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Management of Information Systems

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Meet the editor

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Contents

Preface

Management of Information Systems deals with the application of management and information systems to practical business areas as a support for managerial decision-making. The book discusses the relationships, needs, and possibilities of using IT as a support for management and information systems. The conditions for their efficient use and applicability as a support for scientific decision-making are also examined. The book contains three sections as follows: The role of information technology as a support for the management of information systems, Management of human resources systems, and Practical case studies of the management of information systems.

The first section discusses the importance of the management of information systems.

In the first chapter, the authors describe how to develop the interrelations between management and information systems functions. Management functions were developed first as a systematic step to carry out management activities, while implementation of information components followed as part of management elements. Given the solutions to the case studies, the authors state that to achieve goals and benefits in excellent performance, it is necessary to design and develop an integrated model that will coordinate management functions and information system components as an integrated process.

In the second chapter the authors discuss the possibilities of quantitatively supported managerial decