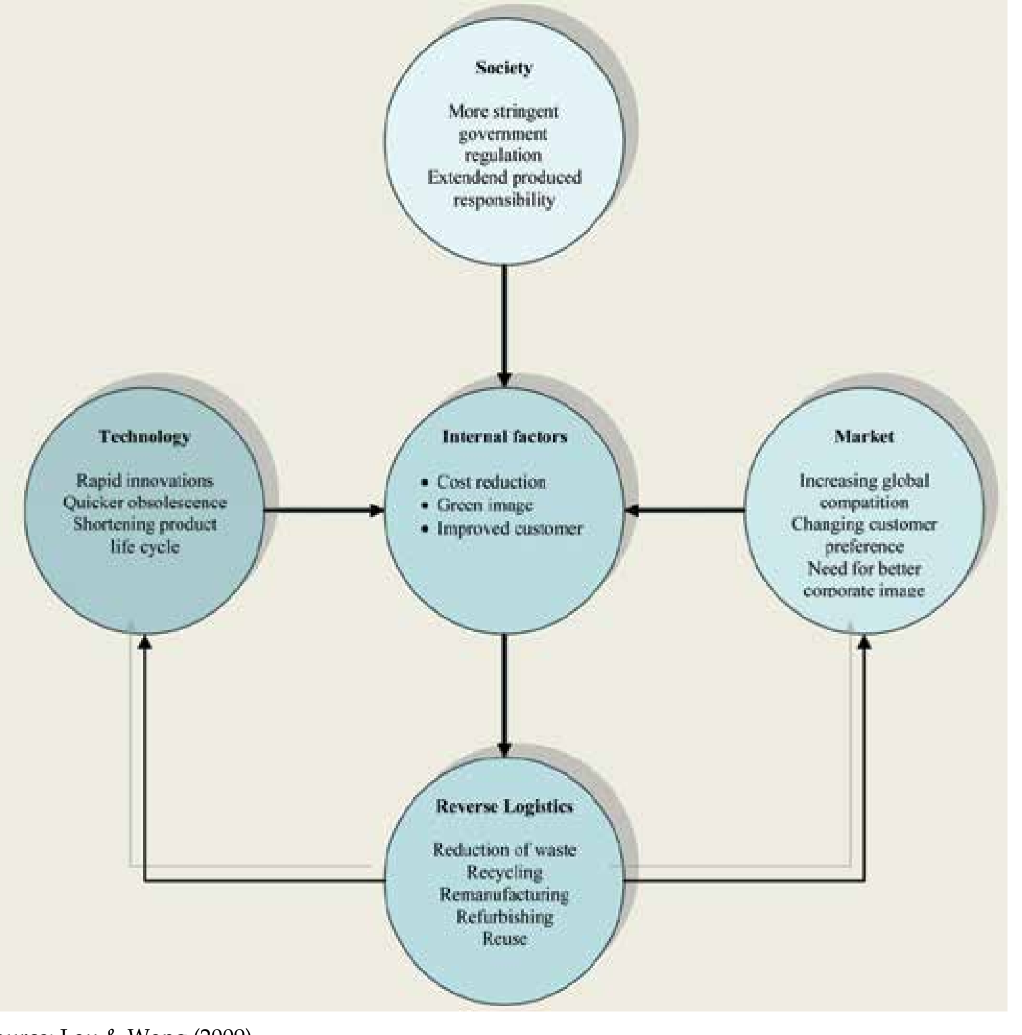
If we analyze carefully these definitions most of the authors agree that they are basically discarded products, used products, products or parts previously shipped, hazardous and non-hazardous waste from packages and products, information, raw materials, in process inventory and finished goods. These inputs identify the scope of the RL process. Some of them limit the input to only waste or recycled products, but others allow a more wide concept where information, raw materials, inventories and goods are managed through the RL system. We believe this last consideration is more adapted to the RL concept, since it includes the entire "reverse flow" of things through the supply chain, and is not limiting the RL to either the waste management or the used products, which we think is a misleading and narrow vision of the RL concept, but as we can appreciate it is very commonly used. Most recently, according to the Reverse Logistics Association (2006), reverse logistics deals not only with returns processing but also with repair, customer service, parts management, end-of-life manufacturing and order fulfillment. The reverse logistics operations are different from the traditional logistics operations because the behavior of consumers introduces uncertainties in the quality, quantity, and timing of product returns (van Hillegersberg et al. 2001). The following are main characteristics of reverse logistics:

1. There is an uncertainty of returned time of a product.
2. There is an uncertainty of quality of a returned product, i.e. uncertainty of recovered value.
3. There is an uncertainty of configurations of parts or components of returned products.
4. There is an uncertainty of locations.
5. There is an uncertainty of amounts of recovered products

We would like to remark that Reverse Logistics is different from waste management as the latter mainly refers to collecting and processing waste (products for which there is no new use) efficiently and effectively. The crux in this matter is the definition of waste. This is a major issue, as the term has severe legal consequences, e.g. it is often forbidden to import waste. Reverse Logistics concentrates on those streams where there is some value to be recovered and the outcome enters a (new) supply chain. Reverse Logistics also differs from green logistics as that considers environmental aspects to all logistics activities and it has been focused specifically on forward logistic, i.e. from producer to customer (see Rodrigue et al., 2001). The prominent environmental issues in logistics are consumption of nonrenewable natural resources, air emissions,congestion and road usage, noise pollution, and both hazardous and non-hazardous waste disposal (see Camm, 2001). Finally, reverse logistics can be seen as part of sustainable development. The latter has been defined by Brundland (1998) in a report to the European Unionas "to meet the needs of the present without compromising the ability of future generations to meet their own needs." In fact one could regard reverse logistics as the implementation at the company level by making sure that society uses and re-uses both efficiently and effectively all the value which has been put into the products. Reverse Logistics also differs from green logistics as that considers environmental aspects to all logistics activities and it has been focused specifically on forward logistic, i.e. from producer to customer (see Rodrigue et al., 2001). The prominent environmental issues in logistics are consumption of nonrenewable natural resources, air emissions, congestion and road usage, noise pollution, and both hazardous and non-hazardous waste disposal.

3. The driving forces

In the literature of reverse logistics, many authors shows that a firm's reverse logistics activities are affected by intraorganizational factors, including a sincere commitment to environmental issues and succesfully implemented ethical standards, and the existence of policy entrepreneurs who make a strong commitment and take personal responsibility for organizational adoption od an environmentally friendly philosophy. The literature also indicates that a firm's reverse logistics activities are directly affected by one or more environmental forces: customers, suppliers, competitors and government agencie (Stock 1992; Pohlen and Farris, 1992; Barry and others, 1993; Kopichi and others, 1993; Livingstone and Sparks, 1994; Murphy and others, 1995; Cairnecross, 1992). The presence or absence of these factors can become drivers or barriers to reverse logistics implementation in a particolar industry. Knemeyer et al. (2002) propose a conceptual model that puts the various exogenous and endogenous factors together. Under this model, the external (or macro) environment or task environment may be defined as the specific organization or group that is relevant to goal setting and goal attainment, and that affects decisions, actions, and outcomes. It includes sectors with which the organization interacts directly and that have a direct impact on the organization's ability to achieve its goals: industry, competitors, customers, techniques of production, suppliers, stock market, raw materials, market sectors, government and perhaps the human resources and international sectors. Firstly, the government has the potential to control, legislate, or otherwise influence an organization's polizie and practices. Governments in developing countries have become increasingly concerned over the threat to human and environmental safety posed by end-of-life phones and other electronic products exported there for disposal. Internally, the firm must examine key strategic factors in designing its reverse logistic system, such as strategic costs, overall quality, customer service, environmental concerns, and legislative concerns, and operational factors, such as cost-benefit analysis,transportation, warehousing, supply management, remanufacturing, recycling, and packaging, that a firm must examine. These factors are critical and must be considered prior to operational factors. Strategic costs can include the costs of equipment for dismantling products, the cost for qualified workers to run the reverce logistics system, and the costo f additional warehous faciliries. These costs are considered strategic due to the need to allocate sufficient resources (financial and humans) to these initiatives (Stock, 1998) as opposed to the resources going to other areas of the company. Minimizing strategic costs depends on effective utilization of current resources, methods and technologies wich are essential for a succesful reverse logistics system. In relation to operational costs, these costs were dependent on both the input and output streams destre for the proposed system. Specifically, the strategic decision to place a heavier amphasis on refurbishing as opposed to recycling, the greater the costs associated with labor, transportation and warehouse facilities must be considered. The employees skills and the storage space requirements increase dramatically as the focus shifts to value added EOL products refurbishing. It is important to note that internal and external forces are not mutually exlusive. Without the external pressures, even the most savvy of policy entrepeneurs may not be able to convince others within the organization to become personally committed to the undertaking (Knemeyer et al., 2002). Conversely, without a policy entrepeneur to drive the program, stakeholder commitment, and an effective incentive system, the company may very well respond to external pressures by making only minor, cosmetic change to its systems rather than by implementino programs that are environmentally friendly. In fact, a greater understanding of organizational behavior can be gained by examining how organizations interact with their environment. Fig. 1 shows how external factors influences reverse logistics programs and activities. This conceptual model suggests that the external environment is comprised of four sectors:input, regulatory, competitive and output. The input sector represents an analysis of possible suppliers of products.



Source: Lau & Wang (2009)

Fig. 1. The internal and external drivers of reverse logistics

The regolatory sector esamine how governement and other external groups impact the system participants. The output sector focuses on the ultimate demand markets and, finally, the competitive sector addresses the level of competition within the sector. Within these sectors are key interorganizational partnerships including suppliers, competitors, government agencies and interested aggregators, such as consumer and lobbyng groups, which influence the governemnt and regulatory bodies. In particolar, we categorize the driving forces under three main headings:

- Economics
- Legislation;
- Corporate citizenship

Legislative, economic and social factors all contribute to an organisation's decision to adopt reverse logistics activities as part of their supply chain management processes. The following sections list some of the factors involved.

3.1 Legislative factors

Over the past few years, reverse logistics has been gaining increasing attention and awareness in the supplì chain community, both from practioners and researchers. This can be attributed to increate regulatory pressure such as estende producer responibility,partucularly in Europe, consumer expectations and societal sustainability demands, as well as to the intrinsic value that can be regained from collected products (De Brito, 2003). Lately, due to new waste management legislation (especially in Germany), the emphasis has been shifting towards recovery, due to the high costs and environmental burdens of disposal. Firms become more and more responsible for collecting, dismantling and upgrading of used products and packaging materials. The overall result is an increase on reverse logistics activities on a whole range of industries, from the transport sector, consumer electronics, press and media to textiles and clothing, to mention just a few. The management of return flows is becoming increasingly important for a growing number of businesses. Governmental policy and legislation, such as the WEEE Directive and environmental regulations restricting the disposal of potentially hazardous product and packaging materials, have forced manufacturers to take responsibility for the take-back of used goods from customer markets.

In Europe there has been an increase of environmentally related legislation, like on recycling quotas, packaging regulation and manufacturing take-back responsibility. The automobile industry and industries of electrical and electronic equipment are under special legal pressure (see Bloemhof et al., 2003). Sometimes companies partecipate "voluntarily" in covenants, either to deal with (or get prepared for) legislation. The UK Government promotes a "producer responsibility" policy which underlies the approach taken in implementing the EC Directives described below (Defra, 2006a). All these producer responsibility directives were identified in the European Union's Fifth Environment Action Programme as "priority waste streams" because of growing concern about their impact on the environment. In these Directives, responsibility is clearly placed on producers to bear the costs of collection, sortation or treatment and recycling or recovery. Such legislative actions can drive companies to utilise reverse logistics to recover products and certain types of waste from downstream supply chain stakeholders, and ensures the compliance with existing and future legislation (Bettac *et al.*, 1999). The EC Directive on **Packaging and Packaging Waste** (94/62/EC) seeks to reduce the impact of packaging and packaging waste on the environment by introducing recovery and recycling targets for packaging waste, and by encouraging minimisation and reuse of packaging. The EC Directives on **Waste Electrical and Electronic Equipment (WEEE)** (2002/96/EC) and on the **Restriction of the Use of Certain Hazardous Substances (RoHS)** in Electrical and Electronic Equipment (2002/95/EC) aim to reduce the quantity and environmental impact of waste from electrical and electronic equipment and increase its reuse, recovery and recycling. The Directives affect producers, distributors and recyclers of electrical and electronic equipment, including household appliances, IT and telecoms equipment, audiovisual equipment (TV, video, hi-fi), lighting, electrical and electronic tools, toys, leisure and sports equipment. Increased recycling of such electrical and electronic equipment will limit the total quantity of waste going to final disposal. Producers will have responsibility for taking back and recycling electrical and electronic equipment. There is an incentive for manufacturers to design electrical and electronic equipment in an environmentally more efficient way, which takes waste management aspects fully into account (Europa, 2006). The EC **End-of-life Vehicle (ELV)** Directive (2000/53/EU) is concerned with cars, vans and certain three-wheeled vehicles. It aims to reduce the amount of waste from vehicles (cars and vans) when they are finally scrapped. In particular, it includes tightened environmental standards for vehicle treatment sites, requires that last owners must be able to dispose of their vehicles free of charge from 2007 (and requires producers to pay all or a significant part of the free take-back from this date), sets rising reuse, recycling and recovery targets and restricts the use of hazardous substances in both new vehicles and replacement vehicle parts. Another EC Directive which will impact on the transportation and other requirements of reverse logistics is the Directive on **Distance Contract** (97/7/EC), which stipulates that anyone who makes a purchase on the Internet or by phone, fax or via mail order is able to change their mind about the purchase during a "cooling-off" period of seven working days after the goods are received; no explanation for the rejection of goods is required. The onus of returning such goods is likely to lie with the potential customer, and many of these returned goods will be transported back to the original retailer or manufacturer by traditional delivery services. However, it is likely that more of these rejected items will be recovered through dedicated reverse logistics processes as they become more prevalent, particularly in response to the WEEE Directive.

3.2 Economics factors

The question whether product recovery is economically attractive or not has to be viewed within the legal framework in which the firm operates. However, as Buellens (2004) points out, a company that is considering adopting a reverse logistics or product recovery programme may be able to overcome any technical or legal difficulties, but might be dissuaded from adopting such processes due to the financial implications. Resources make reverse logistics programs more efficient and more effective, but there is recompense only when the resources are used in such a manner as to develop innovative capabilities/approaches to handling returns (Richey *et al.*, 2005). Nevertheless, late entrants into reverse logistics have the advantage that they can utilise knowledge and experience from early adopters, and should be able to manage available resource in a more profitable way (Richey *et al.*, 2004). However, the existence of a reverse logistics programme has been shown to bring direct monetary gains to companies by reducing the use of raw materials, by adding value with recovery, or by reducing disposal costs (Rogers *et al.*, 2001; De Brito *et al.*, 2003). Some other retail-related issues that reverse logistics can affect in a financially beneficial way are (DfT, 2004):

1. customer service – good returns policies may give a retailer an advantage over less liberal competitors;
2. effective inventory utilisation – removing old or slow-moving stock and replacing with newer, more desirable products can help promote sales;
3. recapturing product value – if unsold products can be quickly and effectively disposed of (for example, sold on by auction, or to Jobbers – someone who buys surplus or unwanted merchandise from one source, and profits by selling it on), some of the value may be reclame;
4. security of technology – by recovering all its own products, a company can prevent competitors accessing sensitive technologies, and thus may retain an advantage in the marketplace.

Even with no clear or immediate expected profit, an organization can get (more) involved with Reverse Logistics because of marketing, competition and/or strategic issues, from which are expected indirect gains. For instance, companies may get involved with recovery as a strategic step to get prepared for future legislation (see Louwers et al., 1999) or even to prevent legislation. In face of competition, a company may engage in recovery to prevent other companies from getting their technology, or from preventing them to enter the market. As reported by Dijkhuizen (1997), one of the motives of IBM in getting involved in (parts) recovery was to avoid that brokers would do that. Recovery can also be part of an image build-up operation. For instance, Canon has linked the copier recycling and cartridge recycling programs to the "kyo-sei" philosophy, i.e. cooperative growth, proclaiming that Canon is for "living and working together for the common good" (see Meijer, 1998; and, www.canon.com). Recovery can also be used to improve customer's or supplier' relations An example is a tyre producer who also offers customers rethreading options in order to reduce customer's costs. In sum, the economic driver embraces among others, the following direct and indirect gains:

- Direct gains:
- input materials;
- cost
- reduction;
- value added recovery;
- Indirect gains:
- anticipating/impeding legislation
- market protection;
- green image;
- improved customer/supplier relations;

Properly and thoroughly executed RLA significantly improve bottom-line performance. Certain value is inherent to well-managed RL: for finance, operational cost controls and asset recovery; for sales, increased customer satisfaction; and for quality, valuable customer data which can lead to product design improvements. Enhanced custode service, improved customer satisfaction, increased control of inventory, reduced costs, higher profitability, and enhancement of corporate image have all been identified as potential benefits that firms with effective RLA may enjoy. Product recovery can also be a part of an image-building operation or can be used to improve the relationship with a customer or supplier.

3.3 Social factors and extended responsibility

"Extended Responsibility", or "Corporate Citizenship" concerns a set of values or principles that drive an organisation to become responsibly engaged with particolar activities, including reverse logistics. The extended producer responsibility is that producer must be responsible for the whole life cycle (including production process and life ending stage) of production made by themselves, and particularly recovery, and recycle, reproducing, reuse of the end of lofe product, in order to realize the recycling resources and the purpose of environmental protection. Extended producer responibility has now almost become a norm for all large International enterprises particularly in the electronic and auto motive industry. In 1997, Europe Union formally come on the statute of Re cycling of the electrician and electronics products, which rule every manufactory or importer of marketing the electrician and electronics products into European market must recover and remanufacture and reuse the EOL (the end of life) products caused by marketing, so that the concept of extended producer responsibility was put forward. Nowaday, the green image has been increasingly recognized a san important marketing element and can improve customer relations. Many compagnie now have extensive programs on responsible corporate citizenship where both social and environmental issues become the priorities.

4. Different type of returns

The high level of uncertainty arisen as a result of the different characteristics in terms of quantity and quality of the returned products, makes more complicated the production planning task and increases the complexity of the inventory control process. A good way to understand this uncertainty is to analyze the most common causes of products' return. The reasons for products being returned are discussed by a number of authors. De Brito *et al.* (2003) categorise returns under three headings:

a. **Manufacturing returns** – raw material surplus, quality-control returns, production leftovers or by-products;
b. **Distribution returns** – product recalls, commercial returns (unsold products and wrong or damaged deliveries), stock adjustments, functional returns (distribution items, carriers, packaging);
c. **Customer returns** – reimbursement guarantee returns, warranty returns, service returns, end-of-use, end-of-life returns.

Rogers and Tibben-Lembke (1998) describe the principal causes for which the people return the products. Table 2 shows the common causes of products'returns. Manufacturing returns as all those cases where components or products have to be recovered in the production phase. This occurs for a variety of reasons. Raw materials may be left over, intermediate or final products may fail quality checks and have to be reworked and products may be left over during production, or by-products may result from production. Raw material surplus and production leftovers represent the product not-needed category, while quality-control returns fit in the "faulty" category. Distribution returns refers to all those returns that are initiated during the distribution phase. It refers to product recalls, commercial returns, stock adjustments and functional returns.

Product recalls are products recollected because of safety or health problems with the products, and the manufacturer or a supplier usually initiates them. B2B commercial returns are all those returns where a retailer has a contractual option to return products to the supplier. This can refer to wrong/damaged deliveries, to products with a too short remaining shelf life or to unsold products that retailers or distributors return to e.g. the wholesaler or manufacturer. The latter include outdated products, i.e.those products whose shelf life has been too long (e.g. pharmaceuticals and food) and may no longer be sold. Stock adjustments take place when an actor in the chain re-distributes stocks, for instance between warehouses or shops, e.g. in case of seasonal products (see De Koster et al., 2002). Finally, functional returns concern all the products which inherent function makes them going back and forward in the chain. The third group consists of customer returns, i.e. those returns initiated once the product has at least reached the final customer.

	Manufacturing return	**Distribution returns**	**Customer returns**
Products	Raw material surplus, quality-control returns, production leftovers	Unsold products and wrong or damaged deliveries, stock adjustments, functional returns	Defective/unwanted products, recalls, end-of-use, end-of-life returns., service returns

Source: Adapted from Rogers *et al.* (1999)

Table 2. Common causes of products' return

5. Recovery options and reverse logistics activities

Once a product has been returned to a company, the firm has many disposal options from which to choose: 1) direct re-use (and re-sale); 2) product recovery management (repair; refurbishing; remanufacturing; cannibalization; recycling); and 3) waste management (incineration and land filling).

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. 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. The main reverse logistic processes are the following (see Figure 2):

a. Collection;
b. Examination and processing;
c. Re-processing or direct recovery;
d. Redistribution

The first stage in the process is **collection**, that is, all those activities that are necessary for reclaiming returned products, surplus or by-products and transporting them to a point of recovery where they will be subjected to further examination and processing i.e. their quality is assessed and a decision is made on the type of recovery. This issue is central at the stage of **inspection/selection and sorting**, w h e re a decision must be reached as to whether a product (or parts of it) will be re -used, remanufactured, recycled or disposed. Physical inspection is necessary for determining further processing for most commercial products.

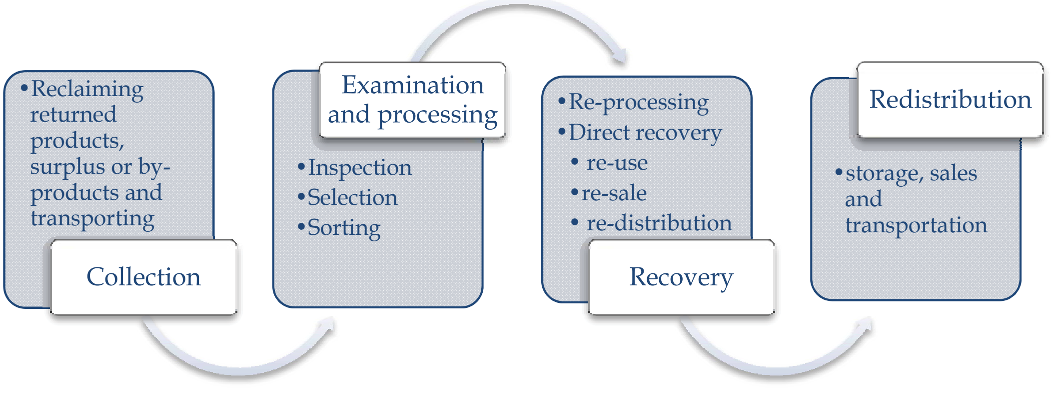


Fig. 2. Main reverse logistic processes

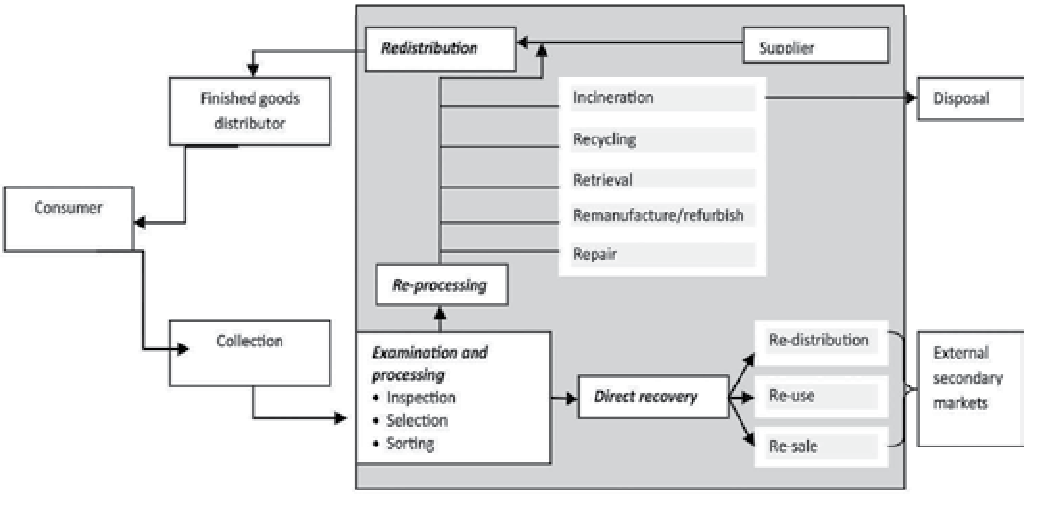
The third process is the **recovery**. Once a product has been returned to a company, the firm has many disposal options from which to choose. If the quality is "as-good-as-new," products can be fed into the market almost immediately through direct recovery. Direct recovery involves three options: re-use; re-sale and re-distribution . Re-use refers to cases where returned products have such a good quality that they can be re-used almost immediately in the same or an alternative market. This happens for re-usable bottles, containers and most leased or rented equipment. Re-use is a situation in which the product is used again, but there is no purchase, e.g. unse spare parts. Re-sale applies to situations where the product is sold again. Finally, re-distribution refers to products like carriers, that are simply distributed again and again. The second option is the re-processing that includes the following recovery options:

- repair (at product level),
- refurbishing (at module level),
- remanufacturing (at component level),
- retrieval (at part level),
- recycling (material level), and
- incineration (energy level).

At module level, the product, e.g. a large installation, building or other civil object gets upgraded (refurbishment). In case of component recovery, products are dismantled and used and new parts can be used either in the manufacturing of the same products or of different products (remanufacturing). In material recovery, products are grinded and their materials are sorted out and grouped according to a quality wish, so recycled materials can be input raw material, such as paper pulp and glass. Finally, in energy recovery products are burned and the released energy is captured (incineration). If none of these recovery processes occur, products are likely to go to landfill.

Finally, **re-distribution** refers to logistics activities required to introduce a product into a market and transfer it to customers (i.e. storage, sales and transportation).

Figure 3 shows a schematic of a typical supply chain, with the inclusion of the recovery process.

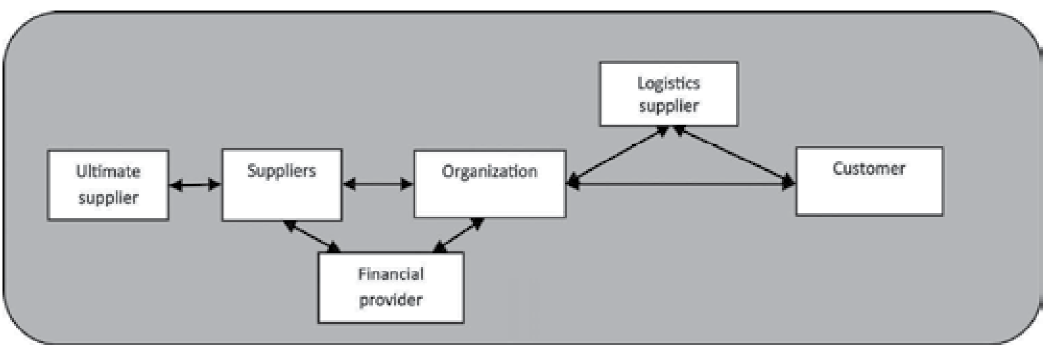


Source: adapted from Srivastava (2008)

Fig. 3. Reverse flows in the supply chain

6. Managing product returns and organizational design

The organizational implications of RL management concerns what kinds of inter-firm relationships are relevant. Halldórsson and Skjøtt-Larsen (2007) identify the two reverse supply chain 'extremes' – at one extreme, there is the centralized reverse supply chain, whereby one organisation has responsibility for collection, inspection, disposition and redistribution of returned items. At the other extreme is the decentralized reverse supply chain, which consists of multiple organizations involved in all these processes. Between the two extremes are various hybrids. The reverse flows management requires planning, managing and controlling these flows through the integration of key processes, from consumers to the original suppliers. Mentzer et al. (2001) identify three degrees of supply chain complexity: a "direct supply chain," an "extended supply chain," and an "ultimate supply chain." A direct supply chain consists of a company, a supplier, and a customer involved in the upstream and/or downstream flows of products, services, finances, and/or information. An extended supply chain includes suppliers of the immediate supplier and customers of the immediate customer, all involved in the upstream and/or downstream flows of products, services, finances, and/or information. An ultimate supply chain includes all the organizations involved in all the upstream and downstream flows of products, services, finances, and information from the ultimate supplier to the ultimate customer (Figure 4).



Source: Mentzer et.al. (2001)

Fig. 4. Channel relationships

Companies are responding to the challenges, in particular through a focus on:

- building greater value for their customers and shareholders;
- integrating traditionally distinct business functions across the entire business network;
- developing distinctive capabilities around their relationships with their trading partners, the design of information systems, and the re-structuring of their business models.

The companies have started to work more collaboratively with their suppliers and logistics partners in order to provide a seamless service to their customers. This trend has brought about the adoption of a new and more complex business model that includes coordination and collaboration with channel partners, which can be suppliers, intermediaries, third-party service providers, and customers. These companies are interdependent in such a way that an individual company's performance affects the performance of other members of the supply chain.

7. Outsourcing reverse logistics: The role of fourth party logistics provider

According to Berglund et al. (1999) two factors lead companies to outsource: the size of the demand and the size of the supply chain. In an adaptation of the topics suggested by Bolumole (2001) and Jaafar and Rafiq (2005), below is shown a summary of the motivations and reasons for a company to outsource logistics services:

- Concentrating efforts on their own business and gaining new markets;
- Reducing logistics costs and avoiding investments in assets unrelated to the company's business;
- The presence of a complex supply chain due to a fragmented suppliers base;
- Increasing product restitution (reverse logistics);
- Coordinating logistics activities in a wider context;
- Improving and controlling the quality of logistics services and activities;
- Greater flexibility and efficiency in logistics operations;
- Access to new Information and Communication Technology (ICT) and logistics knowledge.

Langley et al. (2007) asserted that, by incorporating new activities required by the market, the LSP has changed in recent years, a movement that demonstrates the progress and maturity of these operators. However, clients expect to achieve greater skills in service development, relationship improvements, relevance in information and involvement of integration rules and concepts in the supply chain through the LSP, and to build expertise and dedicated operations. Likewise, for these authors, the market turns to solutions proposed by companies focusing on logistics coordination. The following are expectations for the LSP:

- Evolve into a solution provider for the supply chain;
- Increase the portfolio of outsourced services through a larger number of activities (expand services for its clients)
- Continuous improvement in technology and ability to provide the necessary services;
- Focus on the client's needs (provide the right solutions, become involved in the client's plans for integration and understand the industry-client)
- Expand its relationship with the client;
- Continue to acquire companies and expand businesses;
- Act in global markets;
- Move toward logistics coordination solutions as a 4PL;
- Search for long term relationships, based on contracts with duration exceeding two years.

As the practice of reverse logistics outsourcing and SCM have become increasingly important as a source of competitive advantage, researchers have started to explore various research topics related to reverse logistics outsourcing and the role of specialized reverse chain players (Carter and Ellram, 1998; Sanders, 2005). Increasingly, as a strategy, to compete on services, companies offer repair and replacement services for their products under the warranty periods. The defective products are often shipped across international borders to common repair centers to be refurbished and returned to the originating station. Logistics service providers who offer these services have to tackle issues pertaining to duty payment on refurbished products, customs documentation and the establishment of collection points for repair for the customers.

The outsourcing of an increasing number of logistics activities to Logistics Service Providers (LSP) is a growing trend and business practice followed world wide by the industry. The outsourcing of logistics activities can be defined in three levels, the transactional outsourcing, the tactical outsourcing and thestrategic outsourcing. The transactional outsourcing is based on logistics transactions, with no long-termcontracts and no bonding between the Logistics Service Providers (LSP) and the outsourcing company. The tactical outsourcing is the logistics reinforce and improve the network's performance. Such logistics activities are, for instance, transportation, inventory management, storage, material handling, packaging, production planning, information processing, facility location, purchasing, demandforecasting, customer service, and design, redesign and control of the logistics network outsourcing on a long-term basis with negotiated contacts and integrated IT systems to facilitate freeinformation flow and create supply chain visibility. The strategic outsourcing is based on long-term relationships with successful outcomes where LSP business entities become partners with their clients in the logistics-network management and establish transactional transparency.

More and more firms now realize that the reverse logistics is a business process by itself and needs core competency to successfully manage it (Lieb, R. and Bentz, B.A., 2003). As legislation such as the WEEE directive comes into force, and organizations have to be able to deal an increasing volume and variety of returns. There are opportunities for the small and medium firms to cooperate with other organizations to create sufficient volume to justify the developmente of reverse logistics programmes. As firms develop core competency in the fulfillment process, the core competency on the reverse logistics too may be difficult to attain for the same firm. Fortunately, there are specialized firms in the market now that have already developed core competency in many of the business processes involving reverse logistics, and are rapidly becoming the preferred outsourcing alternatives for the firms (Verstrepen S., et.al.,2007). According to John Gattorna, "While outsourcing third-party logistics is now an accepted business practice, 4PL is emerging as a breakthrough solution to modern supply chain challenges...to provide maximum overall benefit". The concept of Fourth-Party Logistics (4PL) Provider was created and first defined in 1996 by Accenture as the use of a consulting firm to integrate and manage a company's logistics resources and LSP partners including Third-Party Logistics (3PL) providers and other transportation companies. In particular, Accenture defined a 4PL Service Provider as an integrator that assembles the resources, capabilities and technology of its own organization and other organizations, to design, build and run comprehensive logistics network solutions. Fourth-Party Logistics (**4PL**) providers, who, in addition to the classic 3PL operations can manage all of the "information systems" interfaces needed to mobilise all of the resources of the upstream (suppliers) and downstream (distributors, service providers) actors involved in the e-supply chain.

The 4PL are companies which have no physical assets of their own but specialize in buying and coordinating logistics. Andersen Consulting defined a Fourth-Party Logistics Providers as: "A supply chain integrator who assembles and manages the resources, capabilities, and technology of its organization with those of complementary service providers to deliver a comprehensive supply chain solution." Central to the 4PL success is a "best of breed" approach to providing services to a client. The development of 4PL solutions leverages the capabilities of third-party logistics providers, technol-ogy service providers, and business process managers to create a solution through a centralized point of contact. As a result, 4PLs have become logical alternatives for business process outsourcing by providing visibility and integration across multiple enterprises. Users of a 4PL can focus on core competencies to better manage and utilize company assets and resources, as to inventory and personnel. There are only a few studies in the literature that examine the role of 3PL/4PL in reverse logistics. Some autors pointed out that the use of specific technological capabilities may facilitate more effective integration across companies in the sup-ply chain (Van Hoek 2002). For 4PLs, ICT capabilities can assure the rapid customisation of products and maintain competitive lead-times. Mukhopadhyay and Setaputra (2006) provide a a model to develop optimal decision polizie for seller and 4PL. Information and communication technology (ICT) has become an important element of 4PLs competitive capability as it enables higher levels of reverse logistic integration. Specifically, the type of IT used largely determines the nature and quality of interactions the company has with customers, suppliers, and trading partners. A high level of IT capability has been shown to provide a clear competi-tive advantage and can be a differentiating factor in terms of company perfor-mance (Earl, 1993; Kathuria et al., 1999). The result is that competitive advantage in the 4PL industry will be based increasingly on creating value for customers as many value-added activities are directly or indirectly dependent on ICT applications (Crowley, 1998). The development of 4PL(TM) solutions leverages the capabilities of third-party logistics providers, technology service providers, and business process managers to create a solution through a centralized point of contact. For exemple, in Italy CCR Italia is a reverse logistic service provider located in Torino, and it is a specialist in the development and implementation of Europe-wide reverse logistics solutions for products, components and materials with a focus on B2B solutions. The company operate in the Italian market as a “solution integrator” that manages an integrated reverse logistics processes (recycling, land-filling and reuse) for a single client, and coordinate a complex network in which the 4PL combines the resources and capabilities of several third party logistic provider (Fig.5). A 4PL is treated as a strategic partner, rather than a tactical one and is a supply chain integrator that synthesizes and manages the resources, capabilities, and technology of its own organization with those of omplementary service providers to deliver a comprehensive supply chain solution. The 4PL Service Provider is an external organization which completely integrates its client’s logistics network. Planning and management of the total logistics network are put into hands of an external company that acts as the single contact between the client and the 3PL Service Providers.

The core value offered by a 4PL firm is in the management and integration of the information flow between the outsourced logitics-network partners and the enterprises that employ them. By taking care of the planning, steering and controlling of all logistics procedures, the Fourth-Party Logistics (4PL) Service Provider is able to combine the economy of skill with the economy of scale. Fourth-Party Logistics (4PL) is the next generation of LSP firms, with operations that extend beyond 3PL and include logistics-network analysis, design and planning. While the present logistics activities provided by a 3PL service provider simply include the coordination of the distribution from one place to another, 4PL providers make possible for the companies to develop a superior expertise in transportation, warehousing and other logistics fields. 4PL companies are suppliers which have the expertise to manage resources, value delivery processes and technology for their clients in order to allow their clients to totally outsource their logistics management activity. The 4PLs do not compete with 3PLs as they have superior expertise in their respective fields by virtue of their investment and specialization. 4PL providers do not own assets for transportation or warehousing, but rather leverage the solutions created by 3PL, in order to identify and provide 'best in class' services to their clients.

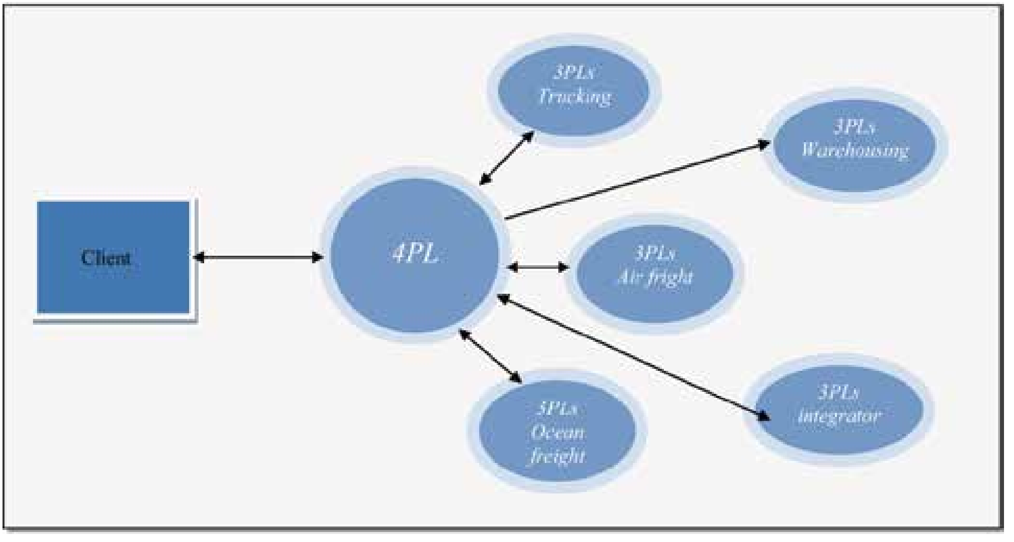


Fig. 5. 4PL as a solution integrator

There are many variations of the 4PL model that are practiced. Three different models are summarized as under:

a. Lead logistics provider: The 4PL provider acts as an in house freight management company, it might or might not have a role in the selection of 3 PL partners. It takes care of transport invoicing and the monitoring of the performance of the 3 PLs;
b. Solution Integrator: In this variant of the model, the 4PL acts as the integrator of various 3PLS and as a single window for freight negotiations, 3PI selection and freight management on behalf of its client;
c. Industry Innovator: Under this model the 4PL uses its expertise and resources to create a solution not for any single client, but for offering 4PL services to a number of clients in an industry.

The services provided by a 4PL provider are show in table 3. The 4PL Service Provider integrates 3PL Service Providers together with IT Service Providers supporting simultaneously and managing its clients' business processes. A 4PL actor can achieve greater logistics functional integration and broader operational autonomy managing its clients' logistics networks from upstream todownstream and from a holistic perspective.

	Basic	Intermediate	Advanced
Physical Services	None	None	None
Administrative services	Tendering & contracting carriers Insurance services	Payment services Financial services Order administration & customer service Claims handling Track and trace information Providing one stop logistics services purchase Export and import clearance	Design of individual logistics setup Operation of customers' logistics setup Responsible for the customers' logistics oparations Exception management

Table 3. 4PL Services

The outsourcing of logistics activities requires creating synergetic relationship between the partners with the objective of maximizing customer value and providing a profit for each supply chain member. Coordination within a supply chain is a strategic response to the challenges that arise from these dependencies. There is a growing body of academic research, in a variety of disciplines, on coordination in supply chains, particularly addressing the potential coordination mechanisms available to eliminate sub-optimization within supply chains. Similarly, there is a growing interest in industry to better understand supply chain coordination and the coordination mechanisms that are available to assist the supply chain manager.

8. Reverse logistics information systems and 4PL capabilities

The new operating environment and the emergence of the extended enterprise model present many logistical challenges.Two particolar forces are at work in the evolving operating environment for supply chains. On the one hand, new technology is enabling the more rapid adoption of true supply chain integration within companies and collaboration across the supply chain of multiple companies. But on the other In particular, they note that information needs to cross organizational boundaries in order to support management decision-making. From the perspective of integrated supply chain management, it is necessary to establish a total supply chain network with an integrated database capable of supporting each activities and processes (Bardi, Raghunathan, and Bagchi 1994). Thus, information support is particularly critical to achieving efficient reverse logistics activities.

Bowersox (1989) proposes that the process of supply chain integration should progress from the integration of internal logistics processes to external integration with suppliers and customers. Internal and external integration can be accomplished by the continuous automation and standardization of each internal logistics function, and by efficient information sharing and strategic linkage with suppliers and customers. Major element in supporting this new business model is the timely availability of relevant information made available through the exploitation of information systems (IS). Reverse logistics is frequently characterized by uncertainty and a need for rapid timing/processing. While some industries can rely upon historical information to project the type and amount of returns, returns in other industries are much less easy to predict. Even in those less predictable industries, although managers may not know when products will be coming back, they must be prepared to quickly process and handle the products on demand. Thus, prompt and accurate exchange and access to information should be considered a top priority. So despite the open access to new technology and the increate availability of information, which are the lifeblood of reverse logistics integration, relatively few companie have improved their integration and collaboration capabilities across supply chain.

In such situations, information coordination is complicated because different are the actors involved. As Blumberg (1999) notes, there is great need for coordination between the parties to ensure maximum efficiency. Communication becomes particularly critical to facilitate daily interaction and to promote longer-term business relationships. The flexibility of a company's transaction processing system, the capability to transfer and gain access to information, and the real-time visibility of operational data are also essential elements in building the extended enterprise business model.

Rapid developments in information technology (IT) have many implications for the organization and management of the reverse logistics networks and offer the potential for businesses to exchange and share such information in real-time. The Internet, in particular, is providing an opportunity for companies to lower costs dramatically across the extended enterprise. The Internet, however, needs to be seen as part of the infrastructure supporting the integration of the extended enterprise. Several information systems (e.g. EDI, RFID and GPS14) are needed and can support the control and decision-making upon the efficiency and effectiveness of the modern logistics networks.

The IS provided by Fourth-Party Logistics (4PL) Service Providers mainly assist the participating actors throughout the logistics network to develop functional and technical requirements for logistics information systems incorporating logistics database design, customer response systems, inventory management systems, supply and production management systems, transportation management systems, warehouse management systems (e.g. WMS), and supporting logistics decision support tools.

Information and communication technology (ICT) has become an important element of 4PLs competitive capability as it enables higher levels of supply chain integration. Sauvage (2003) noted that in a highly competitive business characterised by time compression, technological effort becomes a critical variable and a significant tool for differentiation of logistics services. Its technological capacitation is also essential for the implementation and integration of services. Thus, technological support for data transfer and transactions has become a powerful tool for the LSP. With up-to-date information and communication technology, new configurations are presented for logistics management by the LSP, as several authors suggest (Hoek, 2006; Langley and Allen, 2005; Visser et al., 2004) when defining 4PLs as integrators or logistics leaders in a coordinating function that is broader than a simple operation. Specifically, the type of IT used largely determines the nature and quality of interactions the company has with customers, suppliers, and trading partners. For 4PLs, ICT capabilities can assure the rapid customisation of products and maintain competitive lead-times. The result is that competitive advantage in the 4PL industry will be based increasingly on creating value for customers as many value-added activities are directly or indirectly dependent on ICT applications (Crowley, 1998).This means information must be continuously accessible and shared across organizations. Such information support is a critical aspect of reverse logistics. ICT systems developed for the control and coordination of reverse logistics processes assist in the decision making for the recovery options of returns (reuse, remanufacturing, recycling) and support administrative tashs related to returns handling that contribute to more efficient returns management. Readly available abd accurate informations provide necessary support for accommodating non routine events such as product returns. Information support helps to reclaim value that might otherwise be lost and it also serves to improve buyer-seller relationships through improved customer service/satisfaction. IT allows supply chain partners to communicate directly over data-rich, easy to use information channels, which reduces coordination costs faster than in house production costs and promotes the trend toward outsourcing. In general it is important to know what product will be returned at which point in time at which place, in which conditions and under what grounds. Electronic Data Interchange (EDI) allows trading partners to Exchange information electronically in a very compact, concise and precise way and it provides different transaction sets for various types of business activities. One result of this development is CCR NET, a web-based order and documentation system developed by CCR that illustrates virtually the logistical process chains of industrial goods in the real world. Web-technologies to offer unique services for handling returns. For the customers, a large number of reports are available for downloading at any time. A range of operational performance and inventory data may be filtered according to different criteria, displayed and downloaded in the standard data formats (Excel, HTML, PDF and others), in line with individual requirements. CCR NET allows the cus-tomers different user roles - like, for instance, the overall view, but also partial views down to the smallest unit imaginable - in order to take account of the inter-nal structures of our customers. On the basis of CCR NET, the provider's specialists assemble the necessary documentation (as specified by legislation on waste disposal) for internal verification and for the authorities. Verification may take place via reports, or via electronic interfaces to the IT systems of its customers and the authorities. For example, this includes waste balance sheets, substance flow proofs, recycling quotas and individual verifications, and even weight forms or in-dividual delivery documents. Within the clearing functionalities, money and material flows may be directed according to the individual requirements of customers. This includes payments to consumers or commercial businesses for deposits or material values which are transferred by CCR on the order of the customers. The customers decide on the type or characteristics of their deposit or bonus sys-tems, according to their objectives; CCR for its part organises the flows of mate-rials, information and money by means of its comprehensive reverse logistics sys-tems. Those receiving payments are, as a rule, also integrated into the circulation of information via CCR NET, and can pursue and monitor their entitlements and incentive bonuses there, by means of appropriate reports. The provider confirmed that its IT solutions allow effective information sharin with clients, increase transparency, safety and efficiency in the return processes. One of the first visible effects associated with the increasing dissemination of ICT in the CCR reverse logistics service is the integration of traditional reverse logistics activities with information-based services. The linking of data-streams and the prompt review of goods transport processes in an electronic data processing system are becoming more and more important for the optimisation of monitoring and control functions, but also in ensuring transparency and safety and lower coordination costs. It maps all the relevant data of a reverse logistics process and involves all those taking part. Having developed it selves brings the enormous advantage that the provider can offer competent and efficient customer-specific solutions and undertake tailor-made adaptations. Thanks to skilled technical and information system solutions the company allowing the customers to: close integration with the customer's processes and IT systems; securing and uti-lising secondary resources, thus strengthening the company's environmental and social responsibility; facilitates access to new markets and supports sales revenues; reduce handling of products; improve performance efficiency; greater flexi-bility; reducing communication errors, better visibility and customer satisfaction.

However, effective fast cross organizational sharin of information is possible if information systems are compatible, such a sit refers to how easy it is to use. In a reverse logistics context, this would means that channel members' information systems must be compatible, i.e., in agreement. IS support compatibilità implies the existence of congruent systems that facilitate Exchange between separate organizations. Chapman et al. (2003) reported that logistic organizations are redesigning their structures and relationships, creating a knowledge chain that facilitates and improves data, information and knowledge communication, as well as coordination, decision-making and planning. They should mainly synchronize activities between agents of the supply chain (aiming to gain and integrate knowledge) and operate with information and communication technology, thus providing greater efficiency and productivity for the chain. Ratten (2004) highlighted that many logistics alliances have been made based on technological changes, and improved data transmission and transactions. In this case, alliances with companies of the technology sector may be necessary for the LSP.

9. Conclusion

The exchange of information through customers and 4PL is an essential condition for realizing the potential benefits of collaborative relationships (performance). ICT systems developed for the control and coordination of reverse logistics processes assist in the decision making for the recovery options of returns (reuse, remanufacturing, recycling) and support administrative tasks related to returns handling that contribute to more efficient returns managemen. The increased speed and flexibility of information and knowledge transfer allowed for more efficient coordination, and eventually higher revenes and profits, for all members of the supply chain, reducing communication errors, facilitating information knowledge sharing and increase integration between the supplier and buyer firms. Especially, the relationship and collaboration with customers is very important for e-service innovation. The findings of our study also have implications for managers both of

4PL providers and logistics users. The first is that 4PL managers must realize the importance of IT capability, as superior IT capability is a source of competitive advantage. The critical role of IT in saving costs, improving service quality and providing a variety of services cannot be ignored. Our study clearly shows the importance of technology orientation in the development of IT capability. 4PL firm managers are therefore recommended to dedicate themselves to the development of an organizational culture that favors IT. A stronger technology orientation in a 4PL firm helps top business managers to facilitate resource allocation to IT investment and encourages their involvement in IT strategies and planning (Segars and Dean 2001). Well-developed IT capability in a 4PL firm can improve the efficiency, effectiveness and productivity of business operations and thus provide a cost advantage. For example, the adoption of e-business by 4PL firms may help them to expand their customer base and save costs through automated online transactions. Our findings are consistent with other empirical studies that find support for the positive effect of IT capability on cost advantage (e.g., Ravichandran and Lertwongsatien 2005).

Finally, we recommend that the managers of logistics users consider the IT capability of 4PL firms in making outsourcing decisions. Especially, such a consideration is more important for logistics users which aim at long-term relationships with 4PL firms (Knemeyer and Murphy 2004; Cox et al. 2005). The developing strong, long-term partnerships required design managerial components and relationship activities that support the development of intangible connections (trust, commitment, cooperative norms, etc.) with partners.

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7

Environmental Impact of Supply Chains

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1. Introduction

Focus on sustainable development and green economics has been growing in the past two decades in a myriad of different fields. As such, there has been a great deal of research performed in the fields connected with supply chains and logistics. Different buzzwords have been used such as green supply chain management, green logistics, sustainable supply chains, sustainable transport etc.

The first part of the chapter summarizes the meaning of terms "green" and "sustainable" while outlining their importance in relation to supply chain management. The relation is emphasized with end consumer product examples from the viewpoints of green and sustainable.

The second part of the chapter provides a literature review of recently published scientific papers of the fields relating to green and sustainable supply chain management. The review includes scientific papers from various research fields such as supply chain management, operations research, sustainable development, green environment, logistics etc. Several other reviews that were conducted in past decade are also referenced in order to provide additional insight into the field. Special focus of the literature review lies on interdisciplinary papers that cover different interconnected fields of research with focus on sustainable development, green environment and supply chains.

Third part of the chapter presents main drivers and barriers for companies and supply chains when adopting green and sustainable supply chain management concepts.

Based on literature review the outlines for further research are presented in the last part of the chapter.

2. Green and sustainable. Which is what?

Focus on sustainability and green has been growing in the past two decades in a myriad of different fields. As such, there has been a great deal of research performed in the fields connected with supply chains and logistics. The words green and sustainable have been popularized and used in connection to various other terms. As a result different buzzwords have been coined such as green supply chains, green logistics, sustainable supply chains, sustainable transport etc.

Even though the terms green and sustainable development have been widely popularized there are often misconceptions or misunderstandings as to what they mean. Therefore this section of the chapter will briefly describe both terms and provide several examples which will provide clear and concise differentiation between the two.

Sustainable development has become widely used and promoted by various government and non-government organizations since the eighties (Bebbington & Gray, 2001). The most known and widely used definition for sustainable development is the one from the United Nations World Commission on Environment and Development which defines sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Our Common Future (The Brundtland Report), 1987).

However, lack of consistency of interpretation of sustainable development phrase has been identified (Lélé, 1991). Therefore, many different interpretations of sustainable development are possible, with some of them presented in Hopwood, Mellor and O'Brien (2005). The authors also propose a classification and mapping methodology of different trends of thought on sustainable development, their political and policy frameworks and their attitudes towards change and means of change, all of which is an extension of previous research of this field.

Since the goal of this chapter is to provide insight into differences between green and sustainable development a general definition of sustainable development based on the research presented above is defined. Sustainable development stands for ways of environmental exploitation that will enable the same or comparable exploitation for further generations. Therefore something that is sustainable lowers the pressure on environment to such levels that the environment can renew the exploited sources which will be used by future generations.

The other term which we deal with is "green" as in relation to green economy. The term is often used in relation to sustainable development; however they do not necessarily mean the same thing. Pearce (1992) argues that achieving environmental improvement will require policies that use selfishness rather than opposing it. Another often used expression is also green economics. An extensive history on development of green economics can be found in Wall (2006) where the author also discusses green economics in relation to global economy.

The latest definition of green economy is based on United Nations Environment Programme (United Nations Environment Programme, 2010) which implies that green economy results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities.

Based on definitions presented above it is therefore possible to discern the difference between sustainable and green, even though both expressions are often used interchangeably. Therefore we briefly outline a consumer product point of view and associate it with green and sustainable development. A consumer product can be green which means that it lowers the impact on environment by its use while it is not necessarily sustainable as in produced in a way which ensures minimum impact on the environment in forms of resource exploitation and pollution.

Below are a few examples of consumer products where we try to discern if they are green and sustainable:

- Bicycle. A bicycle enables lower pollution when used for travel in urban areas. If compared to alternatives such as a car, a motorcycle or even public transport which consume fuel and pollute the air or consume electricity, it presents a much "greener" alternative. However, an important question that needs to be asked is whether the bicycle is also a product that helps to add to sustainable development. The answer depends on the way the bicycle was designed, manufactured, shipped and sold. If the manufacturer uses out of date production processes, shipper uses high polluting vehicles and the store discards defective bikes instead of properly dismantling them, then there is a high chance that this particular bicycle will not add to sustainable development, since the impact on environment from manufacturer to the end customer would be too high to offset the benefits of the "green" use of the bike when compared to other mentioned transportation options. It is important to note the role of supply chain in the above example.
- Sports car. This is a product that enables travel, however the fuel consumption is a lot higher that a lot of other means of travel. Therefore it cannot be labeled as a green product. However, a sports car can be manufactured in an advanced manufacturing plant, using state-of-the art technologies which have a very low impact on the environment. Additionally, materials used in vehicle production can come from recycled products while the vehicle itself can be recycled after the end of its use. Therefore a sports car can be a sustainable product while not being a green product.

Both of the above products can be both green and sustainable and the presented examples are just extreme examples. Below is another example of a product that is both green and sustainable:

- Digital reader. Digital reader enables the consumer to read various published content without use of paper. Since a digital reader consumes very low amount of power compared to alternatives (such as other types of displays) it can be considered green. If the production and distribution of the reader also leaves minimum impact on the environment it is also a sustainable product.

As we can see from the examples above supply chains have a significant impact on whether a product is considered sustainable, green or both.

Therefore we present a recent literature review on green and sustainable supply chains and supply chain management in the next section of this chapter. The last section of the chapter presents a conclusion and outlines possibilities for further research in this field which are based on the literature review.

3. Green and sustainable supply chains

As seen in previous section of this chapter the importance of green and sustainable supply chains is increasing as the companies start to compete on a supply chain level instead on a level of a particular company. Therefore the need for the research of sustainable development and green environment is also rising, in particular in connection to supply chain management. Therefore this section of the chapter provides an outline about past and current research conducted in these fields. The conclusions and further research pointers are presented in the last section of the chapter.

There are several different definitions of green supply chain management and sustainable supply chain management. Some of the most recent ones based on extensive literature reviews are presented in the following paragraphs.

Srivastava (2007) identifies green supply chain management as "integrating environmental thinking into supply-chain management, including product design, material sourcing and selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life."

Sarkis, Zhu and Lai (2011) define green supply chain management as "integrating environmental concerns into the inter-organizational practices of supply chain management including reverse logistics".

Carter and Rogers (2008) define sustainable supply chain management as "strategic, transparent integration and achievement of an organization's social, environmental, and economic goals in the systemic coordination of key inter organizational business processes for improving the long-term economic performance of the individual company and its supply chains" which is based on intersection of social, environmental and economic performance and the supporting facets of this triple bottom line which are risk management, transparency, strategy and organizational culture.

Seuring and Müller (2008) define sustainable supply chain management as "the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements".

The above definitions provide an important insight in what a green and sustainable supply chain is. Green supply chain management definitions place the emphasis on integration of environmental issues into supply chain management. On the other hand the sustainable supply chain management definitions employ three different dimensions to sustainable supply chains, which are economic, environmental and social.

While green supply chain management research places the emphasis on one of the three dimensions, the sustainable supply chain management research tries to address all three. As we will see in the following chapter the most often researched dimension is economic, followed by environmental dimension, while social dimension has not often been included in the research.

Promotion and development of reverse logistics and closed loop supply chains in the past decade has paved the road for green supply chain management (Hoek, 1999). It is not enough for supply chains to merely introduce a reverse flow of goods, but they also need to be properly re-manufactured, disassembled or disposed of (Hoek, 1999). While reverse logistics can be seen as a part of sustainable development they differ from green logistics as that considers environmental aspects to all logistics activities and has been focused specifically on forward logistics (De Brito & Dekker, 2003).

The research interest in everything that is green and sustainable in connection with supply chains, logistics and transport has increased dramatically in the last decade.

Table 1 shows data obtained on ISI Web of Science and relates to the number of publications per year when searching for different keywords.

Year	Number of hits
2011	58
2010	86
2009	45
2008	48
2007	42
2006	20
2005	20
2004	17
2003	16
2002	11
2001	8
2000	13
1999	10
1998	8
1997	8
1996	6
1995	3
before 1995	3

Table 1. Search results for different keywords on Web of Science

The keywords that were used for searches presented in Table 1 were green supply chain, green logistics, sustainable supply chain, sustainable logistics, green transport and sustainable transport. The number of hits for each year presents the cumulative of hits for all search results. The highest search results were for the keywords sustainable transport, which constitute for about one third of overall searches, followed by green supply chain and sustainable supply chain keywords.

Due to the time of this publication the search results for year 2011 are only available for first half of the year. If the result was to be extrapolated to the entire year 2011 the number of hits would be well over 100.

The amount of hits before year 1995 is cumulative, indicating that there was not much research interest in this field before that date. One of the reasons for lack of hits before year 1995 is also the late development of the term supply chain management which was first introduced in the eighties (Ganeshan, Jack, Magazine, & Stephens, 1998).

As we can see from the above fast growth in research interest has led to a fast rise of publications on the green and sustainable supply chain topics, therefore the need for literature classification has arose with different literature reviews on topics of green supply chain management and sustainable supply chain management being conducted.

Below we present several literature review papers that have been published in the last few years that deal with literature review of either green or sustainable supply chain management and propose further research which is summarized in the last section of this chapter.

A throughout research on the topic with proposed framework for sustainable supply chain management that includes papers from 1994 to 2007 has been conducted by Seuring and Müller (2008). Authors assume that economic dimension has been covered by all papers included in research since the papers were from management journals and publications, therefore only environmental and social issues were an issue. Papers which included all three dimensions were classified as sustainable. Out of 191 papers only 31 were classified as addressing sustainability related issues. The proposed framework consists of three parts: triggers for sustainable supply chain management, supplier management for risks and performance, and supply chain management for sustainable products. Drivers and barriers of the proposed framework are presented under section 4 of this chapter.

Another literature review has been conducted by (Srivastava, 2007) which includes around 1500 published units in forms of books and papers dating back to 1990. The research classifies green supply chain management based on the problem context in supply chain's major influential areas, which are literature highlighting the importance of green supply chain management, literature on green design and literature on green operations, while ignoring literature on green logistics as is operational and not strategic in nature. Another proposed classification of green supply chain management literature in the research is by methodology and approach usage: thought papers and perspectives, frameworks and approaches, empirical studies, mathematical modeling approaches, reviews. The authors' findings show that emphasis in green supply chain management research was on quality, operations strategy, supply chain management, product and process technologies. However, they suggest that more integrative contributions are needed such as intra- and inter- firm diffusion of best practices, green technology transfer and environmental performance measurement.

Categorization of green supply chain research under nine broad organizational theories has also been conducted (Sarkis et al., 2011), focusing on the theories that were used more often in the published papers, which include complexity theory, ecological modernization theory, information theory, institutional theory, resource based view, resource dependence theory, social network theory, stakeholder theory and transaction cost economics. Authors argue that organizational theory provides a very valuable source of theoretical underpinnings for investigating and furthering research in green supply chain management and that this type of research has future potential. Furthermore, authors also identify organizational theories that would help to further understand green supply chain management which are diffusion of innovation, path dependency, social embeddedness and structuration theories.

Carter and Rogers (2008) perform a large-scale literature review and use conceptual theory building to introduce the concept of sustainability to the field of supply chain management.

They propose a sustainable supply chain management framework based on resource dependence theory, transaction cost economics, population ecology and resource based view of the company. They suggest that sustainability is an intersection of environmental, social and economic performance.

Further research (Carter & Easton, 2011) has shown that environmental aspects of supply chain management have been the leading focus. The share of research employing any sort of theory has been increasing, with stakeholder theory being the most prevalent. Furthermore, the research shows that the sustainable supply chain management research focus in past twenty years has focused on consumer related and transport industries; however the majority of studies focus on multiple industries. Majority of sustainable supply chain management research uses survey as the primary data collection methodology but the number of papers using this methodology is declining. On the other hand research using case studies, archival data and individual interviews are on the rise.

Other authors agree that in the past most of the research has been focused on environmental aspects of manufacturing while largely ignoring other aspects of sustainability or the challenges for the service sector (Piplani, Pujawan, & Ray, 2008).

Another recent literature review concerning green supply chain management has been published by Carvalho and Machado (2009). The paper amongst other things identifies supply chain characteristics that must be managed to assure supply chain's harmonization with the ecologic and environmental aspects that production processes may attend.

4. Drivers and barriers of green and sustainable supply chain management

One of the most important questions is why green and sustainable supply chain management would even be considered. Companies strive to achieve maximum profitability which does not always include sustainable development or green products. Therefore companies and supply chains need incentives in order to pursue green and sustainable supply chain management. These incentives can be found from different sources, usually internal and external.

A recent literature review and an explorative study (Walker, Di Sisto, & McBain, 2008) has identified several different drivers that promote green supply chain management. On one side there are internal drivers in form of different organizational factors, while on the other side there are external drivers such as regulation, customers, competitors, society and suppliers. Organizations that were included in the research tend to be more incited by external drivers than internal drivers.

Seuring and Müller (2008) determine that external pressures and incentives that are most common are legal demands, customer demands and response to stakeholders, while reputation loss is one of the least common incentives. On the other hand internal barriers for sustainable supply chain management were higher costs, coordination complexity, coordination effort and insufficient or missing communication in the supply chain, while important internal supporting factors are company-overlapping communication, management system, monitoring, evaluation, reporting, sanctions.

Another recent study (Mann, Kumar, Kumar, & Mann, 2010) identified drivers that promote sustainable supply chain management which are also separated in two groups: internal and external. Internal drivers are financial, internal business process and drivers related to customers. External drivers according to this study are legislation and environmental drivers.

Empirical study of sustainable supply management (Ageron, Gunasekaran, & Spalanzani, 2011) ranks different factors in accordance to their importance according to the study. Most important motivator for companies to employ sustainable supply chain management is customer satisfaction, followed by supplier's ability to innovate. The least important are supplier lead-time and order fulfillment costs. Authors conclude that external factors are more important than internal.

Next to drivers some authors also indentify pressures and form a joint group of drivers and pressures (Zhu & Sarkis, 2006). Those drivers and pressures are: regulations, marketing, suppliers, competitors and internal factors. The drivers are not universal across different industries which means that companies or supply chains are influenced by the industry that they operate in (Zhu & Sarkis, 2006).

Distinction must also be made when comparing different sizes of companies that are included in supply chains. The drivers for green supply chain management initiatives for small and medium suppliers can be different from drivers of large companies and consist of buyer influence, government involvement and company's internal green supply chain readiness (Lee, 2008).

However, there are also barriers when considering green supply chain management. Walker et al. (2008) identify two types of barriers. Internal barriers are costs and lack of legitimacy while external barriers are regulation, poor supplier commitment and industry specific barriers. Ageron et al. (2011) provide a research study which financial factors as ones that present the greatest barrier, namely the difficulty in assessing the amount to invest and evaluating the return on investment.

5. Conclusion and outlines for further research

In the first part of the chapter we provided general definitions for sustainable development and green economy. We have emphasized the importance of both concepts in relation to supply chain management. Hence we delved deeper into this connection in the second part of the chapter where we provided the definitions for both green and sustainable supply chain management and outlined the differences between the two. Green supply chain management only addresses environmental dimension of supply chains while sustainable supply chain management also addresses economic and social dimensions of supply chains. Due to identified increased research interest in both topics we exposed several of the recent studies about research on green and sustainable supply chain management. A separate section is also devoted to the drivers and barriers that companies face when introducing green and sustainable supply chain management.

Green and sustainable supply chain management has become an important research topic in the past decade and its popularity is still increasing. Therefore there are a lot of new research questions and issues that are being identified throughout research and practice. We conclude that environmental impact of supply chains can be enormous due to the presented green and sustainable supply chain management concepts in this chapter. Furthermore, many additional interdisciplinary research questions are being identified by several different researchers and practitioners.

Some of the research challenges in the fields of green and sustainable supply chain management that were outlined by different authors in the past few years are listed and briefly described:

- Promoting the usage of different organizational theories in green and sustainable supply chain management research (Sarkis et al., 2011), with emphasis on transaction cost economics organizational theory (Carter & Easton, 2011).
- Focus on research of individual industries in order to identify types of sustainability activities that are specific to those industries (Carter & Easton, 2011).
- Expanding sustainable development from environmental improvements to social improvements (Seuring & Müller, 2008).
- Changing the unit of analysis from a company to an individual manager in order to find out what drives managers into sustainability commitment (Carter & Easton, 2011) and in relation to that finding out how environmental concern on the minds of the management of firms is independent from that arising from legislation, customer pressure or social activism (Mann et al., 2010).
- Sustainable supply chain management research needs more emphasis on collecting empirical data from companies (Ageron et al., 2011), while also keeping importance of assessing validity instead of only reliability of data used in sustainable and green supply chain management research (Carter & Easton, 2011).
- Focusing more on a theoretical background for green or sustainable supply chain research (Seuring & Müller, 2008).
- Focus on service supply chains instead of just manufacturing supply chains (Carter & Easton, 2011).
- Cross-country empirical studies need to be conducted in order to see if there is any difference in the emerging models for sustainable supply chain management (Ageron et al., 2011).
- Exploring the consequence of green supply chain initiatives in terms of economic and environmental performance of both buyers and suppliers (Lee, 2008).

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8

Logistics and Supply Chains in Agriculture and Food

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1. Introduction

During the recent two decades, goods flow has been tremendously increased, even though the amount of goods remains at the steady state. Increased variety of goods, the just-in-time delivery system, low load rate, specialization and centralization of production systems, globalization of marketing and seasonal variations are among the main challenges of logistics system which may lead to the necessity of developing effective logistics in the sector. Effective logistics and technologies are a critical success factors for both manufacturers and retailers (Brimer, 1995; Tarantilis et al., 2004). Effective logistics requires delivering the right product, in the right quantity, in the right condition, to the right place, at the right time, for the right cost (Aghazadeh, 2004) and it has a positive impact on the success of the partners in the supply chain (Brimer, 1995).

Food chain logistics is a significant component within logistics system as a whole. The food sector plays a significant role in economy being one of the main contributors to the GNP of many countries, particularly in developing countries. According to the European Commission (2010), the food and drink industry is one of Europe's most important and dynamic industrial sectors consisting of more than 300,000 companies which provide jobs for more than 4 million people.

The current trend in food value chain is characterized by three overriding features:

a. greater concentration of farms, food industries, and wholesalers into smaller number with large sizes;
b. the evolution of integrated supply chains linking producers and other stakeholders; and
c. ever increasing consumers demand for food quality and safety (food that is fresh, palatable, nutritious and safe) and animal welfare (Opara, 2003). However, to date, the linkage between logistics systems of the stakeholders in the agriculture and food supply chains is rather loose and fragmented. Even within individual firms, the vertical and internal integration as related to freight and logistics is loose, and therefore they are both economically and environmentally inefficient and not sustainable. In this regard, effective and efficient logistics will be a critical success factor for both producers and retailers.

In addition to the increase in transport of agricultural and related goods in the recent decades, empty haulage is common in agricultural sector and the load capacity utilization level of vehicles is very low (it varies between 10 and 95%) (Gebresenbet and Ljungberg, 2001). Therefore, efficient use of vehicles could be among the methods to reduce transport work and attenuate negative environmental impact (Gebresenbet and Ljungberg, 2001).

Within the agri-food chain, meat chain became societal interest and area of attention by researchers because of animal welfare, meat quality, and environmental issues as transport and handling of slaughter animals are associated with a series of stressful events for animals, compromising their welfare and meat quality. About 365 million farm animals (45 million cattle, 95 million sheep, 225 million pigs, and 300 000 horses) are transported per year within the 15 member countries of the European Union (EU)

The resulting transport intensification leads to environmental degradation by contributing to air pollution, global warming, ozone depletion, resource depletion, congestion and traffic accidents, particularly in the densely populated areas. The aforementioned constraints in the Agri-food chain necessitate the development of innovative logistics system taking into consideration, road and traffic conditions, climate, transport time and distance, and queuing at delivery points to:

- strength the economic competitiveness of stakeholders in the food supply chain
- maintain quality or adding value of food and improve animal welfare
- attenuate environmental impact

The objective of this chapter is to highlight the logistics system in the Agri-food chain and present case studies. In most of the case studies, mapping out the material flow; investigating the possibilities and constraints of coordinated and integrated collection of primary production and goods distribution; and investigating the food products and means of production that supported by information technology were carried out. Optimization of collection/distribution and the reduction in emissions from the vehicles as a result of optimization are presented. It is assumed that the information achieved through this investigation will assist to develop an effective transport-logistics system, which may enable an efficient utilization of vehicles to meet the current demand for attenuating environmental impacts.

The main methodologies employed in the case studies that will be included in this chapter include one or more of the following:

a. Mapping out goods flow through comprehensive field data collection using questionnaires, interviews and measurements
b. Optimization including location analysis and route optimization
c. Coordination of distribution and demonstration
d. Clustering and integration
e. Modelling and simulation
f. Estimation of economic and environmental impact

The studies were carried out through interviews and literature studies, field measurements, simulation and optimization. Data collection on daily distribution and collection including geographical location of collections/distribution points and routes was done using the global positioning system (GPS) and geographical information system (GIS). Optimization of distribution/collection centers and route optimization were done using the gathered data and the software LogiX (DPS, 1996). Air emissions were calculated using the simulation model developed earlier by Gebresenbet and Oostra (1997), where the following parameters were considered: vehicle type, time (loading; unloading and idling), goods type, load capacity utilization level, transport distance; vehicle speed, geographical position of depot and delivery points, routes, and air emissions from vehicles.

In local food systems, the distribution infrastructure is partial, fragmented (Brewer et al., 2001; Saltmarsh and Wakeman, 2004) and often inefficient, as in non-centralized distribution, the share of the transportation cost per unit of the product is relatively high. This is an area that offers great potential for improvement with potential benefits both to suppliers and outlets. Case studies focused on local food systems, were carried and these studies confirmed that coordination and logistics network integration in food supply chain promote positive improvements in logistics efficiency, environmental impacts, traceability of food quality, and the potential market for local food producers. Such improvement is important as developing food product traceability systems has been a major challenge both technically and economically (Wallgreen, 2006; Engelseth, 2009).

In the case of animal transport and abattoir system, the operations considered involve loading, transporting and unloading animals and the slaughter chain from lairage box to cooling room for cattle carcasses. Data collection was carried out through truck-driver interviews; activity registration on routes and at delivery, and slaughter chain activity registration. Time and distance of transport could be reduced through route optimisation. The analysis of animal collection routes indicated potential for savings up to 20% in time, for individual routes (Gebresenbet and Ljungberg 2001).

In this chapter, the concept and case study on clustering and network integration is presented. In the case study, the locations of 90 producers and 20 delivery points were displayed on maps using ArcMap of GIS software and based on geographical proximity, 14 clusters were formed. The clustering and logistics network integration approach could provide an insight into the characteristics of fragmented supply chain and facilitate their integration. It indicated positive improvements in logistics efficiency, environmental impacts, traceability of food quality, and the potential market for local food producers.

2. Concept of logistics in agriculture and food supply chains

2.1 Logistics services in developed countries

The role of production and supply chain management is increasing worldwide due to the growing consumer concerns over food safety and quality together with retailer demands for large volumes of consistent and reliable product. In developed countries, product losses (post harvest losses) are generally small during processing, storage and handling because of the efficiency of the equipment, better storage facilities, and control of critical variables by a skilled and trained staff. Recently, the concept of Agricultural and Food Logistics has been under development as more effective and efficient management system is required for the food production planning, physical collection of primary produce from fields and homesteads, processing and storage at various levels, handling, packaging, and distribution of final product. In the food supply chain many stakeholders such as farmers, vendors/agents, wholesalers, rural retailers and suppliers and transporters are involved. At all levels, information flow and management of produce is essential to maintain the food quality throughout the chain (see Figure 1). The flow of input resources from farms to consumers needs to be described in detail and the constraints in each sub-process needs to be identified to develop appropriate solutions for logistics related problems.

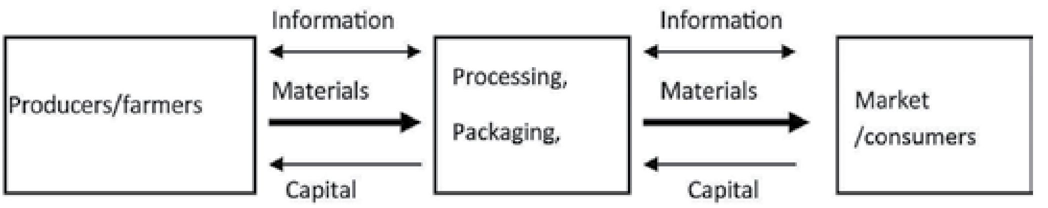

Fig. 1. Material, capital and information flow between producers (farmers) and consumers

It is important to note that lack of packaging facilities may be one of the constraints in the logistics system of small-scale farmers during the transition from subsistence to commercial farming. Significant post-harvest losses occur when especially vulnerable crops and fruits are subjected to mechanical damage (Ferris *et al*, 1993). Therefore management of packaging should be taken into consideration in the development of agricultural logistic systems.

2.2 Logistics service in developing countries

The development of smallholder agriculture in developing countries is very sensitive to transport strategies. Many isolated farmers have little opportunity to escape poverty, as their potential marketing activities are hampered by inadequate or poor transport facilities. The rural transport planning must address the needs of people, as much as possible at the household level. Such well planed transport system enables smallholders make the transition from subsistence to small-scale commercial farming. This helps them to harvest and market crops more efficiently, reduces drudgery and, by facilitating communication, helps stimulate social integration and improve quality of life. Availability of road infrastructure (that includes feeder roads, tracks, and paths), storage facilities and transport services increases mobility and encourages production (Gebresenbet and Oodally, 2005).

Typical transport activities of a small-scale farmer could be represented as in Figure 2. The arrows show people mobility and goods flow to and from a homestead. Rural transport is usually classified into on-farm and off-farm transport.

On-farm transportation includes:

a. transportation within fields
    i. collecting harvested crops to one point for processing in the fields and temporary storage;
    ii. distribution of fertilizers and seeds;
    iii. transporting of firewood, timber and
    iv. water,
b. transport of agricultural products from fields to homesteads,

c. transport of agricultural implements from homesteads to fields and vice-versa,
d. transport of seeds and fertilizers to the fields;
e. transport of implements between different plots etc.

Off-farm transportation includes:

a. transport of agricultural products including animals to local markets,
b. transportation to grinding mills
c. transport of industrial products (commercial fertilizers, implements, seeds, etc) from markets to homesteads,
d. transportation to health centres and schools, religion centres, and
e. transportation to towns and bigger market

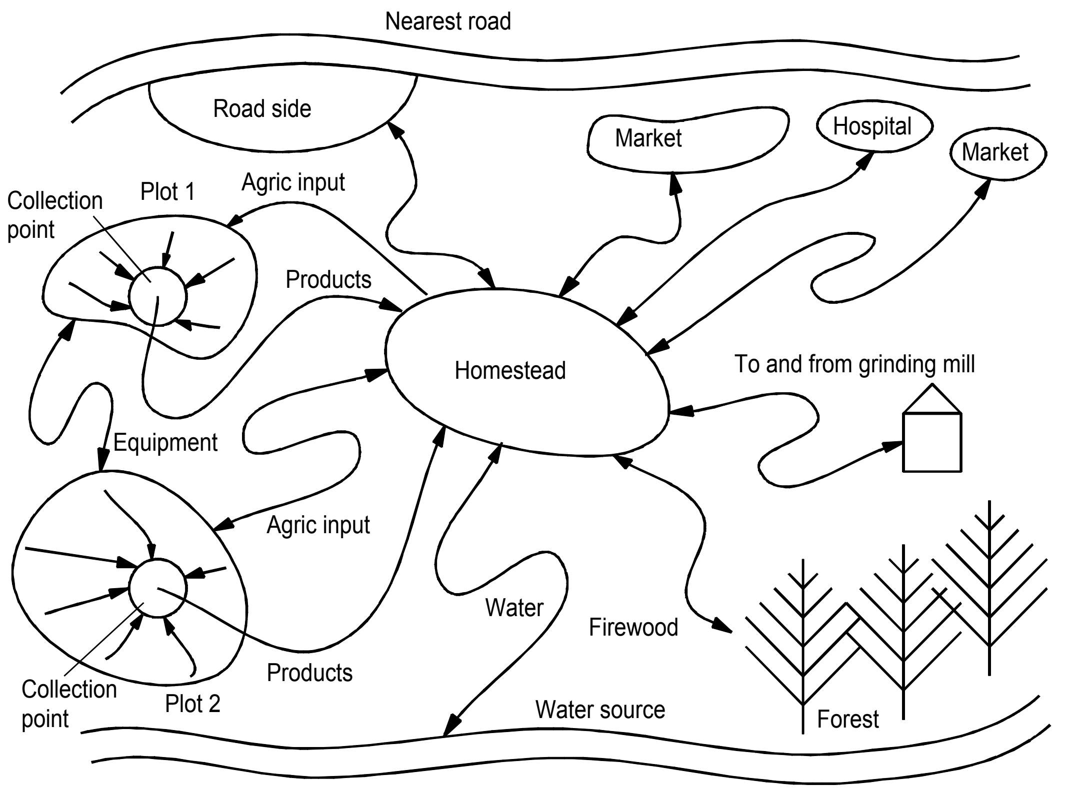

Fig. 2. Transport requirements for a typical small householder (Gebresenbet, 2001)

In agricultural systems of developing countries, animal power is used to replace human power and facilitate transport tasks. Animals are used to pull carts or sledges and as pack animals. At least ten species have been so domesticated, and their (absolute) capabilities depend primarily on body size. In relative terms, pack animals can carry 12 to 30 % of their body weight and can pull horizontally 40 to 60% of their body weight. These values depend on species, but field observations have returned higher values, probably at some cost of animals' well being.

In rural agricultural transport, in developing countries, special emphasis should be on collection, packaging, storage and distribution of agricultural primary products. Among the urgent tasks that formulated by the 8th plenary meeting of General Assembly of United Nation in June 1986, regarding transport and related infrastructure in developing countries, were improving and expanding the storage capacity, distribution and the marketing system; and development of transport and communications. Training of farmers (producers) may reduce loss due to harvest and temporarily storage, while other stake holders (for examples service providers) should take the responsibility to minimize loss. Loss in processing, storage and handling is high because of poor facilities and frequently inadequate knowledge of methods to care for the produce. Post-harvest losses run up to 40% varying from 15 to 25% on farm and 10 to 15% in trade. The high losses in developing countries represent not only a severe economic loss for the regions but also a major loss of nutrients to already malnourished populations (FAO, 1989).

The basic concept described in Figure 1 is also applicable for small-scale farmers in developing countries. However, the challenges of rural transport may be promoting the application of the concept of rural logistics (see Figure 1); developing rural infrastructure (storage and packaging facilities, collection points and centres); developing efficient and effective management of product and information flow; developing strategies to promote best transport services. Some of the main issues that require immediate attention are: encouragement of private entrepreneurs to take the responsibility of service provider in storage, packaging and transport services; development of collection centre systems to promote marketing possibilities by facilitating coordinated transport services. Constraints associated with the flow and storage of produce and services in food and agribusiness exist in developing countries include lack of adequate storage facilities and knowledge of handling; poor processing, management and transport services.

In the absence of coordinated product delivery system, farmers themselves transport most of the produce, either as head loading or using pack animals, to both nearby and long distance markets. There are many constraints of such transport conditions: Amount of produce that can be transported by head loading or pack animals is limited; Transport time and distance is long; Drudgery on farmers; and Spoilage of produce during transport, etc. These constraints may result in reducing production and marketing opportunities for farmers, and consequently shortage of food for consumers. The reduction of spoilage and damages that could improve the marketing value of the produce may necessitate the availability of adequate processing, packaging and storage facilities and management for each varieties of produce (Gebresenbet and Oodally, 2005).

3. Logistics in abattoir chains: Animal supply and meat distribution

From effective logistics management point of view, an integrated approach from farm-to-table is required for effective control of food hazards which is a shared responsibility of producers, packers, processors, distributors, retailers, food service operators and consumers (Sofos, 2008). This is important issue, because the increase in world population and improvement of living standard increase the meat consumption and, especially in developed countries, consumers prefer food with no additives or chemical residues; food exposed to minimal processing; safe and economic food (Sofos, 2008; Nychas et al., 2008).

The increasing interest in transparency of food supply chain leads food industries to develop, implement and maintain traceability systems that improve food supply management with positive implications for food safety and quality (Gebresenbet et al., 2011; Smith et al., 2005). As animals stressing may damage meat quality, and lead to more contamination with pathogens, humane treatment of animals is getting more attention (Sofos, 2008). Tracking slaughter animals from birth to finished products and tracking food shipments are becoming area of focus recently (Smith et al., 2005). This helps to control the risk of animal disease, to reduce risk of tampering, to generate detail information on country of origin and animal welfare in the global food supply systems (Smith et al., 2005).

Animal identification and traceability as well as meat processing and distribution are some of the issues related to meat safety challenges (Sofos, 2008). In the process of establishment of animal identification and tracking systems, countries should take the following into consideration: Selection of appropriate technology and precision requirements, maintenance of confidentiality, payment of costs, premises number and animal identification number, livestock feed and meat safety (Sofos, 2008).

Underfeeding and stress of slaughter animals starts earlier than loading for transport to abattoir and continues at different steps until the time of slaughtering. Especially, the way non-ambulatory animals are managed at abattoirs has been reported as the ugliest aspects of pre-slaughter handling. Gregory (2008) indicated that, in US, about 1.15% of cattle waiting in pens at abattoirs in 1994 were downer animals and it was reduced to 0.8% in 1999. Recent study in a developing country, Ghana, indicated that about 7% of cattle waiting at abattoirs were downer animals (Frimpong et al., 2011).

For animal transport, besides the improvement of vehicles design and handling methods, continuous and accurate measurement and report of stress inducing factors and stress response parameters, and continuous observation of animals are necessary and essential to improve animals' welfare and the quality of meat, the final product. A complex instrumentation system, described in Figure 3 was developed at the Engineering department of Swedish University of Agricultural Sciences (Gebresenbet and Eriksson, 1998) to carry out the measurements of the parameters mentioned earlier simultaneously and continuously starting from the farms to the abattoir. The on-board instrumentation and the satellite steered position of the vehicles were controlled from the cabin of the vehicle. The instrumentation may be classified into four groups: Video cameras for monitoring animal behaviour, Heart rate sensor, GPS for measuring transport route, geographical location, vibration sensors, temperature and humidity sensors, emissions, and information transmission from vehicle to stationary database.

Although long distance transport and poor handling are stressful and compromise animals' welfare, there is tendency to reduce the number of abattoirs due to specialisation and centralisation. Since such long distant transport has a negative impact on animal welfare, meat quality and environment in the form of emissions emanating from vehicles, studies are undergoing to identify means of reducing the transport distance , transport time and animal stress in animal supply chain and meat distribution (Bulitta et al., 2011). Especially loading and unloading during transport for slaughter are identified as very stressful activities for animals.

Fig. 3. (a) Sketch of instrumented vehicle showing the positions of sensors , video camera and GPS; (b) vibration sensors mounted on animals

Gebresenbet and Ericsson (1998) made a continuous measurement of heart rate on cows from resting conditions at farm throughout the trip to abattoirs up to the point of stunning. The authors reported the performance of heart rate in relation to various activities from farm to stunning point (see Figure 3). The typical output result is presented in Figure 4, and as it can be observed the heart rate increased from about 45 bpm (beats per minute) to about 108 bpm during loading (separation of the animal from its group and forcing the animal to clamp the ramp into the truck). After loading, the heart rate falls and stabilized as soon as the animal was tied and maintained its position in the pen (Figure 4). The heart rate again raised as the vehicle started its motion. Another high heart rate peak occurred (Figure 4) when animals met unfamiliar animals from other farms, and the final rise in heart rate was during unloading. It is important to note that the heart rate profile reported in Figure 4, confirmed that loading and unloading activities are the most events that compromise the welfare of animal during transport. Bulitta et al. (2011) modelled (using exponential function) and analysed how cattle heart rate responds to the stressful loading process and indicated that heifers' heart rate rose exponentially from its mean resting value (80 ± 6 bpm) to a peak value (136 ± 35 beat per minute) confirming that loading is very stressful process for animals.

Two possible strategies for improving animal welfare during transport from farm to abattoirs are:

i. Minimising stress-inducing factors through improving animal transport logistics and handling methods. These include improving animal handling throughout the logistics chain, improving the loading and unloading facilities, improving the driving performance and slaughtering activities at abattoirs.
ii. Minimising or avoiding animal transport by promoting small-scale local abattoirs or developing mobile or semi-mobile abattoirs.

In both alternatives effective logistics is an important aspect to logistics chain of farm-abattoir system which encompasses all activities from loading animals, transport from farm to abattoir, unloading at the abattoir, operations in the slaughter chain from lairage box to chill room for carcasses (see Figure 5). It is important to chill meat and meat products before transportation. The primary chilling is the process of cooling meat carcasses after slaughter from body to refrigeration temperatures. The European Union Legislation requires a maximum final meat temperature of 7 °C before transport or cutting. After primary chilling, any following handling such as cutting, mincing, etc., will increase the temperature of meat, thus the secondary chilling is required to reduce temperature below 7 °C. Such a secondary chilling is also of great importance in the case of pre-cooked meat products, because the temperature of meat after the cooking process should be rapidly reduced from about 60 to 5 °C, to prevent or reduce growth of pathogens that have been survived the heat process or re-contaminate the product (Nychas et al., 2008).

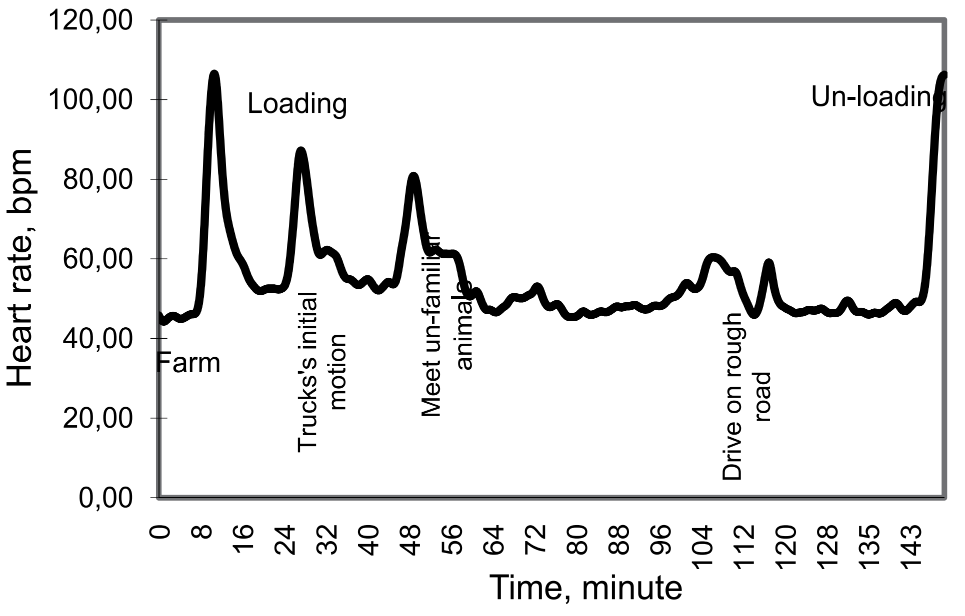

Fig. 4. Typical measured cow's heart rate profile during handling and transport. The peaks of the measured data indicate various events: loading of the animal on the truck; the vehicle starts moving; mixing with un-familiar animals i.e., when loading other animals from other farm; transport on the rough road; and un-loading at the abattoir (Gebresenbet and Eriksson, 1998)

Meat spoilage may occur during processing, transportation and storage in market. An important aspect of fresh meat distribution and consumption is effective monitoring of time/temperature conditions that affect both safety and overall meat quality. Appropriate packaging, transporting and storage of meat products are important, since meat products spoil in a relatively short time. Scientific attention on meat spoilage increased when shipment of large amounts of meat products started (Nychas et al., 2008). The EU legislation requires a maximum final meat temperature of 7ºC before transport and the vehicle for meat transport must be provided with a good refrigerated system. The meat transport from cold storage to retail outlet and then to the consumer refrigerator are critical points for meat quality and safety (Nychas et al., 2008). Animal collection from many farms and transporting to abattoirs requires a dynamic planning process taking into consideration stress inducing factors such as road conditions, climate and traffic conditions transport distance and time, queuing at the gate of abattoir for unloading (Gebresenbet et al., 2011).

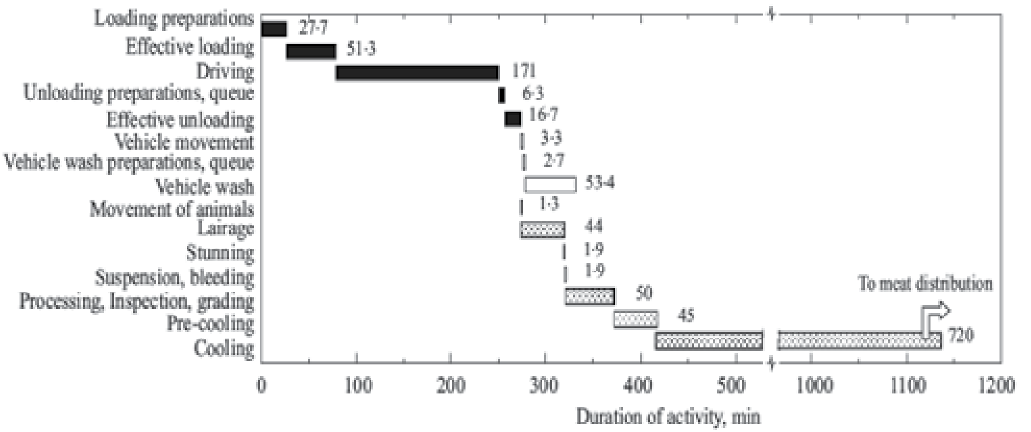

Fig. 5. Duration of activities in the cattle transport chain, from loading to slaughter; observed mean values; for the activities following after suspension and bleeding, the values were obtained from interviews; for loading and driving, average accumulated durations for transport routes involving loading of cattle only (at on average 4 farms), are represented; ▬, full vehicle; ▭, empty vehicle; ⬚, animal/carcass (Ljungberg et al., 2007)

A study conducted in Sweden (Gebresenbet et al., 2011a), comparing a small-scale local abattoir (situated at the best location in the vicinity of targeted consumers outside big city) to a large scale abattoir located in the centre of nearby big city indicated that establishment of the small abattoir could play a significant role in increasing consumer confidence in local meat products. In both cases (small scale abattoir and large scale abattoir) route analyses were conducted to explore the potential savings in transport distance, time and emissions related to animal collection from farm to abattoirs and meat distribution from abattoirs to meat shops or consumers. Considering the animal collection from farms to small scale abattoir, transport distance, time and emissions were reduced by 42% and 37% respectively when compared to large scale abattoir (see Table 1). Similarly, considering meat distribution from abattoir to consumers/retailers, the transport distance and time were reduced by 53% and 46% respectively when small scale abattoir was used (Gebresenbet et al., 2011a). In other case studies route optimisation experiments were conducted (i.e. measuring the real world distribution route and re-planning the route by conducting route optimisation experiments using RoutLogiX) on 34 routes of animal transport and 27 routes of meat distribution and the potential improvements were obtained in terms of transport distance and time (see Table 1).

Case study	No. of routes	Distance before optimisation [km]	Time before optimisation [h]	Improvement due to optimization %		Source
				Distance	Time	
Animal transport						
I	19	163	2:47	3.6	4.1	Ljungberg et al., 2007
II	15	2750	46	18	22	Gebresenbet and Ljungberg, 2001
III[n]	30	16500	126:21	42	37	Gebresenbet et al., 2011a
Meat distribution						
II	17	1638	62	17	21	Gebresenbet and Ljungberg, 2001
IV	10	1597	-	4.7	2.7	Gebresenbet et al., 2011b
IV[m]	13	3054	62:45	37.7	32.4	Gebresenbet et al., 2011b
III[n]	7	2256	27	53	46	Gebresenbet et al., 2011a

[n] The case of comparison of small scale and large scale abattoir and improvement is when small scale is compared to large scale abattoir
[m]The case of coordination i.e. improvement is for route coordination (not necessarily for optimisation)

Table 1. Potential savings in distance and time by optimizing the routes of animal supply and meat distribution

Coordination and optimisation in food distribution is a potential strategy to promote economically effective and environmentally sustainable food distribution. A case study conducted in Sweden pointed out that possible coordination of meat distribution in rural area around a city could reduce transport distance and time up to 38% and 32% respectively (see Table 1). The coordination could be formed between different companies distributing different food items and companies distributing only meat; and between companies distributing only meat. In a similar study, first coordinating and then optimising the food deliveries in and around the city could reduce the number of routes by 58%, number of vehicles by 42% and transport distance by 39% (Gebresenbet et al., 2011b). Such coordination in food distribution system could also improve the vehicle load rate, motor idling, emission from vehicles and congestion. Some of the major possibilities for improved coordination and transport planning of agricultural goods transport are: possible coordination of meat and dairy product distribution through combined loading; possible coordination of fodder transport and grain transport through back-haulage; and partial or total optimisation of vehicle fleet (Gebresenbet and Ljungberg, 2001).

Uncoordinated and non optimum food transport systems are not energy efficient in local food systems, although there is considerable potential to increase the efficiency of energy use by organizing the food delivery system in new ways (Beckeman and Skjöldebrand, 2007), using more energy efficient vehicles and/or introducing the production of biofuel in the region (Wallgreen, 2006), increasing the utilization level of vehicles' capacity (Ljungberg and Gebresenbet, 2004) and planning optimum routes for food collection and distribution systems (Gebresenbet and Ljungberg, 2001).

4. Logistics in milk supply and dairy product distribution

Milk is an important agricultural produce that livestock keepers use for both consumption and market. The marketing of milk, surplus to family and farm needs, improves farm income, creates employment in processing, marketing and distribution and contributes to food security in rural and urban communities (Gebresenbet and Oodally, 2005).

In developing countries, demand for milk is expected to increase by 25% by 2025. In such developing countries smallholders are the main producers of milk. Dairy imports to developing countries have increased in value by 43% between 1998 and 2001, and over 80% of milk consumed in developing countries, (200 billion litres annually), is handled by informal market traders, with inadequate regulation (Gebresenbet and Oodally, 2005). From transport services point of view, marketing of milk is difficult for producers who are living in scattered and isolated areas. These farmers can only sell butter to the urban areas and the remaining milk products are for home consumption. Delivery of fresh milk from long distance to urban by small-scale farmers is difficult for two main reasons. Firstly, the daily milk produce is relatively small to deliver to urban area and transporting perishable commodity over long distance is difficult. Secondly, milk quality deteriorates as it is transported over longer time without processing. The only available traditional processing is fermentation. To promote marketing of milk for small-scale farmers, it is necessary to develop strategies for on-farming chilling and collection of milk.

In developed nations, transport companies collect the milk from farms to collection points and thereafter transport to dairy plants (Gebresenbet and Ljungberg, 1998). The dairy industry provides a special milk container in which the farmers store the milk before the transporters collect the milk. Usually tank Lorries and tank trailers are used for collecting milk from farms and deliver to the nearest dairy. The milk supplied to dairy companies is processed and distributed to consumers. The dairy products such as milk, powder, edible fat and cheese are distributed by dairy product distributors. In such a process, the tank Lorries collect milk upto their full capacity and pump to the tank trailer which is usually placed in the best place as illustrated in Figure 6.

Optimizing the routes of milk collection enables to improve the transport distance and time. Gebresenbet and Ljungberg (2001) measured 60 routes of milk collection which totalled to be about 6357 km. By conducting optimization experiments on these routes, using LogiX (DPS, 1996), the authors found that the distance could be reduced by 16%. Similar optimization experiment on the routes of dairy product distribution reduced the distance by 22% and time by 24%.

In developed countries, it is noticed that due to structural changes in the milk production system, the number of farms reduces while the level of production remains relatively constant. This is shown by Figure 7 which illustrates the case of Sweden.

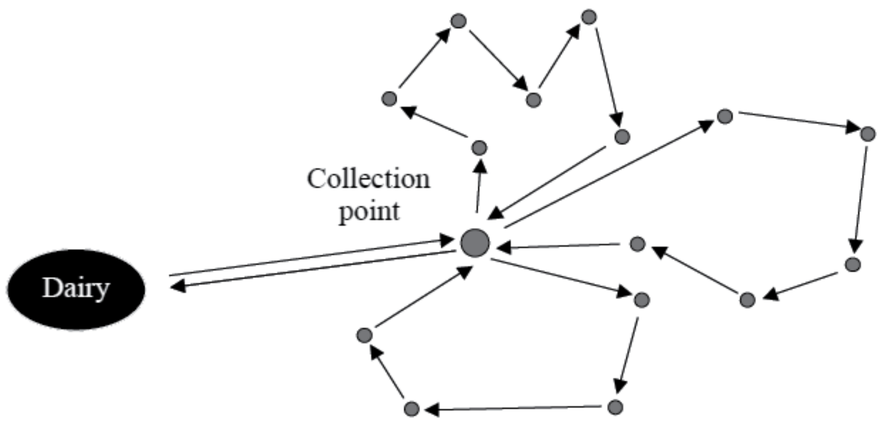

Fig. 6. Schematic presentation of possible way of milk collection from farms and delivery to the dairy industry (Gebresenbet and Ljungberg, 2001)

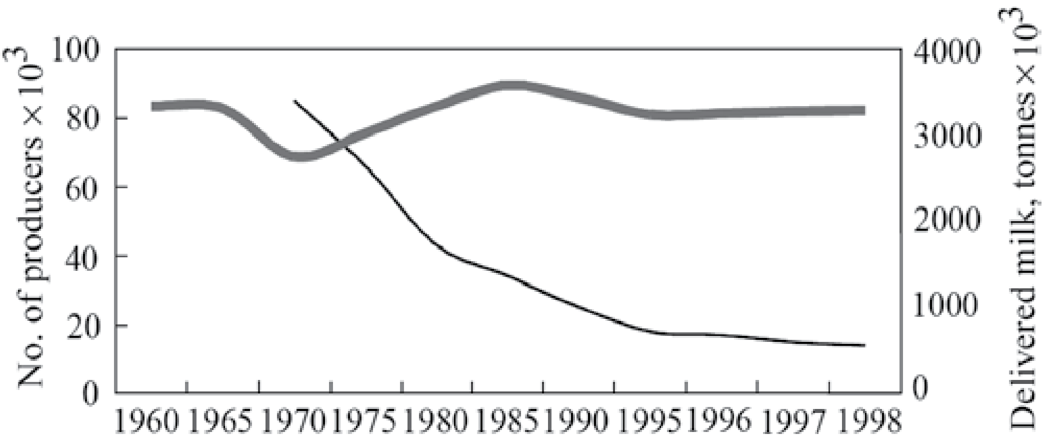

Fig. 7. Total milk production and number of milk producers in Sweden from 1960 to 1998; ——, number of producers; ▬▬ , delivered milk (source: Gebresenbet and Ljungberg, 2001).

The European Union (EU) limits the maximum level of milk production of member countries, for example in Sweden to 3.3 million tonnes per years (Gebresenbet and Ljungberg, 2001; Bouamra-Mechemache et al., 2008). The domestic consumption of dairy products in EU is as high as 90% of its milk production. And still, EU is a major player on the world dairy market and the EU dairy sector is expected to be market oriented in the future (Bouamra-Mechemache et al., 2008). The milk quotas enabled the EU market gain stability for the last 25 years and the international market have also benefited due to strategic product management on the world market. The expected challenge to future dairy industry is world dairy market fluctuations and price volatility due to the increase in EU milk quota by 1% annually until 2015, the year when the quota will be removed ultimately (Geary et al., 2010). This in turn will have impact on logistics of milk and dairy products in the future.

In developing countries individual traders or small scale agencies collect milk from producers and supply to collection centres. Milk may be carried to the collection points as head loads, shoulder slings, on bicycles, on pack animals, animal carts or small boats (Gebresenbet and Oodally, 2005). Advanced milk collection process found in developing countries begins with the producer delivering milk to a collection point where the volume is measured, or the milk weighed, recorded, and sometimes it is sampled and checked for quality. The milk is later transported, to a larger collection centre where, if possible, it is chilled. The collected milk is subsequently sent in bulk to a processing plant by truck. The time-delay from milking to delivery at the processing plant often exceeds five hours and is negatively affecting the quality of non-refrigerated milk, which is often rejected by dairy processing plants and is also not acceptable by consumers (Gebresenbet and Oodally, 2005).

In countries like Mauritius, the marketing of the milk is traditionally undertaken by milk retailers who visit several cow keepers, holding special containers with capacity of 300 litres for transporting fresh milk. The retailer fills the container after visiting 10 to 15 producers and then proceeds to the urban areas to deliver to the consumers. The link between the retailer and the cow keepers is very important as it enables the producers to concentrate on production while the retailer provides a reliable market for the produce. A milk collection system that under-estimated the role of retailers was initiated in Mauritius but failed, because instead of developing policies and effective credit system for the producers and converting retailers into private contractors to supply the factory with milk, the system tried to by-pass them creating a system which was not sustainable (Gebresenbet and Oodally, 2005).

A milk collection initiative in Brazil where a milk collection programme was developed for farmers, most of whom were producing 100 litres per day per farm on average, was found to be successful (Urraburu, 2001). The important element in the programme was the common cooling tank. Within a year, bulk milk collection production grew from 28% to 70% and included 55 private cooling tanks representing some 55,000 litres per day. The impacts of the programme on dairy farmers was the dramatic reduction of transport costs, which in some regions fell by 80%, improvement of product quality as the time between milking and conveying milk to the dairy was significantly reduced (Gebresenbet and Oodally, 2005)

5. Logistics in grain supply chain

During the recent 20 years, goods flow has been tremendously increased, mainly not due to the increase in the amount of goods, but due to other factors such as specialization and centralization of production systems and globalization of marketing (Gebresenbet and Ljungberg, 2001). Agricultural goods transport is a significant component within such increasing goods transport. For example about 13% of the international sea-borne trade is grain transport (Gebresenbet and Ljungberg, 2001). Grain transport is the main component in agricultural transport in general and it includes grain transports from farm to depot/terminals, between farms, between terminals, from farms and terminals to fodder industries and mills and from terminals to ports for export. Figure 8 illustrates the material flows to, within and from agriculture and food sector (Gebresenbet and Ljungberg, 2001).

Due to the legal limit of total weight of a lorry, the drivers have to estimate the load weight and it is not unusual that the actual loads exceed the legal maximum loads due to overloading (see Figure 9). The case study in Sweden (Gebresenbet and Ljungberg, 2001) indicated that the load rate for grain transport routes is as high as 95% at the delivery point during the harvesting season.

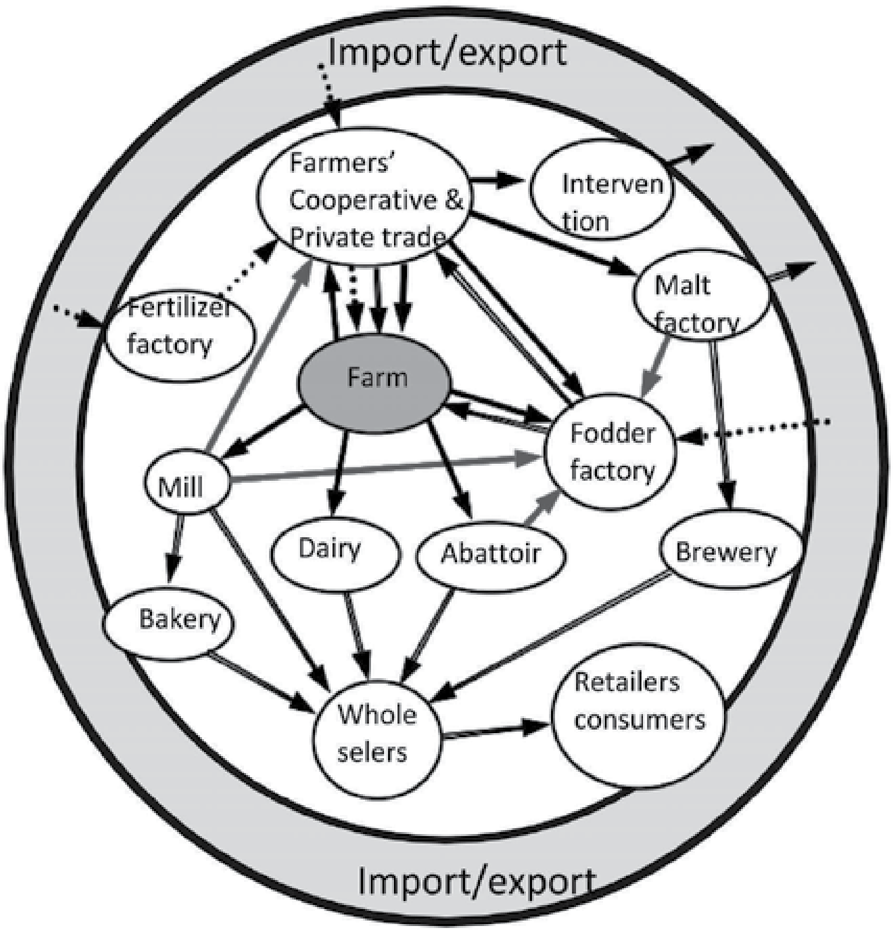

Fig. 8. Material flows from and to farms and other sectors in Uppsala region; *intervention is export subsidized by the European Union (EU); the national department of agriculture buys grain and stores it from season to season before it is exported, to reduce price fluctuations and support the lowest price level:
····►Means of production~seed, ➞ fertilizer ize (commercial), plant protection, supplies to fodder factory, etc.; Agricultural produce~grain, milk, li*v*e and slaughtered animals;
⇒, Processed products~flour, malt, fodder, dairy products, meat;
➞By-products~bran, whey, natural fertilizer, by-products from malt production (Gebresenbet and Ljungberg, 2001).

These authors also mentioned that during grain-related transport routes, unnecessary/unjustified motor idling was found to be more than 30% of stoppage time. They also estimated the emission from vehicles during grain transport before and after optimisation of grain transport routes. Table 2 presents the motor idling and emission reduction by optimising the transport routes of grain in relation to other agricultural products such as milk and meat. Air emissions were calculated using the simulation model developed earlier by Gebresenbet and Oostra (1997), where the following parameters were considered: vehicle type, time (loading; unloading and idling); goods type; load capacity utilization level; transport distance; vehicle speed; geographical position of depot and delivery points; routes air emissions from vehicles.

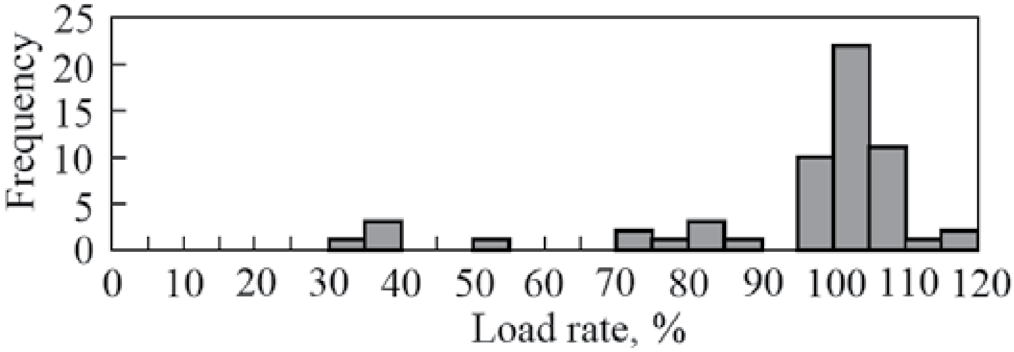

Fig. 9. Load rate distribution at unloading point of grain: The figure illustrates that load rates exceed 100% in many cases (source: Gebresenbet and Ljungberg, 2001).

Description	No. of routes	Distance before optimisation [km]	Time before optimisation [h]	Motor idling** [%]	Reduction of CO2 emissions [%]
Grain transport	45	4995	97	36	6.3
Milk transport	60	6357	185	65	6
Dairy transport	28	2234	92	3.5	22
Animal transport	15	2750	46	1.6	18
Meat transport	17	1638	62	4.6	17

*-source: Gebresenbet and Ljungberg, 2001 with some modification.
**Motor idling time in relation to total time.

Table 2. Motor idling and possible reduction of emission during transport of grain and other agricultural products*

In grain transport systems, back-hauling can be used for the delivery of fodder to farms (Gebresenbet and Ljungberg, 2001). Although the grain transport from farms is concentrated during the harvesting season, there is a possibility to coordinate the delivery of fertilizers and other means of production with grain transport i.e. the farmers can dry their grain and keep it at the farm till the time of delivery of means of production. The intensity of grain delivery at the harvest season causes capacity problems for vehicle resources and transport planning. Planning of production and orders at farm level, to minimize the seasonal effects, would improve the conditions for transport planning and coordination (Gebresenbet and Ljungberg, 2001). In developing countries, grain collectors are responsible for commercialising the grain within the country and exporting surplus. Even though, these grain collectors are considered as informal by the government body in some countries, they served an important role in the grain supply chain. For commercialising grain, it can be collected from individual farmers to a critical size that can be transported cheaply for retail locally, and the surpluses can be exported at premium prices elsewhere (Gebresenbet and Oodally, 2005).

6. Logistics in local food supply chain

In the agriculture sector, globalization of food production has considerably influenced the food supply system by increasing distance the food has to be transported to reach consumers. This situation not only has increased emissions of greenhouse gases but also has reduced the relationship between local food producers and consumers, affecting local food producers, their environment and culture. In terms of distance, locally produced food can be characterized by the proximity of production place to the consumers and usually there is a limit, e.g. 160 km in UK, and 250 km in Sweden. In addition to geographical distance, locally produced food is also considered as food which meets a number of criteria such as animal welfare, employment, fair trading relations, producer profitability, health, cultural and environmental issues (Bosona et al., 2011). Currently it is observed that customers have been motivated (to purchase the local food) by contributing positively to the ecosystem (a more altruistic reason) and by food quality and pleasure (a more hedonistic reason) (Brown et al. 2009; Bosona and Gebresenbet, 2011).

In this section we presents the main results of two case studies in Sweden, concerning the investigation of local food supply chain characteristics and developing a coordinated distribution system to improve logistics efficiency, reduce environmental impact, increase potential market for local food producers and improve traceability of food origin for consumers. In these studies, integrated logistics networks were developed by forming clusters of producers and determining the optimum collection centers (CC) linking food producers, food distributors and consumers/retailers enabling coordinated distribution of local food produces and facilitating the integration of food distribution in the local food supply systems into large scale food distribution channels (see Figures 10 and 11). In these case studies, after mapping the location of producers and delivery points as well as potential collection and distribution centers using geographic information system (GIS), the best collection points were determined using center-of-gravity and load-distance techniques (Russell and Taylor, 2009). Then detailed collection and distribution routes were analysed using RoutelogiX software (DPS, 2004). As summarized in Table 3, the result of the analysis indicated that coordinating and integrating the logistics activities of local food delivery system reduced the number of routes, the transport distance and transport time for the delivery system of local food. Such logistics network integration could have positive improvements towards potential market, logistics efficiency, environmental issue and traceability of food quality and food origin.

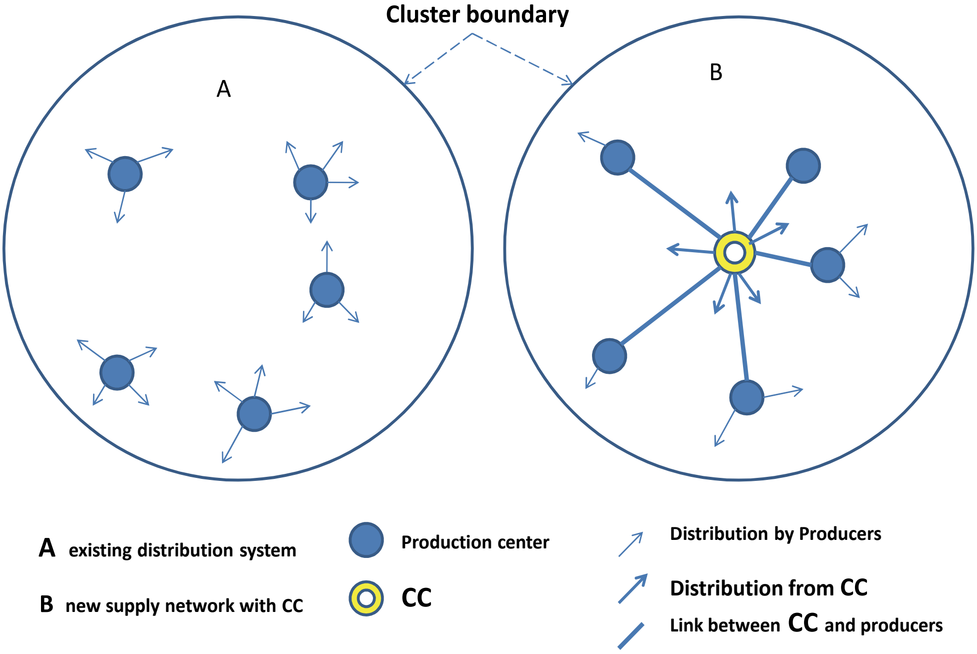

Fig. 10. Fragmented distribution system (existing) and newly proposed coordinated distribution system via CC (collection center) to different customers (Source: Bosona and Gebresenbet, 2011)

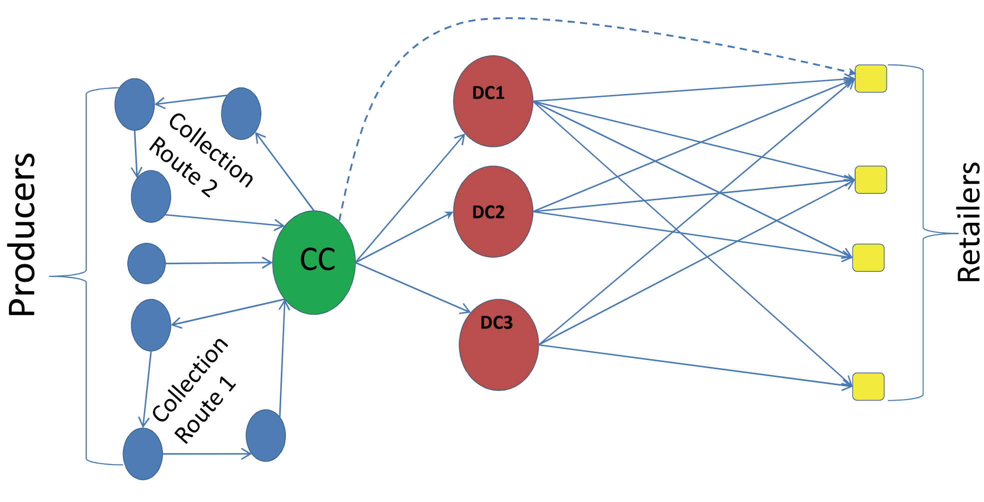

Fig. 11. Network of product delivery system with coordinated collection. DC1, DC2, DC3 represent three of large scale food distribution channels. The dashed line indicates the case of direct delivery from CC to retailers or customers.

Case study	No. of routes	Distance before coordination /integration [km]	Time before coordination /integration [h]	Improvement due to optimization %			Source
				Routes	Distance	Time	
I	81	8935	226	68	50	48	Bosona and Gebresenbet 2011
II*	23	6159	69	87	93	91	Bosona et al., 2011

*- Although there were more scenarios, the scenario with best improvement was chosen.

Table 3. Potential savings obtained by co-ordination and integration of routes for delivering locally produced food

Coordination and network integration in local food supply chain increases logistics efficiency, potential market, access to information and reduces environmental impact (Bosona and Gebresenbet, 2011; Gebresenbet and Ljungberg 2001, Ljungberg, 2006; Ljungberg et al, 2007). In the food distribution system of local food producers, logistics is fragmented and inefficient compromising the sustainability of localized systems and this requires improvement (see Figure 11 and Table 3). Therefore forming the best collection and distribution centres for locally produced food is very important. Such location decisions should be supported technically since the location decisions have the dynamic implication over time (Sabah and Thomas, 1995). Therefore, in the process of developing improved logistics systems in the local food supply chain, detailed location analysis (mapping and clustering producers and determining optimum location of collection and/or distribution centres) and route analysis (creating optimised routes for product collection and distribution, simulating route distance and delivery time) are very essential (Bosona and Gebresenbet, 2011) .

Potential producers of local food want to expand their sales area. However, increasing sales of locally produced food, on small scale bases, needs to overcome the main problems such as low size of production and more volatility of market price and high seasonality of food products on market, inadequate packing and storage facilities, limited or no means of transport and limited knowledge of potential market (Bosona et al., 2011). These problems can be overcome mainly if the local food systems can be embraced by dominant food supermarket and superstore chains and this can be facilitated by integrating the local food system into large scale food distribution channels.

Such integration in local food systems plays a key role in sharing information and scarce/expensive resources as it enables the stake holders get access to the right information at the right time. Well organized information concerning local food is important to satisfy the increasing demand of consumers to have good knowledge and information of the food origin and how it is handled and transported. The logistics network integration is also helpful in creating favourable situation for interested researchers. For example, well established data management might come into existence which in turn helps to conduct more detail studies on the logistics activities enabling further improvements that increase the sustainability of local food systems (Bosona and Gebresenbet, 2011, Bosona et al., 2011). The integration also facilitates improved traceability system which depends on information connectivity and provides an added layer of food security which might be established more easily within integrated systems (Bantham and Oldham, 2003; Engelseth, 2009). One apparent advantage of such a co-ordination and logistics network integration is that each stakeholder in the network concentrates on its specialty and improves its productivity in both quality and quantity (Beckeman and Skjöldebrand, 2007).

Studies (Bosona et al, 2011; Bosona and Gebresenbet, 2011) indicate that in local food systems, producers of local food run mostly their own vehicles and about half of the vehicle capacity is unutilized. Therefore, the coordination and logistics network integration in local food system leads towards positive environmental impact by: (i) Reducing number of vehicles to be deployed for produce collection and distribution of local food products; (ii) Increasing the utilization level of vehicle loading capacity; (iii) Reducing travel distance, time and fuel by following optimized routes where possible; (iV) Reducing green house gas emissions (as the consequence of the facts mentioned above).

7. Conclusion

From effective logistics management point of view, an integrated approach from farm-to-table is required for effective control of food hazards which is a shared responsibility of producers, packers, processors, distributors, retailers, food service operators and consumers. Therefore, tracking slaughter animals from birth to finished products and tracking food shipments are becoming area of focus recently. Studies indicated that, in the food and agriculture supply chains, there are potential area of logistics related improvements in terms of reducing transport routes, distance and time; reducing emission from vehicles; improving the packaging of food products and improving transport services. This can be implemented in collecting, storing and transporting slaughter animals, meat products, milk and dairy products, grain and related products.

These logistics related improvements are possible in developed and developing countries. In case of local food systems, an iintegrated logistics network that embraced producers, customers (delivery points), collection centers and distribution centers in the local food supply chain is very important, because the logistics services in such local systems are fragmented and inefficient, compromising competence of local food producers. Introducing and implementing logistics related coordination and integration in the local food systems greatly improve the sustainability of local food systems. In general, studying and identifying the constraints and developing and implementing more effective and efficient concepts of logistics services in the agriculture and food supply chains is very essential for overall economic growth of a country and for environmental benefits.

General observations for practitioners

Agriculture and food supply chain is specific and complex area with important responsibilities. There are two main demands:

a. Maintaining food quality and safety including animal welfare along the supply chain, and

b. Reducing logistics cost.

The concept of *Agricultural and Food Logistics* is slowly emerging as one of the important types of logistics to reach the requirements for maintaining quality of raw materials for food and food products or even to perform value adding activities in the food supply chain. The questions related to post harvest loss, which ranges up to 70% in developing countries, animal welfare during transport, and the concern of origin of food staffs and how they are produced and processed are societal questions.

In relation to globalization of marketing system, it is a vital for all stakeholders to reduce logistics cost in order to increase their economic competitiveness. Therefore, development of effective and efficient *Agricultural and Food Logistics* is necessary and essential.

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Part 3

Mass-Customization

9

Mass-Customization: From Personalized Products to Personalized Engineering Education

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1. Introduction

During the past two decades, organizations have transitioned from the model of mass-production to the model of mass-customization of products as a way to maintain their competitiveness. Mass-customization refers to the ability "*to customize products quickly for individual customers or for niche markets at a cost, efficiency and speed close to those of mass production, relying on limited forecasts and inventory*" [1]. The key objective in mass-customization is to design products that can be rapidly customized to satisfy a variety of different requirements. While the notion of mass-customization has increased the capabilities of organizations to satisfy diverse customer needs, the costs for mass-customization are considerably higher than those for mass production [1]. Hence, the primary design challenge is to keep the costs low while maintaining high customizability. To address this challenge, the key design principles to enable mass-customization are product platforms, modular design [2], ease of replacing components, part standardization, adjustable designs, dimensional customization, dimensional standardization, supply chain customization, and maximization of external variety while minimizing internal variety [3, 4]. Platform design simplifies product offerings and reduces part variety by standardizing components so as to reduce manufacturing and inventory costs and manufacturing variability (i.e., the variety of parts that are produced in a given manufacturing facility), thereby improving quality and customer satisfaction [4].

In this chapter, we discuss our efforts towards adapting the paradigm of mass-customization from product development to the domain of engineering education. Our rationale for doing this is anchored in the continuing process of globalization and its ramifications on the education sector. In a world in which change is the order of the day, it no longer makes sense to offer a one-size-fits-all education as the competencies required in the workforce of near tomorrow vary significantly from one individual to another. In addition, there is a worldwide increasing demand for online education to accommodate students that, for a number of reasons, are not able to participate in traditional onsite education. In order to address these challenges, the National Academy of Engineering (NAE) has declared 'Advance Personalized Learning' as one of their Grand Challenges, along with, for example, the development of new energy systems. Reflecting on this and relating it to the evolution of product design, the similarities between personalizing products and services in general and educational programs and delivery modes in particular are striking. Hence, we decided to apply the paradigm of mass-customization to engineering education and demonstrate how this could be achieved in the context of a graduate design course.

Educational mass-customization supports personalized learning and thereby the development of diverse knowledge and competencies in a class [5, 6]. Specifically, we present an educational model for personalized mass-customization of engineering education suitable for globally dispersed distance-learning settings [7]. Our approach is anchored in scholarship of education and is based on the following *foundational constructs*: constructive alignment, Bloom's taxonomy, learning organizations and a combination of collaborative, cooperative and collective learning [8]. As a part of constructive alignment, an instructor aligns the planned learning activities and assessment tasks with the learning outcomes. Bloom's taxonomy is a model in which learning is partitioned into six domains of knowledge of varying levels of complexity. The taxonomy is used to scaffold different learning activities. The learning organization construct is adopted to transform a traditional passive learning environment into an active person-centric learning environment. Collaborative learning enhances the knowledge of a group by encouraging diverse individuals to learn from each other [9-11]. The foundational constructs are discussed in Section 3.1.

Based on the foundational constructs various *strategies for achieving mass-customization* are discussed. The strategies include a shift in the role of the instructor and students, providing opportunities to learn, shift from lower level to upper levels of learning in Bloom's taxonomy, creating learning communities, embedding flexibility in the course, leveraging diversity, making students aware of the learning process, and scaffolding learning activities. These strategies are discussed in Section 3.2. Our approach to mass-customization of engineering education has been implemented in a graduate level engineering design course offered at Georgia Tech every spring, namely, *ME6102 Designing Open Engineering Systems*[1]. An overview of this course, its context and content, the way it has been structured and orchestrated, as well as the lessons learned are presented in Section 4.

Before discussing the details of our approach for mass-customization in education and our implementation in the graduate level course, we discuss the strategies for mass-customization employed in product development in Section 2.1. In Section 2.2, we illustrate how those strategies have been extended to the field of engineering education.

[1] ME6102 continues to be offered and developed by Schaefer at Georgia Tech. It has morphed into AME5740 *Designing for Open Innovation* at the University of Oklahoma. In Fall 2011, Mistree and Panchal jointly offered this course from two locations.

2. Mass-customization – From products to education

2.1 Strategies for mass-customization in product development

Mass-customization is important for product development organizations due to the diverse demands from customers, the need for personalized products, and rapidly evolving expectations of customers. The evolution in customer expectations is partly driven by new products coming to the market as a result of fierce competition among companies. The challenges that companies face in providing mass customized products are due to increased number of parts, manufacturing processes, levels of inventory, information required, time-to-market, and overall system complexity. All these factors result in higher costs associated with product design, manufacturing, assembly, storage, inventory management, customer relationship management, and maintenance. In addition to the internal challenges (i.e., within the product development organization), increased product variety also has the potential of creating mass confusion for customers. If customers are provided too much variety, it increases their effort in choosing the right product. In summary, the primary challenges in providing mass customized products are in achieving product diversity while maintaining the costs, quality, time-to-market, and complexity close to that of mass production.

To address the challenges associated with mass-customization, various strategies have been developed by product development organizations and academic researchers. One of the most popular strategies is the design of product platforms. A product platform is defined as a "set of subsystems and interfaces that form a common structure from which a stream of derivative products can be effectively developed and produced" [12]. The set of products derived from a product platform is called a product family. A family of products shares common technology and addresses related market applications.

A widely known example of a product family is the set of power tools developed by Black and Decker [12]. The family consists of power drills of various sizes: jigsaws, power hammers, grinders, sanders, circular saws, etc. In the early 1970s, each of these products was developed and manufactured independently to address a specific market segment. Hence, the types of parts used in one product were entirely different from the parts used in another product. Such an approach resulted in a wide variety of parts and materials. In other words, the products had a very high internal variety, which resulted in high complexity of operations and resulting high costs. To address this challenge, the company decided to reduce internal variety by creating a common product platform with common parts (such as motors, gearboxes, etc.) across all the products. The resulting benefit was the reduced design and manufacturing cost, and in turn, the price that the customers had to pay. The price reduction was up to 50% in many of their products [12].

The principle that underlies platform design is the maximization of external variety and minimization of internal variety [13]. According to Simpson and coauthors [13], the designers' goals for platform design are "to simplify the product offering and reduce part variety by standardizing components so as to reduce manufacturing and inventory costs and reduce manufacturing variability (i.e., the variety of parts that are produced in a given manufacturing facility) and thereby improve quality and customer satisfaction". The product platform strategy is based on four key enablers:

- commonality of components across different products

- modularity of designs
- standardization of interfaces between components
- compatibility of components

There are many advantages of using common components across different products. First, it reduces the complexity associated with manufacturing processes. Second, the inventory costs are also reduced. Third, the assembly and maintenance costs are reduced. Commonality of components can be achieved by modular design and standardization of interfaces among components. Modularity has been extensively studied in the product design literature. Ulrich and Eppinger [14] define modularity based on the mapping between a product's functional and the physical structures. According to the authors, modular architectures have a one-to-one mapping between the functions and the physical components. In addition, any incidental interactions between physical components are minimized. Standardization of interfaces between components reduces the chances of unintended interactions, and increases the compatibility between functionally similar components. Standardization increases the ease of replacing components to address diverse functional needs.

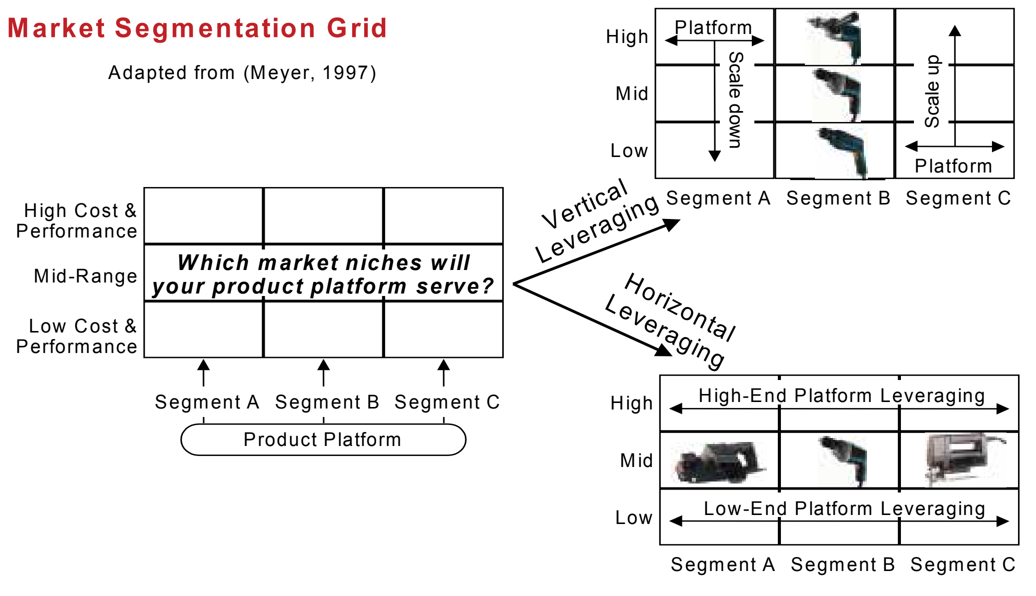

Fig. 1. Illustration of the market segmentation grid and two strategies for platform development (adapted from [15])

The process of designing a product platform starts with the identification of the different market segments. To aid the identification of the market segments, Meyer [15] developed a market segmentation grid with two dimensions – a) the market segments, and b) different tiers of price and performance. The product segments represent customer groups served by the company. The tiers of price and performance are classified into high cost/high performance, mid-range, and low cost/low performance. Having identified the different segments on the market segmentation grid, the next task is to identify the part of the grid that the company will address first and how it will expand its offerings across the grid. Meyer discussed four strategies: a) niche specific platforms with little sharing of subsystems, b) horizontal leveraging of key subsystems, c) vertical scaling of key platform subsystems, and d) the beachhead strategy. The horizontal and vertical strategies are illustrated in Figure 1. In the horizontal strategy, the product platform is leveraged from one market segment to another in the same tier of price/performance. Similarly, vertical scaling addresses a range of price/performance within a given segment. The beachhead strategy is a combination of the horizontal and vertical strategies. Mass-customization is also related to the concept of customer co-creation were the development of customized products is carried out in close collaboration with the customers [16].

2.2 Extending the concepts of mass-customization to engineering education

In this section, we discuss how the concepts of mass-customization presented in Section 2.1 can be extended to the application domain of engineering education. An overview of the mapping between product development and engineering education that highlights many of the striking similarities between both fields is provided in Table 1. The table is divided into three areas – the need, the organizational goals, and approaches for mass-customization.

2.2.1 The need for mass-customization in engineering education

The first step to developing a strategy for mass-customization is to understand the need. Taking the perspective that students are customers, mass-customization is important because of the diversity of students in terms of their:

- Interests and desired career paths
- Competencies to be gained
- Long-term goals
- Backgrounds
- Learning styles
- Physical locations

Learning in students is directly related to their motivation, which is linked to the value of completing the educational activities. According to Eccles and Wigfield [17], students' expectancy beliefs and subjective task values directly influence performance, effort, persistence, and task choice. The *expectancy for success* is an individual's belief about how well he/she will do on upcoming tasks. If the individual thinks that the activity is too difficult, then he/she will have less motivation to carry out that task. If an individual is confident about completing the task, he/she is more likely to complete it. Since different students have different learning styles, different tasks may be more/less difficult based on how they are structured. Within the framework of expectancy-value theory, value has four components: a) *attainment value*: personal importance of doing well on the task, b) *intrinsic value*: enjoyment that an individual gets from performing the activity, c) *utility value*: how well a task relates to current and future career goals, and d) *cost*: the negative aspects of engaging in a task. Similar to the expectancy for success, good design projects have high attainment, intrinsic, and utility values to the students and low cost.

Product Development	Engineering Education
Need	
Diversity in customer demands	Diversity in the needs of students with different interests, long-term goals, backgrounds, learning styles, locations, and career paths
Organizational Goals	
Maximize external variety and minimize internal variety	Maximize external variety in educational offerings by combining modular resources in various ways
Maximize quality	Improved learning experience for students
Reduced time to market	Reduces time for developing and courseware and delivering courses
Reduced effect on complexity	Reduced complexity of managing courseware
Strategies for Mass-customization	
Product platforms (Maximizing external variety and minimizing internal variety)	A common platform – "Learning to Learn" consisting of Assignment 0, learning organization, Bloom's taxonomy, etc. (see Table 2).
Customer co-design	Working with the students to define their specific learning objectives and competencies
Product family	Core lectures and elective lectures
Horizontal leveraging and vertical scaling	Scaling: From short courses to semester long courses Horizontal: Across different departments
Compatibility and commonality	Common theme of Question for the Semester (Q4S)
Standardization	Standard structure of the assignments (same set of general questions)
Modularity (Ease of replacing components)	Making self-contained modules of content (including lectures, reading material, etc.)
Adjustable designs	Adjusting the material based on the responses on Assignment 0

Table 1. A mapping between the concepts of mass-customization between product development and engineering education

Accordingly, educational experiences should be structured in a way that maintains 1) high expectancy for the success of diverse students, and 2) provides high attainment, intrinsic and utility values to the students at low costs. This involves finding out students' prior knowledge and skills before starting the design activity. If an instructor starts with incorrect assumptions about students' skills, he/she may create educational experiences that are either overly difficult for the students or so trivial that the students lose interest. In such a case, the students' expectancy for success may be low, and hence, the motivation will also be low. This is analogous to addressing specific customer needs at minimum costs.

2.2.2 Organizational goals for mass-customization

The fundamental goal for any educational institution is to provide the best possible learning experience for the students. Considering the diversity of students, providing customized learning experiences to students can help educational institutions attain their fundamental goal. Additionally, educational institutions are interested in increasing the variety of educational offerings by catering to: a) students who cannot attend classes physically (due to their location) via online/web-based courses, and b) professionals working full-time via short certificate programs. Such programs not only increase the revenue for the organizations but also enrich the learning experiences of the in-class students (if offered in a blended mode).

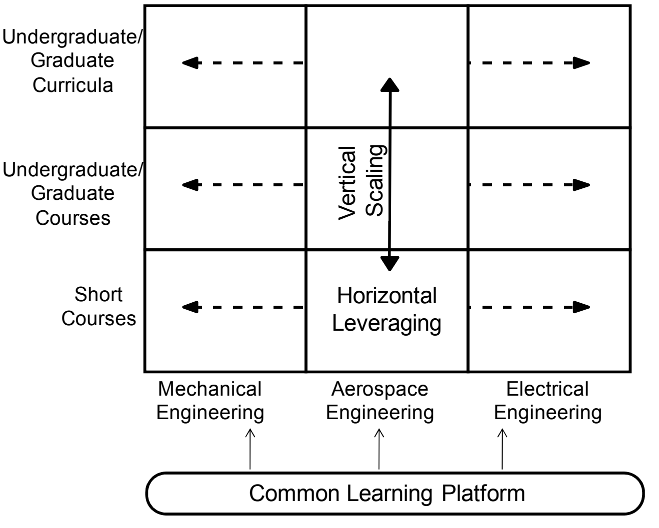

Fig. 2. Using the common learning platform to develop customized courses

At a fundamental level, educational institutions are also based on the mass-production model. For example, a university offers a limited number of degree programs catering to thousands of students; a department offers a limited number of courses for hundreds of students. Very little (if any) flexibility is offered to students by mechanisms such as elective courses and class projects. However, addressing the learning needs of diverse groups of students is challenging. For universities, offering customized degrees to students is challenging both from the management and accreditation standpoints. For instructors, customizing course materials for different students is challenging and requires significant effort and commitment. Further, there is little knowledge available on how to develop "product platforms" for educational material or how to develop standardized learning modules that are suitable for different learning needs (see Figure 2). There is little knowledge on holistic approaches to horizontally leveraging course material across different disciplines (e.g., mechanical engineering, electrical engineering, etc.). Similarly, there is a lack of knowledge about systematic strategies for vertically leveraging educational material for short, undergraduate, and graduate courses. We acknowledge that some instructors have been successful in developing specific courses that span more than one segment in Figure 2. However, those specific initiatives can be compared to hand-crafted personalized products, and do not represent mass-customized products. The effort associated with mass-customization of courses can be discouraging for faculty members at research-oriented universities with significant pressure to perform quality research and recent budget reductions forcing faculty members to teach more courses and with many more students in a class. We believe that these challenges are limiting the adoption of the mass-customization in the field of education.

We believe that some of these challenges can be addressed by adapting the strategies from mass-customization of products to engineering education. Some of the strategies and the underlying educational foundations are discussed in Section 3.

3. Educational foundations and strategies for applying mass-customization in engineering education

3.1 Educational foundations

From an educational standpoint, our approach is based on the following constructs: constructive alignment, Bloom's taxonomy, cooperative, collective and collaborative learning, and a learning organization. Each is discussed in turn in Sections 3.1.1 through 3.1.4.

3.1.1 Constructive alignment

Constructive alignment, a phrase coined by Biggs [18], is one of the influential constructs in higher education. It underpins current requirements for program specification, declarations of intended learning outcomes and assessment criteria, and the use of criterion-based assessment. Constructive alignment consists of two parts:

- students construct meaning from what they do to learn, and
- the professor aligns the planned learning activities with the associated learning outcomes.

The basic premise of the whole system is that the curriculum is designed so that learning activities and associated assessment tasks are aligned with the learning outcomes that are intended in the course. This means that the system is consistent. Constructive alignment fosters clarity in the design of the curriculum, and transparency in the links between learning and assessment. As students learn, the outcomes of their learning display similar stages of increasing structural complexity.

In traditional courses, constructive alignment is achieved by making the students aware of the learning goals and mapping the activities in the course to corresponding learning objectives. In a mass customized educational environment, our approach is to let the students define their own learning objectives and competencies that they want to gain in the course. The activities in the course (such as assignments, learning modules, and project) are aligned to customized learning objectives (defined in Assignment 0, discussed in Section 4.2.2) through a common underlying structure that can be adapted by the students for different learning objectives. The details are provided in Section 4.2.

3.1.2 Bloom's taxonomy

In 1956, Bloom [19] developed a classification of levels of intellectual behavior important in learning. Bloom found that at the time over 95% of the test questions students encountered required them to think only at the lowest possible level, i.e., the recall of information. Bloom identified six levels within the cognitive domain, from the simple recall or recognition of facts, as the lowest level, through increasingly more complex and abstract mental levels, to the highest order which is classified as evaluation. These six levels are: (1) knowledge, (2) comprehension, (3) application, (4) analysis, (5) synthesis, and (6) evaluation (see Figure 3). Bloom's taxonomy provides a systematic way of describing how a learner's performance grows in complexity when mastering academic tasks. It can thus be used to define curriculum objectives, which describe where a student should be operating. In addition, Bloom's taxonomy provides a powerful means to assess students' performance, justify associated grades, and at the same time provide students with feedback on how to improve their performance. In a truly constructively aligned curriculum it facilitates deep learning as the activities are designed for that purpose.

In our approach, learning activities are scaffolded so that students attain the top levels of the taxonomy in addition to gaining technical knowledge and comprehension. The students are introduced to Bloom's taxonomy at the beginning of the semester. The students define their learning goals in terms of the Bloom's taxonomy (discussed further in Section 4.2.2).

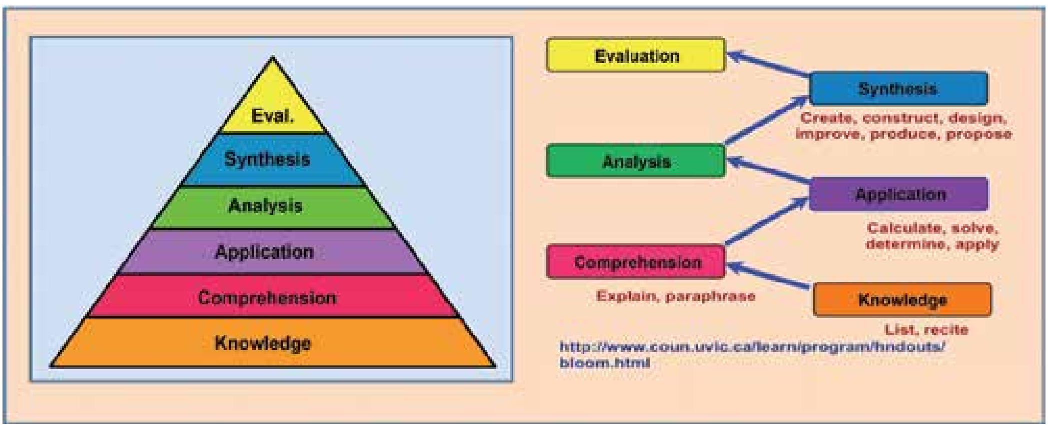

Fig. 3. Bloom's taxonomy of learning

The pedagogical approach adopted in ME6102 embraces elements of collaborative, cooperative, and collective learning. It has been presented in detail in [8]. Research suggests that these instructional approaches foster a deeper understanding of the course content, increased overall achievement of desired learning outcomes, improved self-esteem and higher motivation among students. A brief overview of these instructional approaches with a focus on those aspects most relevant to our pedagogical approach is presented below.

3.1.3 Collaborative and collective learning

Collaborative learning refers to student-centered educational approaches involving joint intellectual effort by learners and instructors. It includes educational methodologies and learning environments in which learners engage in common tasks in which each individual depends on and is accountable to each other. The theory of collaborative learning is tied together by a number of important assumptions about learners and learning processes. These include (a) that learning is an active, constructive process in which learners create new knowledge by using, integrating and reorganizing their prior knowledge; (b) that learning depends on rich context, which influences the success of learning significantly; (c) that learners are diverse in terms of background, knowledge, experience and learning styles; and (d) that learning is inherently social, which makes student interaction an important part of education. All of these aspects of learning are supported by the means of collaborative learning where students solve problems and create knowledge in a diverse group setting.

The term collaborative learning also involves the use of a collection of tools, which learners can use to collaborate, assist, or be assisted by others like they are used in e-Learning and distance learning environments. Such tools include virtual classrooms, chat rooms, discussion threads, as well as application and document sharing. There are three major forms of collective learning: (a) learning in networks, (b) learning in teams and (c) learning in communities. According to Panitz [20], collaboration is a philosophy of interaction and personal lifestyle and cooperation is a structure of interaction designed to facilitate the accomplishment of an end product or goal. Cooperative learning [20-22] is more directed than student-centered collaborative learning and closely controlled by the course orchestrator. The approach presented in this paper features elements of both philosophies.

In our approach, both individual and collaborative learning are blended together to leverage the diversity of individuals and to extract the benefits of learning within a group environment. The activities that are carried out individually include defining individual learning goals and meta-competencies, defining the future environment, and deep reading exercises. Collective activities include answering the questions posed at the beginning of the semester. The details of individual and collective parts are provided in Section 4.2.3 and illustrated in Figure 4. As alluded to before, the field of collective/collaborative/co-operative learning has developed into a major educational discipline by itself. For a detailed discussion please refer to [20, 21].

3.1.4 The Learning Organization

Another foundational construct of our approach is the formation of a learning community in a distributed distance learning setting. The blueprint for this is the model of the Learning Organization (LO) as introduced by Peter Senge in his book 'The 5th Discipline' [23]. According to Senge, a Learning Organization is "an organization that facilitates the learning of all its members and consciously transforms itself and its context". A learning organization exhibits five main characteristics: (1) systems thinking, (2) personal mastery, (3) mental models, (4) a shared vision, and (5) team learning. A brief overview of these, taken from [24], is presented next.

Systems thinking: The idea of the learning organization developed from a body of work called systems thinking. This is a conceptual framework that allows people to study businesses as bounded objects. Learning organizations use this method of thinking when assessing their company and have information systems that measure the performance of the organization as a whole and of its various components. Systems thinking requires that all the characteristics must be apparent at once in an organization for it to be a learning organization. If some of these characteristics are missing, then the organization will fall short of its goal.

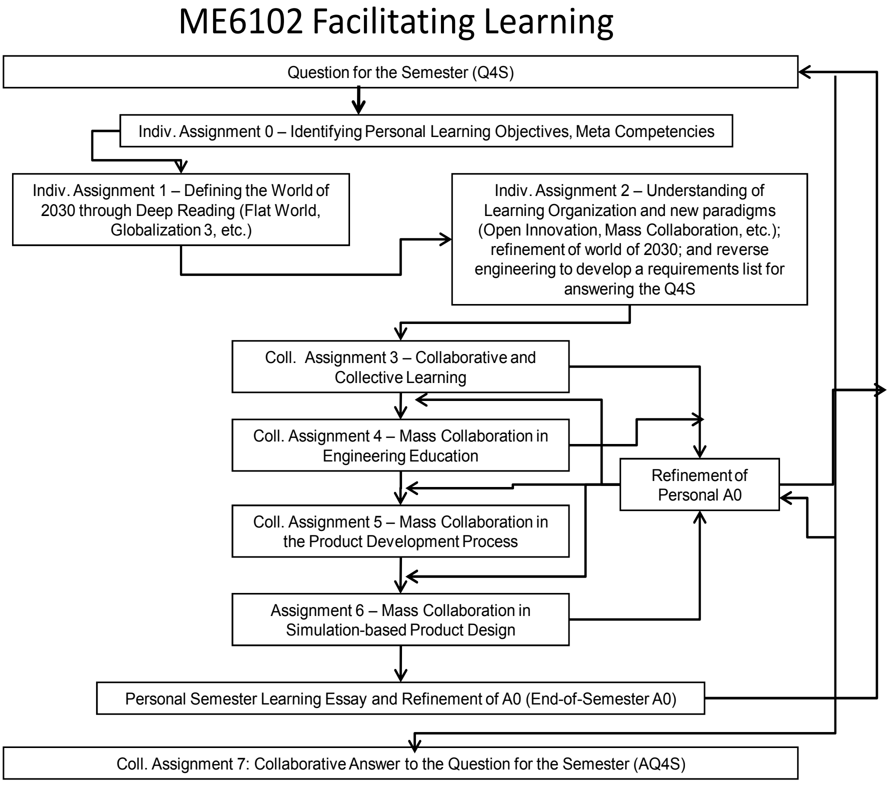

Fig. 4. Relationship between different components of the course

Personal mastery: The commitment by an individual to the process of learning is known as personal mastery. There is a competitive advantage for an organization whose workforce can learn quicker than the workforce of other organizations. Individual learning is acquired through staff training and development, however learning cannot be forced upon an individual who is not receptive to learning. Research shows that most learning in the workplace is incidental, rather than the product of formal training, therefore it is important to develop a culture where personal mastery is practiced in daily life. A learning organization has been described as the sum of individual learning, but there must be mechanisms for individual learning to be transferred into organizational learning.

Mental models: The assumptions held by individuals and organizations are called mental models. To become a learning organization, these models must be challenged. Individuals tend to espouse theories, which are what they intend to follow, and theories-in-use, which are what they actually do. Similarly, organizations tend to have 'memories' which preserve certain behaviors, norms and values. In creating a learning environment it is important to replace confrontational attitudes with an open culture that promotes inquiry and trust. To achieve this, the learning organization needs mechanisms for locating and assessing organizational theories of action. Unwanted values need to be discarded in a process called 'unlearning'.

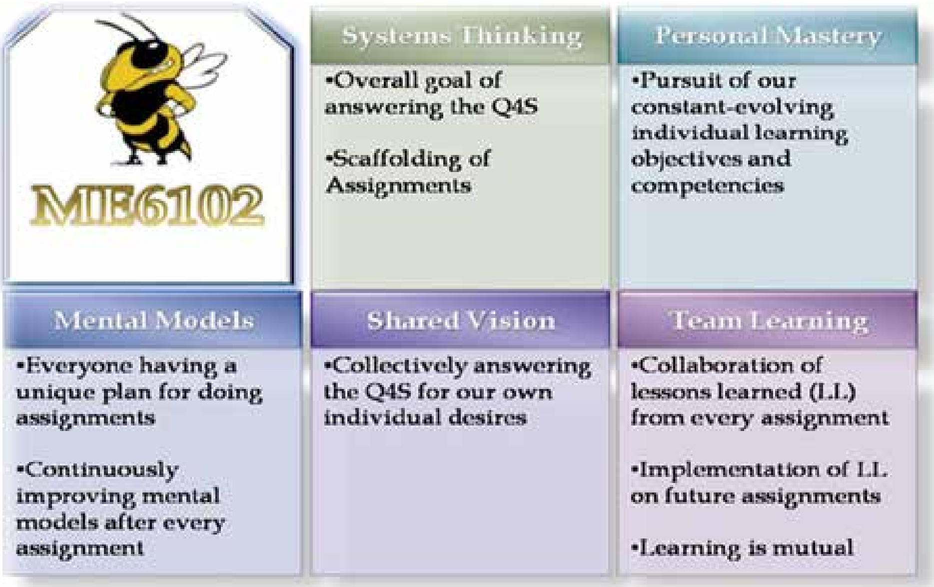

Fig. 5. ME6102 as a learning organization

Shared vision: The development of a shared vision is important in motivating people to learn, as it creates a common identity that provides focus and energy for learning. The most successful visions build on the individual visions of the employees at all levels of the organization, thus the creation of a shared vision can be hindered by traditional structures where the company vision is imposed. Therefore, learning organizations tend to have flat, decentralized organizational structures. The shared vision is often to succeed against a competitor, however Senge states that these are transitory goals and suggests that there should also be long-term goals that are intrinsic within the company.

Team learning: The accumulation of individual learning constitutes team learning. The benefit of team or shared learning is that people grow more quickly and the problem solving capacity of the organization is improved through better access to knowledge and expertise. Learning organizations have structures that facilitate team learning with features such as boundary crossing and openness. Team learning requires individuals to engage in dialogue and discussion; therefore team members must develop open communication, shared meaning, and shared understanding. Learning organizations typically have excellent knowledge management structures, allowing creation, acquisition, dissemination, and implementation of this knowledge in the organization.

The paradigm of the learning organization (LO) was initially developed for companies, based on the business models and practices of the 1990s. To extend the concept of learning organization to educational settings, we analyze the original model of the LO and augment it to better fit the learning needs of the students and the characteristics of the G3 world of near tomorrow. Figure 5 is an illustration of the use of the learning organization framework in the sample course, ME 6102. Systems-thinking is achieved by posing a high-level question for the students to be addressed by scaffolded activities and assignments throughout the semester. The question is referred to as the Question for the Semester (Q4S). The Q4S is discussed in detail in Section 4.2.1. Personal mastery is achieved by defining and striving to achieve personal learning goals that are tied to the development of competencies and meta-competencies. The students are continuously challenged to understand and assess their mental models. Team learning and shared vision are achieved through the process of collectively completing the assignments and answering the Q4S. The details of the approach are provided in Section 4.

3.2 Strategies for mass-customization in engineering education

One of the barriers to mass-customization within engineering education is that focus is primarily on delivering technical content. The first step towards achieving mass-customization is to shift the focus from technical concepts to the process of learning. This is the fundamental difference between traditional approaches to engineering education and our approach to mass customized education. Analogous to the concept of product platforms, our **learning platform** is centered on the notion of "learning-to-learn". Hence, the focus is shifted from just delivering technical information to helping students learn how to learn. The learning platform consists of a set of tools (shown in Table 2) whose role in the learning platform is well defined and standardized. The technical content is adapted to suit the specific needs of different courses and disciplines. The courses derived from this common learning platform constitute a *product family*.

Our learning platform for mass-customization in engineering education is centered on the following principles (see Table 2):

a. *Shift in the role of the instructor*: In traditional engineering courses, the role of instructors is to deliver course content to the students. In contrast, the instructor serves as an orchestrator of learning. The role of orchestrator is to create opportunities for students to learn (both individually and collectively).

b. *Shift in the role of students:* The role of the students also shifts from being passive learners to active learners. The students play a significant role in the learning process. They define their own learning goals (in consultation with the orchestrators) and are responsible for directing their efforts to achieve their goals.

c. *Providing the opportunities to learn*: Instead of solely lecture-based learning, the students are provided various opportunities to learn individually and collectively. These opportunities include lectures from instructors and guest speakers, speculation sessions, discussions sessions, self-study time, forming a learning community, virtual collaboration on global scale, creating new knowledge, collaborative group project, reflective practice, and self and peer evaluation.

d. *Shift in focus from the lower levels to upper levels of learning*: Traditionally, the focus has been on the knowledge of core concepts and their application to technical systems, namely, competencies. The focus in our approach is on higher level learning (i.e., develop meta-competencies) such as the gaining the abilities to analyze, synthesize, and to evaluate (see details in Section 4.2).

e. *Creation of learning communities*: An underlying principle to achieve successful mass-customization in engineering education is "sharing to gain", which is achieved by fostering learning communities.

Traditional Concepts in Engineering Education	Principles for Mass-customization	Tools used in ME 6102
Instructors deliver course content	Shift from instructor to an orchestrator who creates opportunities to learn	Assignment 0, Question for the Semester, Learning essays, Project
Students are passive learners	Students are active learners, i.e., take charge of their own learning	Assignment 0, Question for the Semester, Learning essays, Project
Learning goals are fixed by the instructor	Learning goals are defined by the students in collaboration with the orchestrator	Assignment 0
Focus on lower levels of learning	Focus on higher levels of learning	Bloom's taxonomy
Individual learning	Learning communities	Learning organizations (Senge)
Rigid course structure	Embed flexibility in the course	Assignment 0, core and optional modules, ability to adapt the learning tools
Ignore diversity	Leverage diversity	Best practices, collective learning
Learning process unclear to the students	Making students aware of the learning process	Observe-reflect-articulate construct
Independent activities	Scaffolding	Question for the Semester

Table 2. The principles for mass-customization and the tools used in ME 6102

f. *Embed flexibility in the course*: In contrast to traditional rigid course structures, we embed flexibility in the course by having guest lectures on diverse topics, ask the students to define their own goals, and let the students adapt various parts of the course to suit their learning needs.

g. *Leveraging diversity*: One of the approaches for leveraging diversity is to share students' unique work with the rest of the class. This is achieved by identifying, distributing and discussing "best practice" submissions.

h. *Making students aware of the learning process*: In traditional courses, since the focus is on the content, the students are unaware of their learning process. However, in our approach, we make the students aware of the learning process so that they can understand the role of each activity that they are invited to undertake and the relationship of this activity to their learning. This is carried out through the observe-reflect-articulate construct. Each assignment and learning essay is divided into these three parts to bring alive the observe-reflect-articulate construct.

i. *Scaffolding*: Finally, the most important aspect of our mass-customization approach is scaffolding of the course towards the achievement of individual and collective goals. This is achieved through a question for the semester (Q4S) that is provided to all the students at the start of the semester. All activities in the course are geared towards answering this question.

We have designed a learning platform that embodies the preceding principles and allows us to develop customized courses for different disciplines, technical areas, and at different scales. We have done this for undergraduate and graduate courses in mechanical engineering. This is analogous to horizontal leveraging on the market segmentation grid (see Figure 2). The approach can be scaled down from a course level to a short-course level, and scaled up to a combination of courses (curriculum level). Although the approach has not yet been used for curriculum-level mass-customization, we assert that the underlying principles are valid. We note that the principles are independent of the courses, curricula, or the discipline. Hence, different discipline specific content can be added to develop different courseware. As a result, it serves as a learning platform (product platform) for engineering education that can be customized to generate different courses (products) in the course family (product family). In the following section, we offer the implementation details of the course.

4. Implementation of the approach in a graduate-level engineering design course (ME 6102)

4.1 Overview of ME6102: Designing Open Engineering Systems

ME6102 – "Designing Open Engineering Systems" – is a graduate engineering design course offered at the George W. Woodruff School of Mechanical Engineering at Georgia Institute of Technology. ME6102 is offered to students enrolled at the George W. Woodruff School of Mechanical Engineering's different Georgia Tech campuses - Atlanta, Savannah, and Lorraine (France) and also by distance learning students who were located all over the world. Most students take ME6102 after they have taken some introductory engineering design course in which they have become familiar with a systematic design approach (such as the one by Pahl and Beitz [25]). The course is offered in both live and distance learning modes. To reach all students, synchronous and asynchronous education techniques are incorporated. The lectures are recorded and uploaded so that all students can access them online at any time. Besides in-class interactions, the students are encouraged to communicate with the course orchestrators via email, telephone, video conference or the online forum on the course website. The online forum also enables communication analogous to social networking websites such as Facebook and LinkedIn. To bring the groups of on-campus and distance-learning students closer to each other, we have developed a collaborative learning framework that enables students to interact through a course internal social network. The framework is based on Web 2.0 technologies such as collaborative wikis, and open source software development principles. Through this web-based framework we provide a variety of tools to support both synchronous and asynchronous communication between the participants. The use of such a framework for collaborative learning also provides students the opportunity to experience the challenges and benefits of mass-collaborative environments [26].

Our goal is to provide an opportunity for students to learn how to create knowledge rather than merely learning how to solve problems encountered in design. The emphasis is on problem identification and formulation in a rapidly changing world that is defined by Globalization 3.0. The course setting provides the opportunity for students to learn how to:

- identify opportunities for creating new systems and improving existing systems in the age of global mass-collaboration.

- identify the competencies required to succeed in a changing marketplace and learning how to gain those competencies.
- design open engineering systems in the presence of uncertainty from a decision-based perspective, i.e., to design systems with characteristics consistent with their natural life-cycle dynamics.
- manage uncertainty and complexity in systems and associated design processes.
- make tradeoffs needed to coordinate multiple objectives associated with the design of open engineering systems.
- develop the ability to critically evaluate literature and use this analysis to identify research issues worth investigating.
- continue learning about designing.

The content of the course is based on three concepts: Open Engineering Systems [27], Globalization 3.0 [28], and Mass Collaboration [29]. The students are challenged to determine the requirements for design approaches to work well in the context of the Globalization 3.0 world with its new, game-changing paradigms of mass collaboration, open-innovation, crowd-sourcing, and the like. Hence, the syllabus also contains topics from economics (e.g., globalization, global markets), business (e.g., value chain, supply chain, outsourcing), law (intellectual property protection), IT (e.g., web 2.0) and social sciences (e.g., social networks, cultural differences, motivation).

4.2 Mass-customization in ME6102

The underlying architecture of the course is designed to provide personalized learning experiences in a group setting. The key components of this architecture include:

- *Question for the Semester* as a common thread to tie the components of the course together
- *Assignment 0* to understand the diverse learning goals and meta-competencies of the students
- *Learning activities* to achieve personal goals in a group setting
- *Assignments* to scaffold the learning experience
- *Project* to customize the core topics in the course to particular application based on students' interests
- *Learning essays* and *individual feedback to provide personalized guidance to individual students*
- *Best practices* to enable collective learning, and
- *Assignment A0-EOS* for reflection and self-assessment

The relationships between these components are discussed next.

4.2.1 The Question for the Semester

The question for the semester is used to align the efforts of all the students while providing enough flexibility to the students to explore the topics that are particularly interesting to them. The question for the semester is presented to the students during the first lecture. Every student has to answer this question individually by the end of the semester. Examples of the questions for the semester used during Spring 2008 and Spring 2009 are shown below. To support mass-customization of the course, the students are allowed to particularize this question according to their personal semester goals. The particularization is carried out in consultation with the orchestrators.

Question for the Semester – *Spring 2008*

Imagine that you are operating a product creation enterprise in the era of Globalization 3.0. Your task is to define your company and develop a business plan. This includes answering the following key questions:

a. How do you envision the world of 2030 in such an environment?
b. How do you see yourself and your company operating in this world of 2030? Please take into account your engineering expertise and your passions.
c. What are the *competencies* that you would require to be successful in such an environment? Please identify the drivers and metrics for success.
d. What would your strategy for product development be in the world of 2030? What kind of products / processes do you plan to offer? How would you structure your design and manufacturing process? What kind of collaborations with other companies do you envision? What kind of supply chains do you envision your company to be involved in? How would you utilize the intellectual capital available throughout the world?
e. What would the IT framework for collaborative product realization in 2030 look like?
f. What kind of a product realization method is necessary for your world of 2030? Please provide phases and steps.

Question for the Semester – *Spring 2009*

Imagine that you are operating a product creation enterprise in the era of Globalization 3.0 where individuals are empowered to participate in the global value network. Your brief is to identify the characteristics of the IT infrastructure to support the technical collaboration that furthers open innovation.

Question for the Semester – *Spring 2011*

Imagine that you are operating a product creation enterprise in the era of Globalization 3.0 where individuals are empowered to participate in the global value network. Your brief is to identify and discuss the characteristics, opportunities and challenges of a Product Development Process (Design and Manufacture) that furthers open innovation and is based on crowdsourcing and mass collaboration.

4.2.2 Assignment 0

As a ramification of the ongoing globalization, the skills that were considered valuable yesterday are becoming the commodities of today and tomorrow [30]. Realizing how much the world has changed over the past 10 years, it becomes apparent that this change needs to be better reflected in the way engineers are educated [31-34]. Some educators have articulated that engineering education needs to be considered from a holistic point of view [35-37]. There should be a better symbiosis of societal needs, emerging technologies, cross-disciplinary domain integration, and aspects related to cultural diversity and ethical issues. Our task at hand is to prepare engineers who are capable of identifying and solving problems that do not yet exist with tools and methods that have not yet been invented. In essence, this boils down to educating students with respect to **learning how to learn** and to **empower them to take charge of their own education**. From the perspective of an individual, this translates to identifying and obtaining the competencies needed to become a valuable asset for a dynamic career. Hence, the first step to customize the course is to let the students identify their personal goals for the semester. In ME6102, this is achieved in an assignment (Assignment 0) which is given during the first class. In this assignment, the students' task is to identify the goals that they want to achieve. These goals are referred to as the *personal semester goals*. The goals consist of learning objectives and competencies that they want to achieve during the semester. The learning objectives and meta-competencies identified by one of the students are shown in Figure 6 as an example.

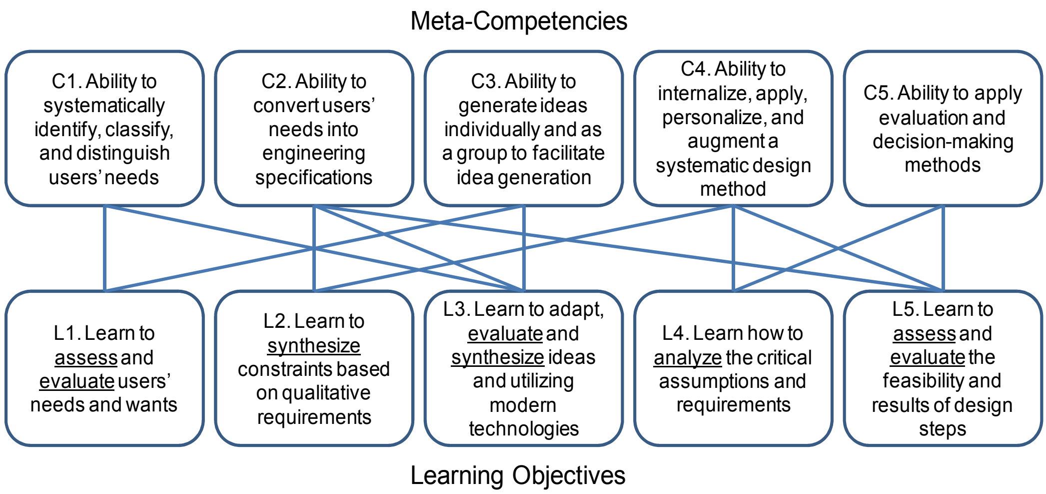

Fig. 6. Examples of Meta-Competencies and Learning Objectives and relationships among them

Competencies are the result of integrative learning experiences in which skills, abilities, and knowledge interact to form bundles that have currency in relation to the task for which they are assembled [38]. On the other hand, learning objectives are generic skills that students wish to attain so that they become competent in performing the task. Learning objectives are defined in terms of the six levels of learning defined in the Bloom's taxonomy (knowledge, comprehension, application, analysis, synthesis, and evaluation). In the examples of learning objectives, the keywords from Bloom's taxonomy are highlighted.

Having identified the students' personal goals, the course orchestrators use a scaffolding scheme to design a personalized learning experience in a group setting, thereby mass customizing the course to different student needs. In Figure 4, the relations between the different components of the course are depicted. The scaffolding is achieved through the "Question for the Semester" (Q4S) and the various assignments. The assignments are scaffolded and provide opportunity for personalization. This ensures that everybody in the class works in the direction intended by the course orchestrators. The lectures are used to convey core course content and additional aspects that may help students with their assignments and learning essays. While answering the "Collaborative Question for the

Semester" the students work in a mass collaborative manner which provides the opportunity to create new knowledge by combining the diverse knowledge in the personalized section of the course.

Mass-customization in education requires catering to students' individual needs, skills and interests. This not only leads to a higher motivation of the students but also enables deeper learning. In ME6102, the orchestrators apply a similar approach to mass-customization as presented by Williams and Mistree [6]. The key for providing personalized learning experience in a group setting is an intensive two-way communication between students and the orchestrators. Therefore the course orchestrators have to get to know their students and their personal semester goals. In ME6102, students' objectives are captured through Assignment 0, which is due at the end of the first week of the semester. The students are asked to provide a brief self-introduction, their expectations of taking this course and their personal semester goals (learning objectives and competencies). They are asked to list five *learning objectives* they want to achieve and five *competencies* they want to gain during the course of the semester. Learning objectives are clear formulations of what a student wants to learn and are usually related to acquisition and creation of knowledge. The details of Assignment 0 are provided in Figure 7.

4.2.3 Individual and collaborative assignments

In ME6102, there are two types of assignments – individual assignments and collaborative assignments. As shown in Figure 4, Assignments 1 and 2 are individual assignments whereas the rest of the assignments are group assignments. In Assignment 1, the students took a closer look at defining their world of 2030 and their views on what a manufacturing enterprise will look like 20 years from today. In Assignment 2, the students identify the components of their answer to the Q4S. In essence, answering the Q4S was their design problem and the answer to this question considered an Open Engineering System they were required to build. Both these assignments are carried out individually in order to maximize the diversity in ideas and to reflect the students' individual interests and passion within the framework of answer to the Q4S. After this stage, collective assignments help in understanding the concepts of mass collaboration. The exact format of the rest of the semesters is customized every semester.

During 2009, Assignment 3 was focused on creating a Virtual Learning Environment (VLE) for collaborative and collective learning in which to work on the assignments. In addition to the technical aspects, this included forming a learning community in a distributed setting plus establishing policies regarding their collaboration and behavior. This is a step towards forming a distributed learning organization. Assignment 4 was on the concepts of Mass Collaboration in Engineering Education. The students were tasked to identify and analyze Web 2.0 technologies with regard to their appropriateness for professional mass collaborative work. In Assignment 5, the students were to look into the topic of Mass Collaboration in the Product Development Process. This included an analysis with regard to the following phases: 1) Idea Generation, 2) Idea Screening, 3) Concept Development and Testing, 4) Business Analysis, 5) Beta Testing and Market Testing, 6) Technical Implementation, and 7) Commercialization. In addition, methods of Mass Collaboration between the various functional units of corporate enterprises were investigated and requirements for a successful implementation identified. Assignment 6 was on the application of Mass Collaboration in virtual product realization environments through the utilization of Simulation-based Design.

Assignment 0

Identify Competencies

1. What is your view of a manufacturing enterprise in 2030? Leverage Lecture 01, Friedman, P&G.
2. Critically evaluate your response in Point 1 and then propose the competencies (in bullet form) that you believe are needed to be a successful designer in the world of 2030. Justify. Hint: See Slides 13 and 14, Lecture 2.
3. Critically evaluate the list in Point 2. This will require you to do a self-inventory of your competencies or lack thereof. List (in bullet form) the 5 competencies you propose to develop in ME6102.
   a. ***Compare*** what you have written under Points 2 and 3.
   b. ***Assess*** the improvement in what you have written in Point 3.
   c. ***Recommend*** what additional fixes are necessary,
4. Analyze the competencies listed in Point 3. Classify. Prioritize. Modify/refine. Propose an improved list of competencies you propose to develop. In context of Points 2 and 1 justify your proposed set of competencies.

Identify Learning Objectives

5. Analyze your response to Point 4. Respond to the following question (bullet form): For me to develop the competencies listed in Point 4 what do I need to learn? For each Competency identify the associated Learning Objectives. **Note: A Learning Objective must contain the word "learn" in it and include transformative words from Bloom's Taxonomy** (see lecture 1).
   a. ***Assess*** whether each of the learning objectives contains the word ***Learn*** and **transformation words** for the appropriate domain of knowledge. If not ***improve.***
   b. ***Assses*** whether the set of 5 proposed learning objectives span a few domains of learning. If not ***improve.***
6. Classify, refine the list. Prioritize, modify / refine and list your 5 Learning Objectives for this class. Justify.

Relate Competencies and Learning Objectives

7. Illustrate the relationship between the competencies identified in Step 4 and Step 6. Comment on the efficacy of the relationship.
   a. ***Assess*** whether the Competencies and Learning Objectives are suitably labeled. If not ***improve.***
   b. ***Assess*** whether the transformative words in the Learning Objectives are highlighted in the illustration.
   c. ***Verify*** whether what you have illustrated is in harmony with what you have written under Point 1 in this evaluation exercise. If not ***improve.***

Value

8. Analyze what you have written in Points 4 and 6 and answer the following questions: What is it you really wish to achieve as a result of taking this course? What have you learned as a result of doing this assignment? Hint: Summarize using transformative words from Bloom's Taxonomy and associated competencies.

Continuous Improvement

In tabular form, record the date and your feelings as you read this at various times during the course. Please modify as you proceed through the semester. Note: You will be making an entry every week. Start off right. ☺

Fig. 7. Assignment 0

In Assignment 7 the students were required to put together all the well-scaffolded pieces they had worked on during the semester. That is, they collaboratively had to write a complete book in which each chapter was dedicated to one of the assignments. The difficult task here was to tie everything together to create a coherent train of thought, starting from the background information on Friedman's flat world, Procter and Gamble's Connect and Develop approach for Open Innovation, Bloom's Taxonomy of Learning, the Q4S, the topics of the subsequent assignments as well as the industrial mini-consulting projects that were embedded into the assignments. In addition, the students had to answer the Question for the Semester.

4.2.4 Learning essays

Learning essays are weekly submissions in which the students usually review and explore topics from the lectures in the context of their personal semester goals (learning objectives and meta-competencies). To guide the students, at the end of each lecture specific guiding questions are suggested that may help them to better relate the lecture content to the big picture of the course. The students also have the freedom to choose other course-related themes for their learning essays. A core aspect of the learning essays is that the students learn how to create new knowledge and enhance their critical thinking skills. Furthermore students learn how to evaluate their work and their progress towards their personal goals from Assignment 0. The structure of learning essays is scaffolded to address learning objectives and competencies (as shown below).

At the end of the semester the students reflect on their learning in the Semester Learning Essay by relating it to a non-engineering analogy or metaphor (e.g., football, cooking, golfing and writing poems). Here, the students can show that they really progressed in achieving their personal semester goals.

Structure of a Learning Essay

Tag Line – Core Notion
Your A0 Goals – Competencies and Learning Objectives
Preamble: Provide context for your learning essay

Observe: State the facts (as per author, professor)
Reflect: Look at the observations from different perspectives. Pose questions and answer them
Articulate: New insights and knowledge
Key phrases: I learned x, I realized x, etc.
Value = Utility / Time Invested
With respect to A0 goals, answer to Q4S, project, etc.

4.2.5 Individual and group feedback

In ME6102 no grades are given until the end of the semester. Hence, the students can concentrate only on their progress towards achieving their personal learning objectives articulated in A0 for the semester. To ensure that the students are on the right track, the orchestrators facilitate self-assessment and provide feedback to the individual and the group through formative assessment of all submissions (assignments and learning essays) throughout the semester. Through Assignment 0, the orchestrators get to know the students and thus are able to provide individual feedback on all submissions according to the students' individual semester goals. To remind both the student and the orchestrator of these goals the students state them at the beginning of all learning essays and assignments and evaluate their learning with regard to these goals. This means that the students get constructive feedback which helps them make progress towards their individual semester goals. Students are expected to record the comments they get on their work in a journal and demonstrate that they utilize them in the following submissions. In doing so, the students can better realize their progress, which can increase their motivation.

4.2.6 Best practices

Learning essays and assignments, that have the potential to add value to the learning of others become "best practices" and are shared with the entire class. Often "best practices" from former students of the course are also discussed in class or presented on the course website. This aspect of the presented approach enables collective learning; students learn from and about each other, get inspired and can build on others work to develop new knowledge. A positive side effect is also an additional incentive to become author of a "best practice" and the experience that an individual's work is taken seriously by others.

4.2.7 Project

The project is another avenue for collaborative learning experience. In the project, the students are expected to validate a part of their answer to the Q4S. Validation is an important aspect of the course because it helps students to learn how to critically evaluate their proposed answer to the Q4S. This relates to the highest level in the Bloom's taxonomy. The students are free to choose the topic of the project related to their research or other personal interests. Examples from the past are "human centered design of a bicycle through a simplified CAD interface for customer interaction" and "motivation and incentive models in online communities and mass collaborative projects". The typical group size is two to four members. This cooperative learning experience is integrated into the presented approach to increase the depth of learning through group learning and discussions.

4.2.8 AO-EOS and self-grading

At the end of the semester, students are called on to close the loop with regard to what each has learned – to what extent each has achieved the competencies and the associated learning objectives proposed in A0 and refined through the semester. The students are required to revisit all their submissions, reflect on the feedback that was provided and take stock of how much each of the learning activities throughout the semester have actually helped them to attain the desired competencies and meet the corresponding learning objectives. To what degree have they learnt how to learn? This process of reflective practice is presented to the students by means of A0-EOS, an extended end-of-semester version of the original Assignment 0.

<u>Assignment 0 – End of Semester</u>

…

A0 Completion - Individual

10. Revisit Value = Utility / Time Invested
    Summarize …
    Assignment 1: Summarize Part 6
    Assignment 2: Summarize Part 4
    Assignment 3 through 6: Summarize Part 3
11. In tabular form, in the context of a learning organization, outline the strategy that you followed in defining your "mental model" for Assignments 3 through 6 AND your contributions to the collaborative assignment.
12. In tabular form summarize your contributions to Assignments 3 through 7 under the following headings:
    a. Themes / ideas proposed by <u>you</u> and adopted by the team …
    b. Themes / ideas proposed by <u>others</u> that were adopted by the team …
    c. Rate the contribution of others[1]: A – above average. B – average. C – below average. You are encouraged to use + and – for the grades you assign. Justify.
    d. In the context of 12 c rate your own contribution: A – above average. B – average. C – below average. Justify.
13. In tabular form, please convey how you progressed in attaining your competencies and learning objectives throughout the semester.
14. In graphical format, please convey the degree to which you attained the identified competencies and learning objectives.
15. Analyze what you have written in Steps 10 through 14. Then, critically evaluate your performance (in terms of competencies and learning objectives) throughout the semester; be sure to use action words from Bloom's taxonomy. Comment on the level of attainment in Step 14, what you would do differently if you had to do it over, and plans for the future.

Grade for A0 End of Semester

16. Reflect on your performance in this class throughout the semester. In tabular form, please suggest a grade for yourself in the following categories and justify[2]:
    a. Contribution to the collective Question for the Semester. Justify.
    b. Degree to which you attained your competencies and learning objectives and why.
    c. Degree to which you learned what you would do differently and why.
17. Overall grade you award yourself for this submission. Not all items are equally important to determine your grade for the course. You may weight items 16a through 16c as shown below.
    - 16a - 30 to 50%
    - 16b – 30 to 50%
    - 16c – 10 to 20%

[1] A+ (4.3). A (4.0). A-(3.7). B+(3.3). B (3.0). B-(2.7). C+(2.3). C (2.0). C-(1.7). D (1.0). F (0.0)
[2] Be sure to reference elements of your responses to Items 10 through 15.

Fig. 8. Fragment of Assignment 0 – End of Semester (A0-EOS)

In addition to revisiting the questions of A0, the students are called on to reflect on their learning process, the quality of their contributions to the various assignments, the value gained with respect to attaining their individual learning objectives and competencies as well as the value added to the overall ME6102 Learning Organization. Finally, based upon this self-reflection, the students are asked to propose a grading scheme for evaluating their own work as well as that of their peers. This includes developing a comprehensive assessment rubric showing the categories of work to be assessed along with justifications for the various degrees of achievement, as well as the articulation of the specific grades they believe they have earned.

In summary, the underlying architecture of the course facilitates mass-customization. While the course does require significant commitment from the orchestrators, its architecture with a core element and customizable components makes it manageable.

5. Closing comments

"*Any customer can have a car painted any color that he wants so long as it is black*" [39]

This well-known quote attributed to Henry Ford epitomizes the traditional concept of mass production. While this paradigm was successful in most part the 20th century, most companies today realize that their long-term success cannot be guaranteed by focusing on a single product. Instead, companies must generate a continuous stream of value-rich products. Unfortunately, the framework of engineering education is still built on the traditional mass production paradigm. Educational institutions around the world are focused on mass-producing graduates with similar skills and knowledge. Many degree programs have changed very little from what they were various decades ago. Educational institutions are generally slower in adapting to the changing workplace. In this chapter, we emphasize that the success of education programs is dependent on the ability to personalize educational experiences. We argue that the need for mass-customization is as much important in education as it is in product development.

Along with the advent of globalization came a huge variety of new job profiles that do not correspond well to what is offered through traditional education and training programs. It is clear that the work force of near tomorrow will have to be very agile and versatile in terms of the competencies and skills to be obtained and that learning how to learn, i.e., becoming a self-motivated, self-organized learner. In light of this, the National Academy of Engineering (NAE) identified Advanced Personalized Learning as one of the Grand Challenges of our time [40]. In response to this, many educational institutions around the world have started developing on-demand digital curricula to drive independent, self-directed learning. One way of facilitating this is to utilize the characteristics of mass-customization, as presented in this chapter, and apply them to curriculum and program design on a larger scale. In terms of a long-term vision, it may be conceivable to offer personalized educational programs based on resources drawn from anywhere in the world. We are aware that current business models do not necessarily support such ideas. However, we believe in the famous Walt Disney quote: "If you can dream it you can do it".

6. Acknowledgements

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10

A Logistics Reference Model for Mass Customization

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1. Introduction

The chapter introduces a reference model for the analysis, configuration and implementation of logistics networks with a dedicated focus on Mass Customization.

Logistics management is often considered as a support process but it can significantly contribute to reach core-business targets of companies because of its relevant impact on costs and performances. As Mass Customization asks organizations to radically change their production processes, logistics should be able to handle small quantities, personalized products and variable demand rates, keeping at the same time the desired service levels.

An accurate configuration of distribution and information networks is thus one of the most aggressive competitive leverages, as confirmed by many market-leader companies that continue to invest in this area to increase profits by strong improvements of efficiency. The markets where modern companies are operating have specific characteristics that don't allow a static attitude. Globalization creates important opportunities of improvement that need an harmonic growth of the whole organization, where a new generation of IT systems (for example RFID) plays a main role in managing different flows of goods.

The simple rationalization of production systems is no more sufficient, while an attention to new perspectives and opportunities in non-core processes can affirm the position of a company towards its competitors. In this scenario, logistics is a strong driver of competitiveness, enabling the sustainability of customization. While many studies already focused on inbound logistics (handling of goods during their production stages) as a key factor to address customization processes, outbound logistics still needs to be deeply analyzed as a strategic issue to maintain and control the level of customization.

A logistics framework for Mass Customization needs a clear definition of the objectives and an accurate analysis of the factors that can influence the performances of distribution networks, to support decisional processes and guide managers throughout the choices of the correct elements to reengineer, both in the case of an existing or in the design of a new network.

2. Literature review and objectives of the chapter

The importance of logistics on Mass Customization is not a novelty as it can, at the same time, limit and enhance Mass Customization. Logistics can be recognized as one of the main drivers of Mass Customization as it can push towards new and unrestricted markets, focusing manufactures on the creation of value for different clusters of customers defined by their location (Svensson & Barford, 2002).

A case analysis on 13 international companies (Moser, 2007) and many other researches (Verbraeck & Versteegt 2001, Cochran and Lewis 2002, Biswas & Narahari 2004, Lu & Storch 2004) identified logistics as a dominant competency for Mass Customization and a key element to customize the supply chain (Browning & Eppinger 2002). Study of application of Mass Customization in specific fields (as for the automotive, one of the most investigated) showed that improvements in the production process aren't sufficient to satisfy the required lead times without dedicated actions on logistics (Holweg & Miemczyk, 2002, 2003).

On the other side, the implementation of Mass Customization processes affects logistics performances, mainly due to the increase in the varieties of products, as the logics of scheduling and delivery of components to assembly tend to increase the level of inventories in order to prevent stock-outs (Aigbedo, 2007). Furthermore, some authors identified the need of a strong direct-to-customer logistics system as one of the limits of Mass Customization (Zipkin, 2001), in particular where e-commerce could open unexploited markets.

The Mass Customization manufacturing system, starting from a wide portfolio of different orders, forces companies to accurately organize workflows (Lu et al., 2003). But, at the same time, while Mass Customization needs an appropriate configuration of the logistics network, business needs and management rules tend to push towards conflicting solutions. For example, Just in Time philosophy, focusing more on managing material flows and reducing inventory than on the flexibility of the whole organizational system (Waller et al., 2000), affects performances of logistics and distribution system (among many: Pine, 1993; Kotha, 1995). Furthermore, outsourcing of manufacturing in low-cost countries or overseas suppliers leads to longer delivery times and bigger batches (Broekhuizen & Alsem, 2002).

The target of Mass Customization ("building of products to customer specifications using modular components to achieve economies of scale", Duray et al., 2000) can so be inherited in logistics where *postponement* can be recognized as the main and most suitable approach to these emerging problems, as showed by Fogliatto & Da Silveira (2011).

Postponement in logistics is the strategy to delay (in time and location) the increase of product's variety, value, volumes and weight to save on inventory, reducing carrying, holding, stock-out and obsolescence costs (Yang et al., 2004). After a first introduction of its general principles by Zinn & Bowersox (1988), Lee (1996) focused the theme on logistics to identify savings coming from the delayed distribution of semi-finished or finished products. Other researches proposed frameworks to assess the possibility of postponement in logistics, evaluating the opportunities on stocking (Pagh & Cooper, 1998), benefits of an alignment with production postponement (Rabinovich & Evers, 2003) and the implications on the whole supply chain (Yang & Burns, 2003). An extended review of postponement in logistics can be found in Yang et al. (2004), to identify challenges of implementation, and in Boone et al. (2007), to notice the slow rate of diffusion of this strategy.

Although the impact of logistics on Mass Customization is clearly visible, few studies offer a guide to the process of redesigning the distribution network to accomplish the target of customization. This is a recent issue (Chow et al., 2005) that needs more investigation (Nambiar, 2009) that was still not present in the 2011 review by Fogliatto & da Silveira as today it only shows specific applications without an overall view on the problem.

The need for an integrated model, as illustrated in this chapter, deals with the actual business environment that pushes organizations to move from a conventional logistics to a direct-to-customer distribution (Zipkin, 2003). In this scenario, as proved by various experiences in literature (Miller et al., 2010), logistics planners look for Decision Support System (DSS) to maintain distinctive advantages of competitiveness in evolving markets (Davenport et al., 1996). Those systems provide specific points of view to support network configuration, for example to select the best supplier of services, to identify the level of data sharing through the logistics processes, to choose the transportation mode or to quicken shipments and deliveries. Anyway, methodologies to design outbound logistics taking in consideration, at the same time, strategic, tactic and operational decision are still missing. The requirement assumes a greater significance if combined with the large investments in infrastructures needed to coordinate transportations and deliveries of materials and products on short notice, trying to contain costs. This leads most organizations to offer built-to-order customized products, using direct deliveries made by external logistics providers, with a relevant effect on the final price to the customers (Broekhuizen & Alsem, 2002).

3. The process of logistics design for customization

The definition of an integrated vision on the logistics network configuration first needs an accurate description of:

- the targets of the distribution processes;
- the factors that can affect decisions of logistics managers;
- the elements of the network that have to be defined.

All these issues that drive logistics performances have to be considered with specific reference to the high level of flexibility required by Mass Customization.

3.1 The targets of the network

The starting point to drive the changes of the outbound logistics is the right definition of the targets of the configuration process that can help to evaluate different alternatives. Two are the main dimensions of analysis that express the mission of a logistics network (Chopra & Sodhi, 2004):

- the satisfaction of customer needing;
- the total cost to fit these requirements.

Customer satisfaction presents many components that have to be accurately balanced, in particular when the level of the demand and its specialization tend to explode. In terms of logistics processes, customer satisfaction can be represented by a mix of (Figure 1):

- variety of products;
- lead time;
- availability of products;
- customer experience;
- traceability of orders;
- possibility of return.

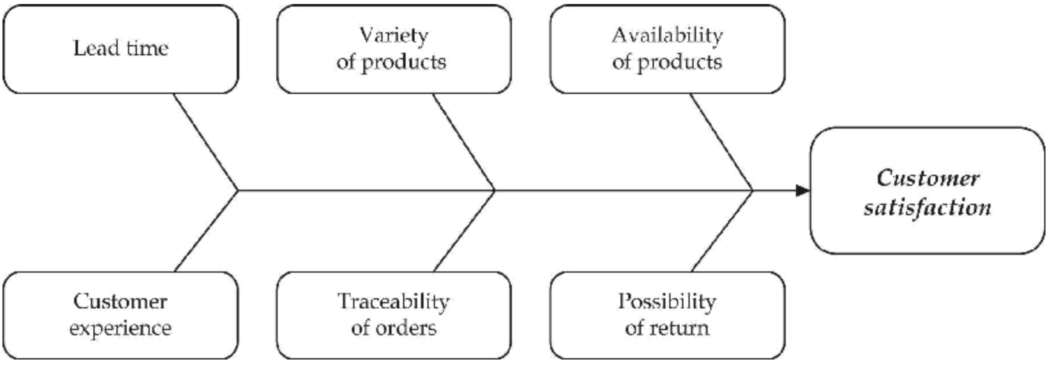

Fig. 1. Components of customer satisfaction

The *variety of products* is the main theme of the chapter and is the main assumption of the approach. Logistics is one of the strategic areas that have to be involved to guarantee that the increase in customization and flexibility can be perceived by the customers. Logistics assets and processes allow the capability of the network to effectively offer a wide range of products, making customers aware of its real possibilities.

Lead time between order (purchasing or production) and delivery is a critical parameter that has to be strictly controlled, in particular when the high level of differentiation is combined with zero-inventory approaches. In the modern environment, where products can be highly substitutable in terms of technical specifications, quicker companies prevail as time to market is one of the most tangible leverage of competitive advantage.

Once defined the portfolio of products to offer, their real *availability* at the retailer stage is a further indication of the service level. After a process of selection in catalogues, internet or other mass media, customers that go to shops and can't find products tend to become a missed opportunity. Low inventory at the production stage has so to be balanced with the right inventory at the distribution stage.

Customer experience is related to the easiness of purchasing, the possibility of having a support during ordering and shipment or, more in general, to the ability of a company to make simple and pleasant any contact with its customers. Mass Customization not always can be accompanied by a high specialization of workforce on the entire range of products, in particular if costs are not covered by the value generated. Setting up internet orders and outsourcing to logistics providers risk to let companies lose their control on this issue.

Traceability of orders is a very common service associated to logistics processes, where consignor and consignee can have real-time information on the position of products in the network so to follow their routes and allow fast and dedicated interventions in case of any problem.

Possibility of return is related to any situation where customers are protected by dedicated reverse logistics channels in cases of defective or unsatisfying products. For example, many e-business companies, realizing that a website can't give the same feeling of a physical shop, developed fast and effective processes of return with pre-paid labels and simple online procedures to solve complaints.

3.2 Factors of influence

Logistics managers have to take their decisions facing the environment where the network has to work, considering that any process of redesign is limited and, at the same time, addressed by the specific context of operations. Three groups of factors can so be identified:

- organizational and market factors;
- technological factors;
- environmental factors.

3.2.1 Organizational and market factors

Among these factors, able to significantly influence logistics choices, it's possible to identify two categories:

- characteristics of the company of the network;
- characteristics of the market where the network acts.

Cultural approach to logistics management is a key theme as many companies still consider logistics only as a service to the production systems even if it can generate significant performances of quality and costs. Furthermore, logistics is strongly influenced by the choices of markets to reach, the investments in infrastructures, the policies of efficiency, the level of relationships to have with the customers, etc. Product customization requires a fully developed logistics, with high competences, skills and a mature organization, not to limit the advantages of Mass Customization.

3.2.2 Technological factors

Customization and technology rates go along together. Advanced information and automation systems (e.g. identification, coding and accounting systems for goods) are factors that have to be considered to enable all the best practice and the alternative configurations. It is necessary to have a complete knowledge of the available technologies to extend the range of possible implementations, identifying (according to budget) the most adequate to manage picking, handling and transportation processes of products, different in terms of quantity, size, weight, packaging or shipment. Furthermore, technologies (e.g. Radio Frequency Identification) have to tune the processes of coordination and collaboration of companies, where interfaces among systems can increase (or reduce) lead times of information sharing and material flows.

3.2.3 Environmental factors

Push towards Mass Customization directly comes from the internationalization of markets where logistics have to face an extension of the coverage of geographical areas. Characteristics of the environment where to invest or operate have to be accurately investigated so to get all the information to understand opportunities and identify criticalities and uncertainties that could affect performances.

Environmental factors include all those specific elements of a certain area that have an influence on the installation of facilities and on the operations of a production-distribution network.

Macroeconomics and industrial maturity of markets are the main feature to assess local contexts. These parameters can't be considered constant and invariant in time but have to be analyzed in terms of possible developments as the network should be able to select the best areas to transit, stock or ship.

Four categories of environmental factors can be identified:

- political and cultural factors, as for stability of countries and respect of legality;
- exchange rates and uncertainty of demand, as a high differentiation of customers should reduce risks but have a significant and transversal impact on the value of stocks;
- taxes, duties and incentives;
- availability of transportation and stocking facilities.

3.3 Elements of the network

Once established the target service level and identified the factors that could influence the network, the decision process should determine the elements to configure and implement to enable the flows of products and information.

The elements that constitute a logistics network are various and generate a wide set of possible alternatives and solutions to all the specific problems, in particular for Mass Customization. At a strategic level, the main results to achieve are:

- the definition of the number of echelons;
- the definition of the number of knots;
- the localization of each knot;
- the assignment of customers to knots and definition of standard paths.

The definition of the *number of echelons*, that is to say the number of levels (e.g. warehouse, distribution and retail) between the production site and the customers, is the first output of the decisional process (Figure 2).

According to the portfolio of products and its possible customization, the number of echelons increases to meet specific requirements and enable postponement strategies in dedicated facilities (e.g. merge centers). On the other side, the introduction of new echelons requires multiple activities of loading, stocking, transfer and unloading of products to ship, facing costs of facilities, infrastructures and management.

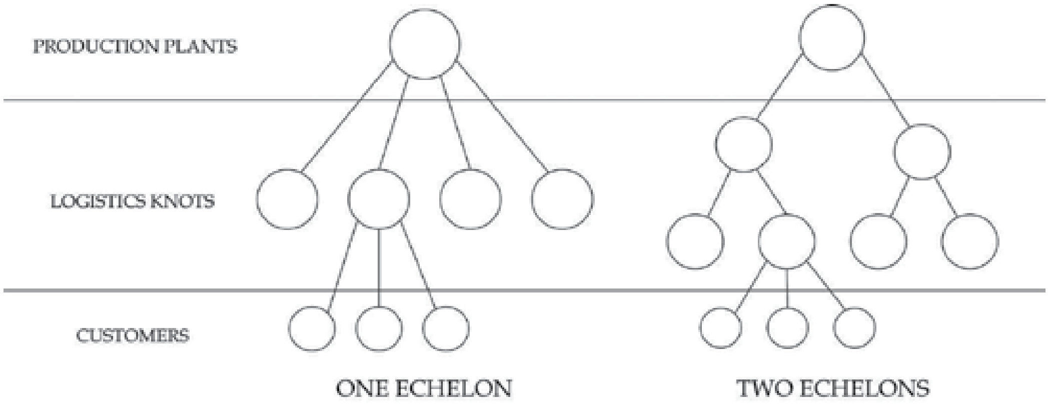

Fig. 2. Logistics network configuration: different number of echelons

At the same time, the *number of knots* with the same operations, to activate in each echelon, allows to better approach customers, hear their voice and reduce delivery times, recovering lead times of customization and make-to-order policies (Figure 3 and Figure 4).

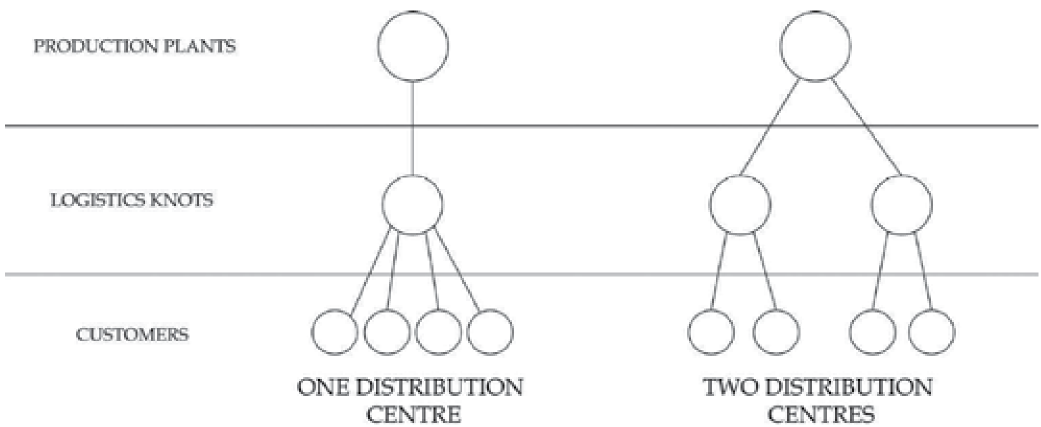

Fig. 3. Logistics network configuration: different number of knots (same number of echelons)

According to the availability of potential sites and resources to invest, the *localization of each knot* of the network is the next step of configuration (Figure 5). The assessment has to consider many different criteria, e.g. the proximity to the main transportation routes and infrastructures (motorways, railways, ports, airports), the location of markets and production sites, the strategies of development and expansion.

The last stage is to *define standard paths* and sequences to deliver products from production sites to cluster of customers, passing through the different echelons and knots of the network (Figure 6). This issue is particularly significant in Mass Customization because low volumes always present significant costs due to Less Than Truckload (LTL) transportations. The optimization of Vehicle Routing Problems can help to find static or dynamic solutions to assign knots and customers to delivery paths, considering the direction of the shipment (delivery or return) and the availability of agents for collection.

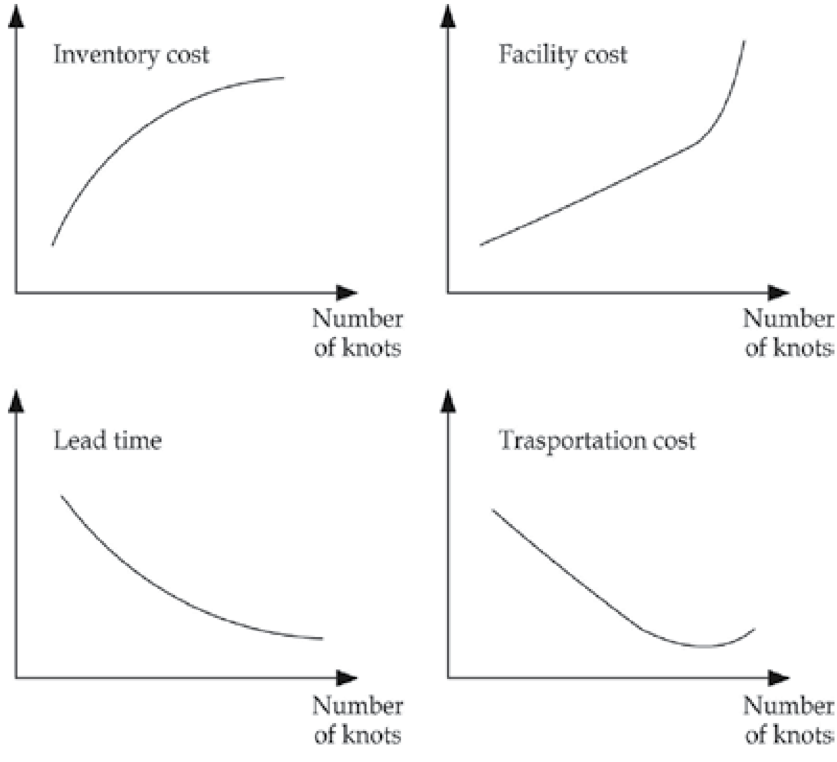

Fig. 4. Number of knots–Performance analysis

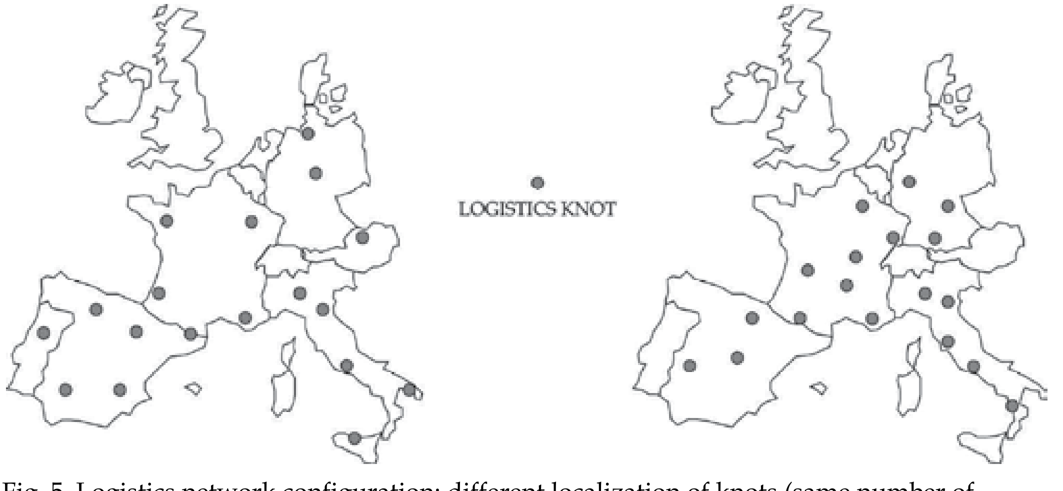

Fig. 5. Logistics network configuration: different localization of knots (same number of knots)

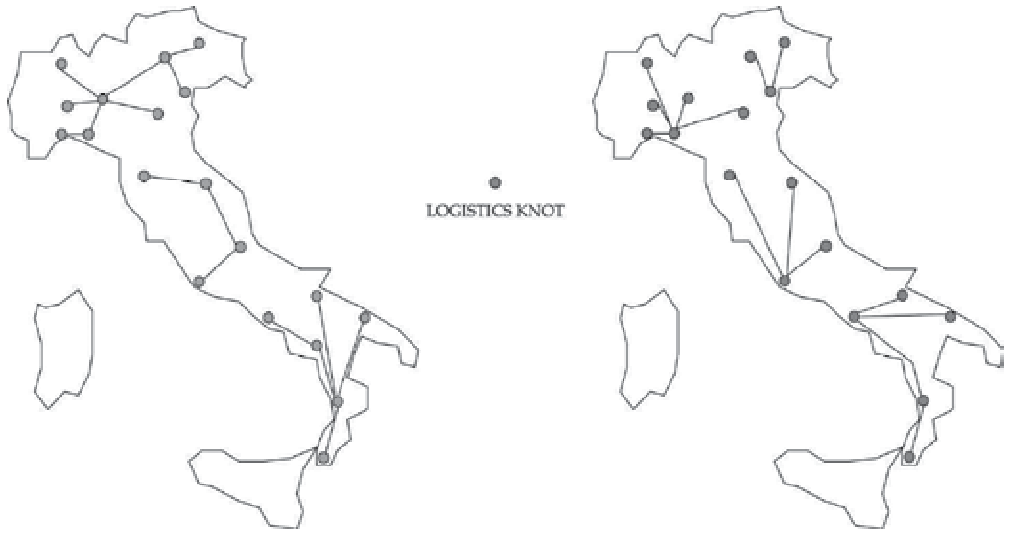

Fig. 6. Logistics network configuration: different standard delivery paths (same number of knots)

4. The levels of the decision process

The design or redesign of logistics network for Mass Customization is not a simple sequential process but needs and integrated vision that has to take in consideration the interdependences and cross impacts among the elements of the network. In literature, the decision process is generally divided into strategic, tactic and operational levels (Ballou, 1992) according to the time extension that the alternatives need to be implemented, achieve targets and compare results (Figure 7).

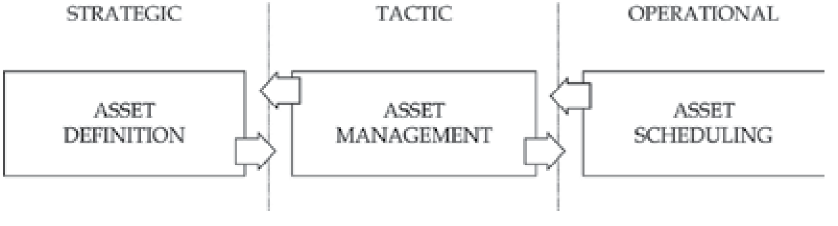

Fig. 7. Levels of the logistics network configuration process

4.1 Strategic level

The strategic level regards all those alternatives of network configuration that present an impact in the long term, over two years, or that need the same time to be realized or modified. This level refers, for example, to the acquisition or installation of infrastructures, selection of transportation means, implementation of information and management systems. All these themes can be summed up in the general problem of the *asset definition*.

Specific choices for Mass Customization are related to the opening or closing of echelons and knots, according to the requirements of agility and time compression. At the same time, it is to consider that high variety and low volumes are subject to uncertainty, causing unpredictable situations that affect the achievement of the desired performances (Bhattacharya et al., 1996). Risk Pooling logics could help to face variability of events, sharing facilities among organizations and aggregating their assets, with a trade-off between the reduction of inventories and an increase of delivery times.

Strategic decisions have to be taken also in terms of insourcing or outsourcing of processes through the evaluation of a cost-benefit profile, balancing the loss of the logistics intelligence and its transfer to specialized agents with the possibility of standardizing programs and generating economies of scale.

4.2 Tactic level

The tactic level regards the definition of the *asset management* rules of the network to reach best performances in terms of production, inventory and transportation. Mass Customization requires a specific focus on lot-sizing of deliveries, standardization of minimum and maximum load units, assignment of inventories areas and levels for each product, definition of material handling processes. As for the strategic level, where the aggregation of assets creates benefits and opportunities, also at a tactic level it is possible to identify methodologies of integrated management able to increase efficiency and effectiveness of logistics so to contain times and costs.

The configuration process starts from the definition of all the management rules that have to be stated from upstream to downstream of the network, trying to correctly implement them into the different knots, avoiding wastes and loss of values and reducing at most organizational constraints.

4.3 Operational level

Logistics operations have to be day by day planned and executed. The operational level regards *asset scheduling*, the programming and control of short term process of orders, deliveries and human resources along the network.

Only at this level the targets defined in the other levels can be realized, according to the information that flows along the network. Increasing the complexity of the configuration (players, business relationships and products) carries a strong need of coordination and alignment techniques to fit customers' requirements.

A detailed definition of the process map of the entire network is so the main tool to address operational choices (Qiao et al., 2004), considering all the logistics activities that each knot has to perform (Logistics Model, 2005).

5. A case study of application

An application of the logistics configuration process for Mass Customization is presented on a specific case study with the following characteristics:

- make-to-order production;
- high differentiation of products;

- variable amounts of products in any order;
- highly distributed market.

The research is centered on a web portal of regional products (mainly food and beverage) from Valtellina (http://www.storevaltellina.it), an Italian territory where the quality of production is guaranteed by local protection Consortia, which keep watch over the quality of typical products and delicatessen. By this e-commerce solution, a group of about 40 local organizations is now able to show off their products and sell them in orders that are totally customizable by customers, from a high quantity of a single product to any selection of products in different quantities.

Once the portal started its online activity, the number of orders increased constantly. The traditional portfolio of customers evolved from local consumers to buyers, brokers, distributors, retailers and merchants, like restaurants, hotels and food shops that finally found through the B2B solution a way to get Valtellina tradition. The geographic area of interest increased as well as the need of a logistics coverage.

At a first stage, the logistics strategy didn't change and some negative effects suddenly occurred. High costs of delivery, outsourced from every producer to express freight companies, were not rewarded due to the disappointing perception of customers that received different shipments for a single order (only certain groups of products travelled together), facing extended lead times due to the consolidation of orders (sometimes caused by the stock-out of a single product) and damages from poor packaging.

Therefore, a redesign of the logistics configuration, according to the presented model on its strategic, tactic and operational levels, defined new elements of the network to answer the following questions:

- how is it possible to reduce lead times and avoid wastes?
- how is it possible to avoid partial shipments and always ensure complete orders?
- is it useful to open a distribution center to stock a certain amount of products and apply postponement strategies?
- is it possible to coordinate flows of materials and information to standardize processes and service levels?
- how is it possible to have a strong relation with the customers to correctly understand feedbacks?

Different opportunities of improvement in this Mass Customization context were assessed in terms of cost-benefit, focusing on a set of possible alternatives that present different combinations of strategies for:

- distributing or concentrating warehouses (*Risk Pooling*);
- potential aggregation of different products in a single shipment (*Merge-in-Transit*);
- organization of vectors on standard delivery paths (*Vehicle Routing*).

5.1 Risk Pooling

Risk Pooling is the advantage that can be realized through a large scale analysis and aggregate forecasting of particular products (e.g. reduction of number and typology of components thanks to standardization): a Risk Pooling strategy can affect the choice of aggregating production systems of different products on different sites (from Production Plant Network to Process Plant Network – Figure 8).

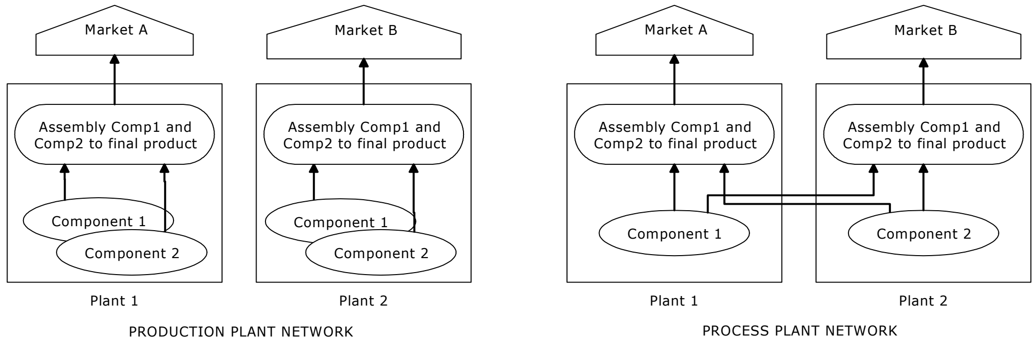

Fig. 8. Production network strategies

This behaviour, characteristic of the consolidation of distribution centers in a unique sorting point, was originally studied by Eppen (1979), the first to analyze effects in warehouse management. The study of Barahona & Jensen (1998) put the basis of the more recent analysis in operation research, for example Schrijver (2000) and Iwata et al. (2001), to solve problems with a huge number of knots in the network. Researchers proved that pooling or aggregating demands reduces the risks associated with forecasting errors and inventory mismanagement (Chopra & Sodhi, 2004) under appropriate conditions (Yang & Schrage, 2009).

Considering a distribution network, where a unique plant feeds regional depots to supply local retailers or customers, operations present two main costs: the first is directly related to an average value of goods transited, caused by stock and handling costs and order management costs; the second is related to safety stock of warehouses, depending on the value of the standard deviation of the customer's demand. Reducing the number of depots and aggregating demands smooth variations and allow lower safety stock levels while generating an increase in complexity of physical distribution. This is a typical opportunity for Mass Customization levels of inventory, where benefits are more consistent when verifying a non-correlation of the markets. The approach generates a reduction of the number of distribution centers and the correspondent pool of stocks among a determined set of markets.

5.2 Merge-in-Transit

Merge-in-Transit (MIT) consists in a logistics practice used where the product needs:

- an aggregation of different products from different sources in a single delivery;
- an aggregation of on-demand orders with components in stock.

This order management methodology was first introduced by Muller (1992), whose activity was enriched by the significant industrial experiences of Hewlett Packard, Dell, Cisco and Ikea. Many studies followed to build mathematical models of MIT (Ala-Risku et al., 2003; Croxton et al., 2003) and to analyze its technical and informative requirements (Kärkkäinen et al., 2002).

Merge-in-Transit is the substitution of direct shipments of a multi-product order with a single aggregated shipment. Instead of executing many direct deliveries, the different lines of order are converged with a direct transportation in a *merge center*. Here the products are placed in the same vector, if necessary after an operation of assembly or consolidation, and delivered to the customer, so to avoid the costs of specific warehouses. The advantage of Merge-in-Transit in Mass Customization is related both to a higher level of customer satisfaction and to a possible decrease of transportation and inventory costs (due to the elimination of warehouses) together with the possibility of increasing a larger range of products on catalogue.

5.3 Vehicle Routing Problem

Vehicle Routing Problem (VRP) has a well-known mathematical formulation where cost optimization is related to the number of shipments and sequencing of journeys, as for Laporte (2000). Many solution algorithms were presented in literature, exact ones (Fisher, 1994), heuristic ones (Shaw, 1998) and meta-heuristic ones (Vigo & Toth, 1998; Gambardella et al., 2005). For an extended review of the problem see Laporte (2009).

In this case, with the opportunity of a multi-level network, the models have to be concerned with the definition of standard routes for multi-knots deliveries to assign to clusters of customers. The total cost is the sum of activation and transportation costs, where the final customer routes (*last mile*) make the difference. The optimization process needs to evaluate every combination of assignment (of customers, vehicles and routes), defining the shortest path and the best configuration. This helps the organization to reach standard delivery times and easily manage shipments even when the freights quantities and typologies constantly change.

5.4 Framework application and results

The redesign of the logistics focused on the implementation of these three strategies (Risk Pooling, Merge-in-Transit and VRP) where the best results for each strategy generate constraints to the other two: for example, decisions about opening a set of distribution centres, obtained by a Risk Pooling analysis, expand or reduce the possible routes to establish with the VRP analysis. This means that the organization needs to define the best sequence of the optimization process, starting from the analysis with the highest impact but not moving too far from the best integrated and balanced solutions.

A three-stage modular architecture can be built to identify priorities and to take them into proper account in a step-optimization (Figure 9). Depending on the environment, infrastructures, products, company background and logistic network maturity, different cost issues can prevail. As a first step, the optimization analysis has to be effectuated on parallel branches to evaluate the impact of each perspective: this could be considered as the weight of non-optimized configurations on the item in focus. In the second step, a comparison among the three different approaches, evaluating the best and the worst cases for each strategy, assigns a greater importance to the perspective of optimization with the higher spread or (as a second criterion of priority) to the most significant in percentage.

Characterizing the models with a degree of their relative impact allows to proceed with a stratified resolution of the problem, from the most relevant effect (Highest Impact Model –

HIM) to the least one (Lowest Impact Model – LIM). Therefore, the optimization process considers the specific results obtained by the HIM, fixing elements of the most important solution, and then running the MIM (Middle Impact Model) with more constrains and less degrees of freedom. The new results create further constrains, input for the last optimization problem (LIM) that completes the network configuration. Figure 10 shows the six possible combinations of priorities, explaining for each stage the constrains generated by the step-optimization to the final logistics solution.

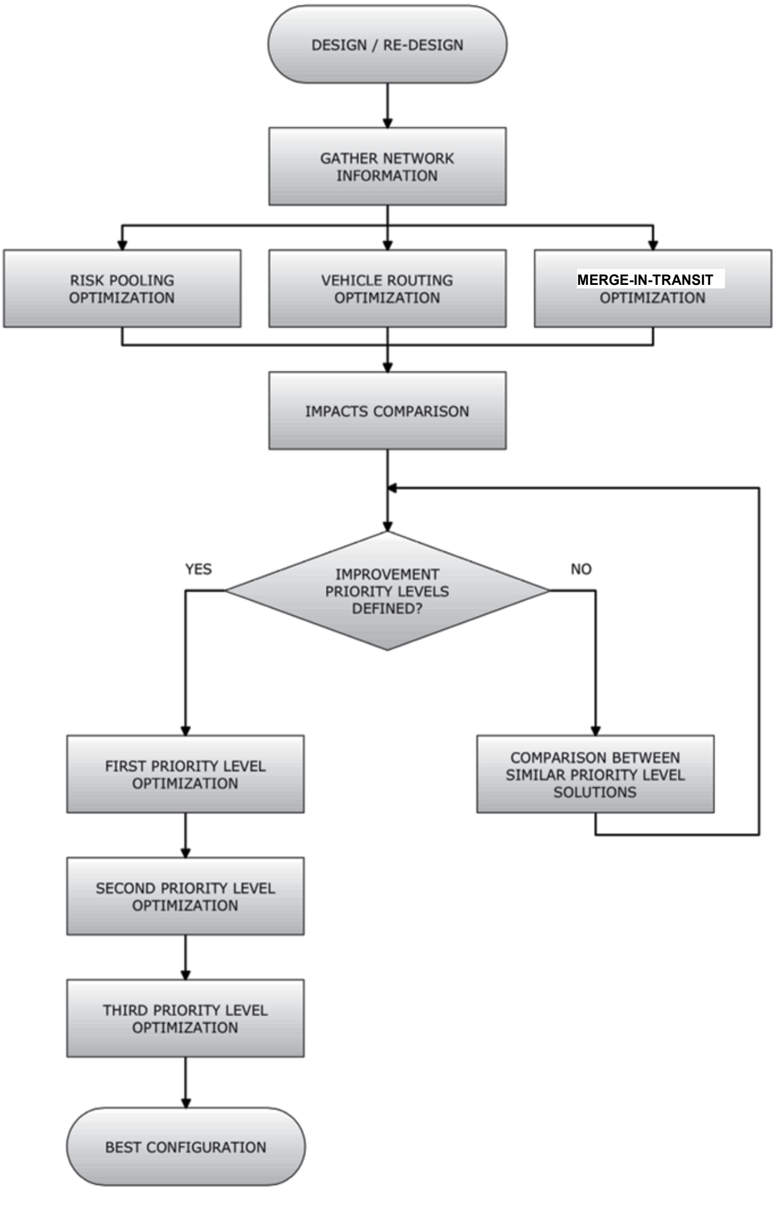

Fig. 9. Applied framework

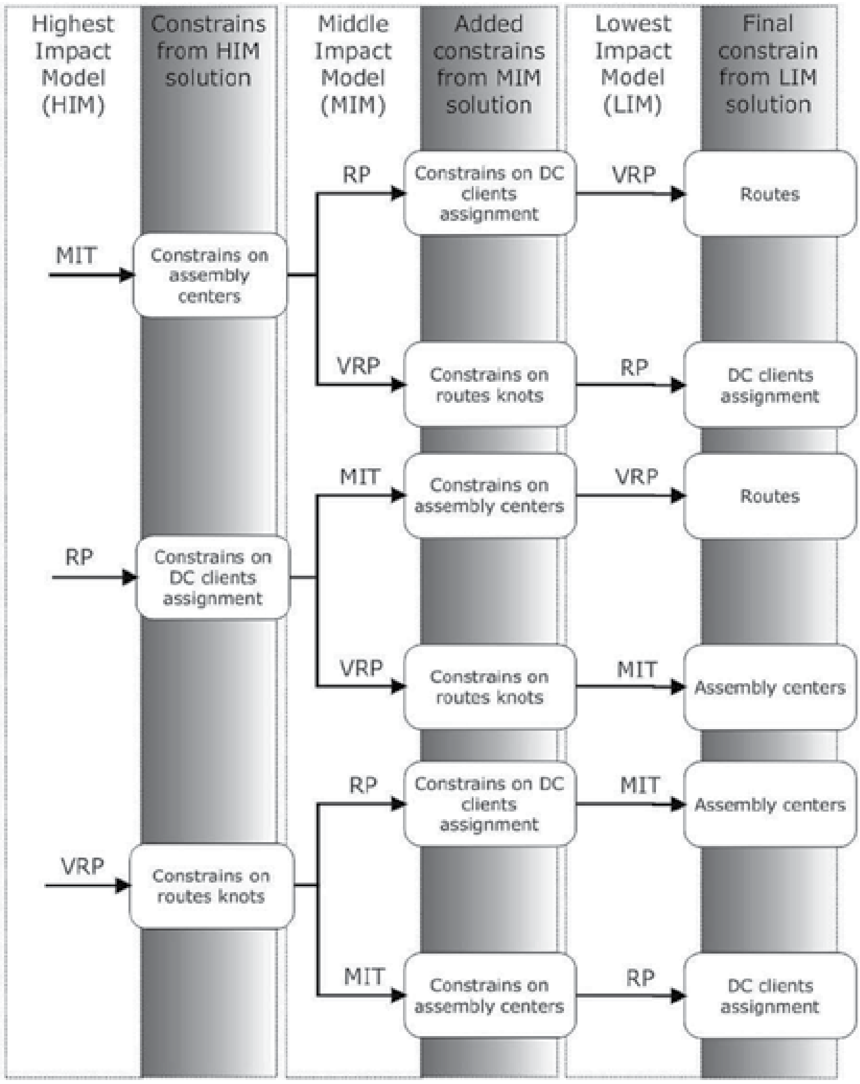

Fig. 10. Possible combinations of priorities

To avoid a classification priority where network characteristics don't allow to identify a sharp difference, a simple tool for measuring the range of impact can be developed, as shown in Table 1. Every model is compared on cost results, considering the best and the worst solution, that means the biggest possible loss for a non-appropriate configuration. Table inputs compare two perspectives a time, by rows with percentage difference between two solutions. The analysis, in terms of absolute variation and relative variation, considers the level of importance of the possible loss related to the total cost. The three pairwise comparisons express the correct priority ranking. When the result of the tool cannot identify a neat preference (values in table from 0.6 to 1) or gives a slight difference (from 0.3 to 0.6), the step-optimization has to be completely carried on for the two alternatives of sequences (in Figure 10) to compare the final cost and define the better path.

Δ_{ij}	80% - 100%	0.2	0.4	0.6	0.8	1
	60% - 80%	0.16	0.32	0.48	0.64	0.8
	40% - 60%	0.12	0.24	0.36	0.48	0.6
	20% - 40%	0.08	0.16	0.24	0.32	0.4
	0% - 20%	0.04	0.08	0.12	0.16	0.2
		0% - 20%	20% - 40%	40% - 60%	60% - 80%	80% - 100%
		$\Delta\%_{ij}$				
[light grey]		High differentiation between impacts				
[medium grey]		Medium differentiation between impacts				
[dark grey]		Low differentiation between impacts				
B_i		Best solution for the analysis *i*				
W_i		Worst solution for the analysis *i*				
$\Delta_i = B_i - W_i$		Weight (absolute) of non-optimization for the analysis *i*				
$\Delta\%_i = 1 - B_i/W_i$		Weight (relative) of non-optimization for the analysis *i*				
$\Delta_{ij} = \Delta_i/\Delta_j$		Percentage variation in the comparison between analysis i and j, calculated with absolute values				
$\Delta\%_{ij} = \Delta\%_i/\Delta\%_j$		Percentage relative variation in the comparison between analysis i and j, calculated with relative values				
i and j ∈ [RP, MIT, VRP]						

Table 1. Prioritization rating

The test on the e-commerce portal ranked first MIT and then Risk Pooling and VRP. This sequence brought to a new logistics network with a merge center close to the producers, a fixed distribution center in the south of Milan and a network of drop-points on the territory, always available for deliveries of the shipper and for the pickup of the customers. The drop-points are assigned to standard routes, not to reconfigure with a day-by-day, stopping or not according to the destinations of orders.

The owners of the portal settled an agreement with producers and assigned all the traffic outbound the local area (from the merge center to the customers) to a single freight transportation supplier. This created a solid partnership that, after four months of activities, carried to the standardization of a small set of packages of standard size.

The new logistics brought a constant service level of less than five working days and a cost reduction of about 20% of the total logistics costs, considering the rent of the distribution center and the new fares agreed with the transportation supplier, chosen through a tendering process that assured the lowest available fees. Moreover, the number of complaints due to the shipping process strongly decreased, mainly because defects in quality are directly blocked at the pickup point without reaching the customers.

6. Conclusion

The study of the literature showed the importance of logistics in implementing Mass Customization strategies without paying this choice with a decrease of performances in terms of costs and service levels. Unfortunately, applications in logistics dedicated to this issue are still short in quantities and concentrated on single aspects (for example, on postponement solutions). This research is a first attempt to identify all the different aspects of the logistics design process to build a reference model for logistics managers that could take into account the requirements of shipping a great amount of small sized orders of highly personalized products.

The logistics network has to be designed considering the targets of the distribution processes, the factors that can affect decisions, the elements that have to be defined. Managers can so achieve new solutions, dedicated to customized production, through a multi-level decision process, assessing the impact of strategic, tactical and operative choices on the possible alternatives of configuration. A structured approach to model these logistics parameters is so presented to give a new perspective and support in defining the characteristics of the network.

The key result presented in the chapter is the reference model that embodies the actual state of the art with an innovative specific point of view on customization issues. The most significant outcomes can be summed up in the identification of a logical framework, applicable to different logistics problems, that integrate solutions moving from a traditional distribution network to a flexible logistics system, with no payoff on performances. The modular methodology, that has to be fed up with different mathematical models and solving algorithms to guarantee a higher speed of calculus, is dedicated to logistics so that a multi-criteria analysis can evaluate different alternatives of solution.

The actual limitations of the study open new directions of research. First, the model for logistics is general in its applicability and can be specialized on specific Mass Customization industry, such as to the distribution of automotive products, airplanes, boats, clothes, computing systems, etc. where every business has its implications, standard solutions and past experiences to develop. Secondly, the analysis defined a high-level reference model but it still needs to be accompanied in real cases with decision support systems, methodologies of improvement, optimization analysis and algorithms to face every single decision of network configurations. A deep research to classify best practices, available for this peculiar issues, could be useful to provide a complete handbook for logistics in Mass Customization.

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11

Incorporating Anthropometry into Design of Products

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1. Introduction

To achieve mass customization and collaborative product design, human factors and ergonomics should play a key development role. In population, accommodation, sizing has been aimed at improving the product to either get better fit, or broaden the range of befitting users (Li, 2006; Nui et al., 2006). Thus, anthropometry is considered the very ergonomic core of any attempt to resolve the dilemma of 'fitting the tasks to the human' (Sanders and McCormick, 1993). As products are designed for specific types of consumers, an important design requirement is selection and efficient utilization of the most appropriate anthropometric database (Wickens et al., 2004). Great effort has been expended conducting numerous surveys to establish anthropometric databases for different population groups such as the armed forces, students, civilians, and farm workers (Mououdi, 1997; Wang et al., 1999). These anthropometric data sets provide critical design information for an enormous range of ergonomics-based tasks such as workplace design (Wang et al., 1999), and sizing for clothes (Meunier and Yin, 2000) and school furniture (Milanese and Grimmer, 2004). Effective utilization of this data, however, requires a thorough analysis of the inherent design problems on the designers' part. Wickens et al. (2004) adopted a systematic approach to utilization of anthropometric data in design, principally through: (1) determination of the target population (the intended users); (2) determination of the relevant physical dimensions; (3) determination of the percentage of the population to be accommodated; (4) determination of the ideal percentile value for the selected anthropometric dimension; (5) incorporation of the necessary design modifications based on this anthropometric data; and, (6) use of mock-ups or simulators to test the design. Thus, key design issues include identification of the target user groups and identification of the most important bodily dimensions. Two cases were presented in this chapter as design for baby diaper, and spoon of children.

2. Case 1: Diaper wearing and fitness of sizing system for infants

2.1 Introduction

Standard sizing systems of garment are very crucial issue, play an even important role for garment manufacturing industry. Under traditional production procedures, garment manufacturers have never developed standard sizing systems for the market, finally resulting in heavy stock burden to garment manufacturers. Standard sizing systems can correctly predict numbers of items and ratio of sizes to be produced, resulting in accurate inventory control and production planning (Hsu et al., 2007).

In late nineteenth century, infants in Europe and North America were wearing the progenitor of the modern diaper. A square of rectangle of linen, cotton flannel, or stockinet was folded into a rectangular shape and held in place with safety pins. The first disposable absorbent pad used as a diaper was probably the one made from unbleached creped cellulose tissue (held in rubber pants) in 1942 by Paulistróm in Sweden, maybe because cotton had become a strategic material due to the war effort. A few years later in 1946, in the United States, a Westport housewife named Marion Donovan, invented the "Boater", a waterproof covering for cloth diapers. Her first model of the disposable diaper was made of shower curtain plastic into which a conventional cloth diaper was inserted. Recent years have brought many improvements to disposable diapers. The disposable diaper evolves quickly. Instead of tissue, a pulp mill was introduced. Using cellulose fibers instead of paper, improved the performance of the diaper. On the other hand, the diaper dermatitis or diaper rash is probably the most common cutaneous disorders of infancy and early childhood. Presence of ammonia caused by bacterial breakdown of urea in the child's urine was believed to be a major factor in the etiology of diaper dermatitis (Jackson, 1995). Although friction of skin-to-skin and skin-to-diaper is not a dominant factor, it may be an important predisposing factor (Wolf et al., 2000). Thus, customers show much concern about picking the diaper for ensuring a perfect fit with their infants.

Diapers are commonly worn from birth until a person is toilet trained. Diapers evolved in the 1960s from a double layer of cotton folded into a triangle and attached with safety pins to products that include a top sheet of plastic and cellulose pulp core. More recently, the core was changed to gel for its absorbency potential. Product innovations include the use of superabsorbent polymers, re-sealable tapes and elastic waist bands. Gel also prevents skin from becoming super hydrated, and as a result diaper rash has been on the decline in recent decades. However, it still occurs, and in most cases, diaper dermatitis is caused by the diaper itself (Gorgos, 2006). Diaper rash or diaper dermatitis is one of the most common skin disorders in infants and toddlers (Liptak, 2001). The etiology is multifocal and a diaper rash may present in various conditions in the pediatric community (Borkowski, 2004). Diaper dermatitis usually occurs as a primary reaction to irritation by urine, feces, moisture, or friction (Van Onselen, 1999). Distribution patterns may vary, but irritative dermatitis typically involves the convex surfaces where the skin is in greatest contact with the diaper. Irritative dermatitis usually spares the inquinal folds, and may be mild red, shiny, and with or without papules (Liptak, 2001; Wysocki and Bryant, 1992).

Thus, care and management of diaper dermatitis can present a challenge for pediatric nurses and care providers. Prevention of diaper rash is achieved through maintenance of skin integrity to prevent damage to the stratum corneum, the skin's barrier. Keeping the baby dry, which entails frequent diaper change, is the ideal way to both treat and prevent irritant diaper dermatitis (Jorden et al., 1986). Diapers should be changed and the area cleaned and allowed to dry as soon as possible after soiling or wetting. The skin should be exposed to the open air for 5 to 10 minutes following each diaper change. The use of plastic pants should be avoided or at least limited and diapers should not be too tight. Changing of diaper brands may be considered with chronic diaper rash breakouts. Irritants should be avoided or removed by washing with warm water and cotton balls and patting dry.

In addition, the argument has been that diaper type (cloth versus paper) is an important factor in controlling the spread of fecal material and therefore a major contributor to the spread of enteric pathogens in the environment (Kubiak et al., 1993). Previous studies have suggested that paper diapers are more effective than cloth diapers in constraining fecal spread (Kubiak et al., 1993; Van et al., 1991). Apart from diaper types, and materials, the sizing system of diaper is another important factor for wearing comfortable. However, the sizing systems of disposable diaper are divided into stages and sold based on three distinct groupings in Seaddlers, Cruisers and Baby Dry (e.g., Pampers Diapers). The sizing systems of diaper are only classified according to growing stage and infants' weigh (Table 1). If an infant is six months with weight of seven kg, how should pick the diaper size to coordinate with her or him (Size 1: Small or Size 2: Medium?). Obviously, selection of diaper size for infants is a problem for parents and care providers.

Diaper Cover Size	Age	Weight
Newborn, NB	NB	NB-4.5 kg (10 lb)
SIZE 1, Small (S)	0 - 3 months	4-6 kg (8-14 lb)
SIZE 2, Medium (M)	2 - 6 months	5-8 kg (12-28 lb)
SIZE 3, Large (L)	3 - 12 months	7-13 kg (16-28 lb)
SIZE 4, Extra Large (XL)	9 -24 months	10-17 kg (22-37 lb)
SIZE 5, Super Large (SL)	2.5-4 years	12+ kg (27+ lb)
SIZE 6 Training	3.5-7 years	16+ kg (35+ lb)

Table 1. Diaper sizing systems

A garment sizing systems are used to fit different groups of the population based on demographic anthropometric data. Persons of the same subgroup have the same body shape characteristics, and share the same garment size (Ashdown, 1998; Chung et al., 2007). With the difference in body dimensions and morphological characteristics, different body shapes can be generalized to a few figure types (Ray et al., 1995). Emanuel et al. (1959) recommended the use of the difference in figure types as the classification of ready-to-wears, and developed a set of procedures to formulate standard sizes for all figure types. According to this system, people of all figure types were first classified into one of four body weight groups (i.e. super heavy, heavy, normal, light. These body weight groups are further subdivided by stature (i.e. tall and short). People were, thus, divided into eight categories based on similar heights and weights.

Furthermore, the purpose of this study was to provide product designs with the anthropometric dimensions of baby and children and analyze along with demographic data, including age. The second purpose was to understand the diaper wearing problems and evaluate the fitness of size system for infants to compare the dimensions of various diapers with anthropometric database and recommend appropriate solutions for design.

2.2 Methods

2.2.1 Subjects

Three hundred subjects who aged from newborn to 3 years old were separated into eight stratifications (i.e. under one month, 1-3 months, 3-5 months, 5-7 months, 7-9 months, 9-12 months, 1-2 years, and 2-3 years old) for further analysis. Registered nurses in Tamsui Health Center have conducted the anthropometric survey.

2.2.2 Methodology of measurement

Altogether six anthropometric characteristics were measured (Figure 1).

a. Stature;
b. Head circumference;
c. Waist circumference;
d. Buttocks circumference;
e. Thigh circumference;
f. Body weight.

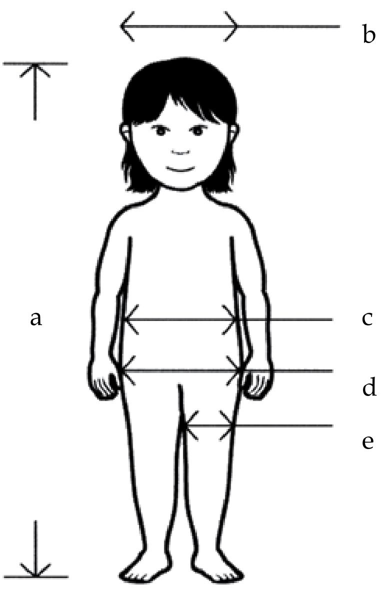

Fig. 1. Anthropometric measurements

2.2.3 Data analysis

All data were coded and summarized using SPSS software for Windows. One-way analysis of variance (ANOVA) was used to investigate the effects of age on dimensions of infants. Where statistically significant differences were determined, the Duncan post hoc test was performed. In addition, the relationships between dimensions were assessed from correlation analysis.

2.3 Results

2.3.1 Effect of age on dimensions

The ANOVA results for the relationships between dimensions and age are presented in Table 2. All mean dimensions were significant differences between age group ($p < 0.001$). Further, Duncan's post hoc tests revealed that mean stature could be divided into seven subsets ($p < 0.05$). Mean stature were the shortest for the age under one month (51.7 cm), followed, in ascending order, by the 1-3 months (56.8 cm), 3-5 months (62.4 cm) and 5-7 months (64.9 cm), 7-9 months (69.2 cm), 9-12 months (72.4 cm), 1-2 years (81.0 cm), 2-3 years old (88.6 cm). Mean head circumference were the shortest for the age under one month (35.6 cm), followed, in ascending order, by the 1-3 months (38.5 cm), 3-5 months (40.2 cm), 5-7 months (41.5 cm), 7-9 months (43.2 cm) and 9-12 months (44.3 cm), 1-2 years (46.5 cm), 2-3 years old (48.7 cm). The mean waist circumference were also lowest for age under one month (34.6 cm), followed, in ascending order, by the 1-3 months (38.7 cm), 3-5 months (41.8 cm), 5-7 months (43 cm), 7-9 months (44.9 cm), 9-12 months (46.5 cm), 1-2 years (47.2 cm), 2-3 years old (49.5 cm). In addition, mean buttocks circumference could be divided into six subgroups ($p < 0.05$). The mean buttocks circumference were also lowest for age under one month (32.7 cm), followed, in ascending order, by the 1-3 months (39.5 cm), 3-5 months (43.5 cm), 5-7 months (43.6 cm), 7-9 months (47.4 cm), 9-12 months (48.3 cm), 1-2 years (50.5 cm), 2-3 years old (53.1 cm). The mean thigh circumference could stratify six subgroups: subgroup 1 (age under one month, 16.7 cm), subgroup 2 (1-3 months (20.3 cm), 3-5 months (21.7 cm)), subgroup 3 (3-5 months (21.7 cm), 5-7 months (21.9 cm)), subgroup 4 (7-9 months (23.4 cm), 9-12 months (23.9 cm)), subgroup 5 (1-2 years (26 cm)), and subgroup 6 (2-3 years old, 28.3 cm). Finally, the mean body weight could stratify seven subgroups: subgroup 1

	Source	Sum of squares	d.f.	Mean squares	F	p
Stature	Between groups Within groups Total	37323.9 9406.5 46730.4	7 292 299	5331.9 32.2	165.5	0.001
Head circumference	Between groups Within groups Total	4170.4 1585.4 5755.8	7 292 299	595.7 5.4	110.3	0.001
Waist circumference	Between groups Within groups Total	4643.4 4521.7 9165.1	7 292 299	663.3 15.4	43.1	0.001
Buttocks circumference	Between groups Within groups Total	8176.4 6194.0 14370.4	7 292 299	1168.0 21.2	98.2	0.001
Thigh circumference	Between groups Within groups Total	2692.1 2461.5 5153.6	7 292 299	384.5 8.4	41.5	0.001
Weight	Between groups Within groups Total	2184.7 630.2 2814.9	7 292 299	312.1 2.1	148.6	0.001

Table 2. ANOVA of dimensions on age group

	Age Group *	N	Mean**	SD	Percentile						
					5th	10th	25th	50th	75th	90th	95th
Stature (cm)	1	14	51.7 a	2.7	48.0	48.0	48.8	52.2	54.2	55.5	55.5
	2	31	56.8 b	4.9	46.6	49.2	54.5	57.0	61.0	62.8	64.0
	3	30	62.4 c	6.1	51.4	54.1	58.0	63.5	66.0	71.8	73.3
	4	24	64.9 c	5.6	57.0	57.1	58.3	66.0	69.1	72.0	74.5
	5	37	69.2 d	5.2	59.0	61.6	65.5	70.0	72.7	76.2	79.2
	6	30	72.4 e	5.4	62.5	65.0	68.0	72.7	76.5	80.0	80.4
	7	85	81.0 f	5.3	71.3	74.0	78.0	82.0	84.5	88.4	90.0
	8	49	88.6 g	7.1	73.0	79.0	84.5	89.0	94.0	97.0	98.0
Head circumference (cm)	1	14	35.6 a	5.4	31.0	31.5	32.0	34.5	36.7	45.0	45.0
	2	31	38.5 b	2.0	36.0	36.0	36.5	38.5	40.0	41.8	43.0
	3	30	40.2 c	2.1	35.3	37.0	39.3	40.5	42.0	42.9	43.1
	4	24	41.5 d	2.1	38.0	38.3	40.0	41.7	43.2	44.1	44.8
	5	37	43.2 e	2.4	38.0	40.0	42.2	43.0	44.5	46.4	48.1
	6	30	44.3 e	2.1	40.8	42.0	43.0	44.0	45.1	47.9	49.3
	7	85	46.5 f	1.9	43.0	43.7	45.0	46.0	48.0	49.2	50.0
	8	49	48.7 g	1.7	46.0	46.5	48.0	49.0	50.0	51.0	52.0
Waist circumference (cm)	1	14	34.6 a	2.3	31.0	31.2	32.0	35.1	37.0	37.4	37.4
	2	31	38.7 b	2.4	36.0	36.1	37.0	38.0	40.0	42.8	44.8
	3	30	41.8 c	5.3	34.6	36.1	38.6	40.0	42.5	50.0	55.4
	4	24	43.0 cd	5.3	36.0	36.3	38.0	42.6	46.7	50.9	51.7
	5	37	44.9 de	5.0	36.9	37.0	40.7	45.0	49.2	51.2	52.3
	6	30	46.5 ef	3.3	40.8	42.1	43.6	46.5	49.0	51.8	52.4
	7	85	47.2 f	3.2	40.3	44.0	45.0	47.0	49.0	51.5	52.7
	8	49	49.5 g	3.6	43.0	44.0	47.8	49.5	52.0	55.0	56.0
Buttocks circumference (cm)	1	14	32.7 a	3.6	27.0	27.5	29.6	32.0	36.0	38.1	38.1.
	2	31	39.5 b	2.5	36.5	37.0	37.5	39.0	42.0	43.0	45.2
	3	30	43.5 c	6.3	34.9	38.0	39.0	42.0	46.2	55.0	57.8
	4	24	43.6 c	5.5	35.8	36.0	38.7	43.5	48.5	51.0	53.2
	5	37	47.4 d	6.0	36.9	39.6	42.2	48.0	52.5	55.2	57.1
	6	30	48.3 df	4.1	42.5	43.0	44.7	48.0	51.0	54.9	56.8
	7	85	50.5 f	3.9	43.6	46.0	47.7	50.0	53.0	56.0	58.0
	8	49	53.1 g	4.1	46.3	48.0	50.6	53.0	55.1	58.0	61.0
Thigh circumference (cm)	1	14	16.7 a	2.3	13.0	13.2	14.7	17.3	18.4	20.1	20.1
	2	31	20.3 b	3.2	16.0	16.0	18.0	20.0	23.5	25.0	26.0
	3	30	21.7 bc	2.9	16.4	18.1	20.0	21.0	23.8	25.2	27.8
	4	24	21.9 c	2.9	17.0	17.5	20.0	22.0	24.0	25.0	28.7
	5	37	23.4 d	2.6	19.9	20.0	21.2	23.0	25.0	27.6	28.3
	6	30	23.9 d	1.7	21.1	22.0	22.0	24.0	25.5	26.0	26.5
	7	85	26.0 e	3.1	20.1	22.3	24.0	26.0	28.3	30.0	30.7
	8	49	28.3 f	3.1	23.6	25.0	25.9	28.5	31.0	32.4	34.0

	Age Group *	N	Mean**	SD	Percentile						
					5th	10th	25th	50th	75th	90th	95th
Weight (Kg)	1	14	3.3 a	0.6	2.4	2.4	3.0	3.3	3.6	4.5	4.5
	2	31	5.4 b	1.0	4.0	4.1	4.7	5.4	6.0	6.7	7.8
	3	30	6.9 c	1.5	3.8	5.1	6.0	6.9	7.9	8.8	10.7
	4	24	7.2 c	1.1	5.8	6.0	6.3	7.0	7.9	9.2	10.0
	5	37	8.1 d	1.4	6.0	6.1	7.0	8.0	9.2	10.1	11.2
	6	30	9.0 e	1.2	7.2	7.5	8.1	8.7	10.0	10.7	11.4
	7	85	10.9 f	1.6	8.6	9.0	10.0	10.6	12.0	13.0	14.0
	8	49	13.0 g	1.7	10.0	11.0	12.0	13.0	14.7	15.0	16.0

*Age group: 1:under one month; 2: 1-3 months; 3: 3-5 months; 4: 2-7 months; 5: 7-9 months; 6: 9-12 months; 7: 1-2 years; 8: 2-3 years old.
** a, b, c, d, e, f, g indicated the results of Duncan's multiple comparison tests.

Table 3. Infants' dimensions, age group and percentiles

(age under one month, 3.3 kg), subgroup 2 (1-3 months, 5.4 kg), subgroup 3 (3-5 months, (6.9 kg), 5-7 months (7.2 kg)), subgroup 4 (7-9 months, 8.1 kg), subgroup 5 (9-12 months, 9 kg), subgroup 6 (1-2 years, 10.9 kg), and subgroup 7 (2-3 years old, 13 kg). The means and standard deviations and infant-dimension percentiles by age group are presented in Table 3.

2.3.2 Sizing system of diapers

Each figure type was classified into several size subgroups based on the control dimensions and size interval. The waist circumference and stature were chosen to represent the control dimensions. Furthermore, the categories of sizing systems could be denoted the seven subgroups by waist circumference and stature. Figure 2 showed that the distribution graph of stature versus waist circumference for seven categories. The waist types could be divided into four types (i.e. thin, medium, slight plump, and plump). In addition, stature could be divided into three types (i.e. short, medium, and tall). A total of 91% of samples have been fit on proposed sizing system (Table 4).

Sizing systems	categories	Waist Circumference (cm)	Stature (cm)	Percent
1	Thin-Short	< 36	< 56	4.3%
2	Medium-Short	36.1-42	<56	6.3%
3	Medium-Medium	36.1-42	56.1-73	18.7%
4	Slight plump-Medium	42.1-48	56.1-73	9.0%
5	Slight plump-Tall	42.1-48	> 73.1	6.7%
6	Plump-Medium	> 48.1	56.1-73	23.0%
7	Plump-Tall	> 48.1	> 73.1	23.0%

Table 4. Sizing system of diapers for infants

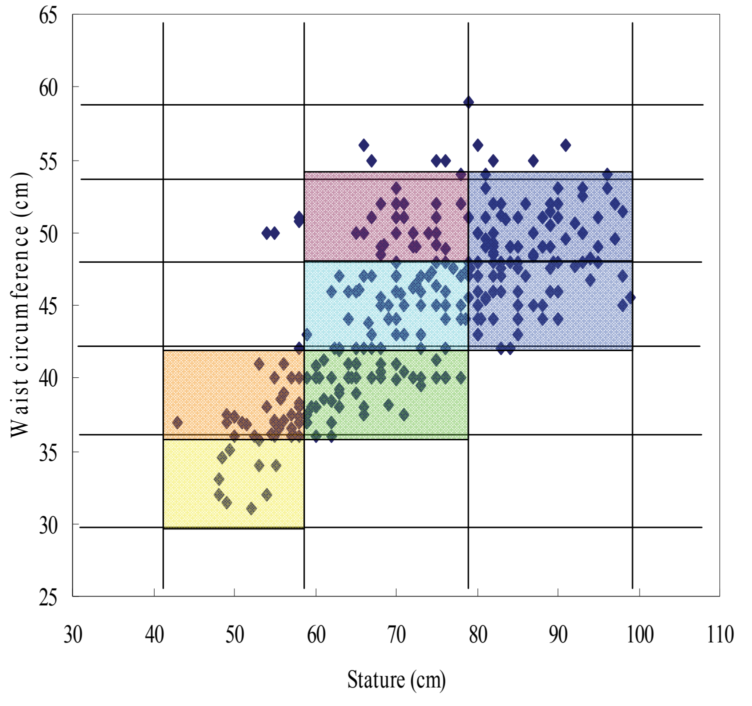

Fig. 2. The distribution graph of stature versus waist circumference for seven categories

2.4 Discussion and conclusions

Present study recorded the dimensions involved stature, weight, including head circumferences, waist circumferences, buttocks circumferences and thigh circumferences from three hundred subjects who aged from newborn to 3 years old were separated into eight stratifications (i.e. under one month, 1-3 months, 3-5 months, 2-7 months, 7-9 months, 9-12 months, 1-2 years, and 2-3 years old). One-way analysis of variance (ANOVA) was used to investigate the effects of age on dimensions of babies. As expected, the results showed that all dimensions were significant age effect. After Duncan's multiple range tests, these dimensions could be stratified six subgroups. However, diapers in the marketplace only have few sizes and classified according age and weight. From questionnaires survey (Lien et al., 2004) revealed that picking the well-suited diaper is more difficult for infants' parents, because the diaper sizes system only labeled the infants' age and weight. However, critical dimensions of the diaper (pants) should be circumferences of waist and buttocks. These are just one-third subjects satisfied with diaper design (Lien et al., 2004). For worse case, even if infants' age and stature in one size, we can't be sure diaper well-suitable for their circumferences of waist, buttocks and thigh. In addition, infants wore the wrong size of diaper, and it is a marked increase in risk of rash. Thus, present study could provide the anthropometric database for infants to redesign the new diaper size. Secondly, apart from infants' age and stature, circumferences of waist should be addressed and referenced. Suggestion of present study showed that each figure type was classified into several size subgroups based on the control dimensions and size interval. The waist circumference and stature were chosen to represent the control dimensions.

3. Case 2: Spoon design for 3-12 year-old children

3.1 Introduction

Carruth and Skinner (2002) reported at 12 months 43% of children were self-feeding with spoons, and 43% of mothers had special spoons that their children used. As early as 10 months of age the children were making hand and body movements indicating their desire to eat from the table and especially their parents' plates (Skinner et al., 1998). By 24 months, 80% of the study children were self-feeding. The children's transition from using specific types of baby spoons to adult spoons began around 16 months of age with over 54% using adult spoons at 24 months. The type of spoon chosen by mothers may reflect their children's ability to grasp a spoon using thumb and fingers to pick up and hold a spoon (palm down) compared to the ability to hold a spoon like a pencil (first two fingers and thumb with palm turned up or towards face). At a mean age of 14.37 months, the children could bring the side of a spoon to their mouth, but within the same age range they also were using their fingers to self-feed. The age of transition from special baby spoon to adult spoon may be associated with the child's receiving food from the parent's plate (using adult spoons) which would provide a differing sensory experience than a child's special spoon. Thus, eating and drinking utensils need design for users associated with motor development.

Use of chopsticks is well known to Chinese. Use of chopsticks for the pleasure of enjoying a meal within either a family or a social context is deeply conceived in the heart of Chinese culture. Chinese children begin using chopsticks at about the age (standard deviation) of 4.6 years (1.13) and throughout life chopsticks are the preferred eating utensils (Wong et al., 2002). However, manipulating chopsticks requires fine-motor control and skills (Sandra, Donna, & Jenna, 2002). Therefore, chopsticks users with children under 4 years old, or cervical spinal cord injury (SCI) or other types of hand impairments frequently are forced to switch to using spoons.

A spoon is a utensil consisting of a small shallow bowl, oval or round, at the end of a handle. It is used primarily for serving and eating liquid or semisolid food (sometimes called "spoon-meat"), and solid foods such as rice and cereal which cannot easily be lifted with a fork. Of course, eating utensils were also hand tools that require more precision or more force than a person's hand can safely sustain. Tool design can affect the user because the interface of the user with the tool will determine what the upper extremity and neck posture will be. Tools that create a need to abduct the elbow or shoulder to do a task will contribute to static muscle fatigue and limit the time the task can be sustained (Eastman Kodak, 1986). Thus, the purpose of this study was to determine the design factors preferred subjectively for choice of spoon. The second purpose was to observe the eating behavior and evaluate the design of spoon for children. It was expected that improved the eating comfortably and ensured the safety.

Apart from ethnic diversity, the most striking difference in body size is related to age. However, few studies have been conducted in the past to study on hand measurement for children particularly and were yet not being considered as an important parameter in the spoons design. Thus, the primary purpose of this study was to construct an anthropometric database about children for spoon design, and analyze it along with demographic data. The secondary aim of this research was to compare the dimensions of spoon in the marketplace with this anthropometric database and suggest the optimal dimensions.

3.2 Methods

3.2.1 Participants

Two hundred and five participants (96 boys and 109 girls) were accidental sampling from kindergarten and elementary school in Taipei and all participants were with no history of trauma or congenital anomalies on hands. The participants who age ranged from 3 to 12 years old were separated into eight stratifications for further analysis. The mean age of the sample population was 6.4 years (sd = 8.1), mean stature 117.3 cm (sd = 10.4), and mean body mass 23 kg (sd = 14).

3.2.2 Methodology of measurement

The main instruments used in present survey were the electronic digital caliper and height measurement. An accuracy of 0.5 mm was the objective and all measurements were recorded in millimeters. Body weight was measured using a portable weighting scale (kg). Altogether two anthropometric characteristics of hand were measured as follow:

a. Length of hand;
b. Breadth of hand;

3.2.3 Data analysis

All data were coded and summarized using SPSS software for Windows. Analysis of variance (ANOVA) was utilized to determine the effects of age on hand dimensions. Where statistically significant differences were determined, the Duncan post hoc test was performed. In addition, present study was to compare the dimensions of various spoons in marketplace products with this anthropometric database and suggest the optimal dimensions.

3.3 Results

3.3.1 Effect of age on dimensions

Mean stature and weight are presented in Table 5. All mean dimensions were significant differences between age groups ($p < 0.001$). Further, Duncan's post hoc tests revealed that mean stature could be divided into six subgroups, followed, in ascending order, by the subgroup 1 (3 years old; 99 cm), subgroup 2 (4-6 years old; 106-111.4 cm), subgroup 3 (7, 8 years old; 123.4-126.8 cm), subgroup 4 (9 years old; 132.8 cm), subgroup 5 (10 years old; 137.7 cm) and subgroup 6 (11-12 years old ; 148-149 cm).

In addition, Duncan's post hoc tests revealed that mean weight could be divided into five subgroups, followed, in ascending order, by the subgroup 1 (3-4 years old; 15-16.8 kg), subgroup 2 (4-6 years old; 16.8-19.6 kg), subgroup 3 (7, 8 years old; 24.3-25.7 kg), subgroup 4 (9-10 years old; 29.8-32.5 kg), and subgroup 5 (11-12 years old; 41.8-44.1 kg).

Mean length and breadth are presented in Table 6. Duncan's post hoc tests revealed that mean length of hand could be divided into five subgroups, followed, in ascending order, by the subgroup 1 (3-4 years old; 106.4 -106.8 mm), subgroup 2 (5, 6, 8, 9 years old; 120.1-132 cm), subgroup 3 (7, 8, 9, 10 years old; 130.1-137.2 mm), subgroup 4 (7, 10, 12 years old; 136.1-146.6 mm) and subgroup 5 (11-12 years old; 146.6-157.6 mm).

Mean breadth of hand could be divided into seven subgroups, followed, in ascending order, by the subgroup 1 (3, 4 years old; 49.66-52.29 mm), subgroup 2 (4, 5, 6 years old; 552.3-57.2 mm), subgroup 3 (7, 8, 9 years old; 63.5-70.5 mm), subgroup 4 (10, 11 years old; 75.8-76.4 mm), subgroup 5 (10, 11 years old; 75.8-76.4 mm) and subgroup 6 (12 years old; 98.2 mm).

	Stature (cm)		Weight (kg)	
Age groups	mean	SD	mean	SD
3	99.39	4.25	15.1	1.55
4	106.0	4.29	16.8	2.41
5	111.4	6.78	19.1	3.17
6	109.7	7.92	19.7	3.46
7	123.4	5.62	24.3	5.56
8	126.8	5.16	25.7	5.70
9	132.8	7.20	29.8	6.75
10	137.7	6.51	32.5	6.81
11	149.1	7.80	41.8	7.58
12	148.2	5.33	44.1	8.92

Table 5. Stature and weight by age groups

	Dimensions (mm)			
	Length of hand		Breadth of hand	
Age groups	mean	SD	mean	SD
3	106.4	7.76	49.7	3.60
4	106.8	14.7	52.3	3.57
5	121.8	9.31	57.2	4.32
6	120.2	9.38	56.4	3.91
7	136.2	6.43	63.4	5.78
8	130.2	10.72	70.5	11.7
9	132.1	17.4	67.3	6.33
10	137.2	17.4	75.8	11.1
11	157.6	6.96	76.4	12.6
12	146.7	8.86	98.2	17.6

Table 6. Hand dimensions by age groups

3.3.2 Spoon design

Present study provided product designer with the anthropometric dimensions of hand for children and recommend appropriate solutions for design. In addition, hand dimensions for 3-12 age children were showed in Table 6.

For Japanese data of hand length, these are about 100 mm, 110 mm, 120 mm, 130 mm 140 mm, 150 mm, 160 mm for 2 years old, 3 years old, 4 years old, 5 years old, first-second grade elementary school, third-fourth grade elementary school, and fifth-sixth grade elementary school. The length of chopstick has determined on increase 30 mm from hand length. Thus, Japanese chopstick of length could be divided into eight various sizes for children. These are about 130 mm, 140 mm, 150 mm, 160 mm 170 mm, 180 mm, 190 mm for 2 years old, 3 years old, 4 years old, 5 years old, first-second grade elementary school, third-fourth grade elementary school, and fifth-sixth grade elementary school (Hashiseiwa Company, Japan). This is general principles for applying anthropometric data to specific design problems. Certain features of equipment or facilities can be designed so they can be adjusted to the individuals who use them. Thus, the length of spoon should be adjustable from 136 mm to 187 mm. Five levels could be set on adjustable length .In addition, open windows could see the indicator of length (Figure 3).

According the principles of hand tool and device design (Fraser, 1980; Freivalds 1987), tools should be designed to be used in the operator's preferred hand. For example, the handle could be moved for left-handed use, if a threaded fastener were provided in the right side of the drill housing (Greenberg & Chaffin, 1977). So, spoon design for right-hand or left-hand user should be considered for convenient. Thus, the prototype of new spoon for children showed in Figure 4. The shallow bowl of present spoon could be turned to right or left and could decrease the wrist radius deviation.

Fig. 3. The length of spoon also adjusted from 136 mm to 176 mm by rotating the back button

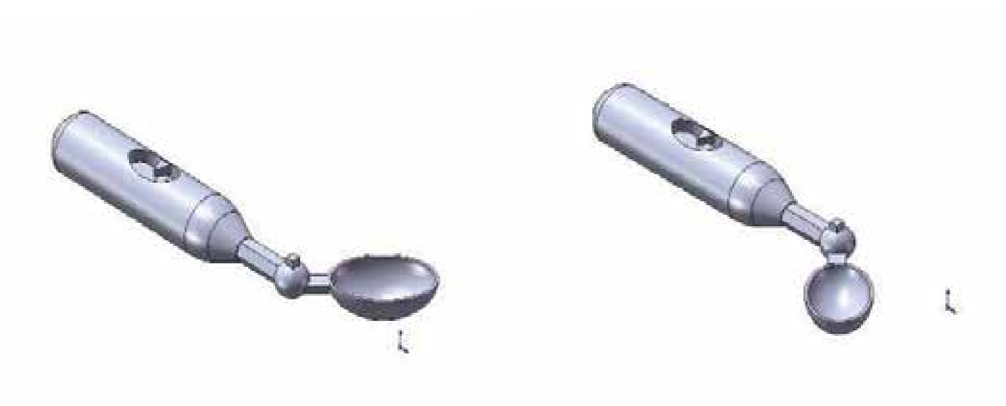

Fig. 4. New spoon could turn the shallow bowl to right and left side

3.4 Discussion and conclusion

Tool design can affect the user because the interface of the user with the tool will determine what the upper extremity and neck posture will be. Tools that create a need to abduct the elbow or shoulder to do a task will contribute to static muscle fatigue and limit the time the task can be sustained (Eastman Kodak, 1986). Hsu and Wu (1991) investigated the effects of the length of chopsticks on the food-servicing performance. Their results showed that the food-pinching performance was significantly affected by the length of the chopsticks, and the chopsticks of about 240 and 180 mm long were optimal for adults and pupils, respectively. Chen, Liu and Tseng (2009) examined the effects of age, chopsticks characteristics and pinching tasks on performance and subjective ratings. Thirty elementary school students were recruited in present study and divided into three groups (8, 10 and 12 years old). Eight types of chopsticks had been evaluated on pinching two objects (corn snacks and chocolate balls). Results of ANOVA showed that the pinching performance was significant difference between ages. In addition, the pinching performance was better in applying the hexagon chopstick with particular length. By contrast, the stainless steel chopstick was worse case. Therefore, manufacturers should make products available in various sizes to accommodate different users at least four sizes for children and various sizes of spoons were based on hand length plus 30 mm.

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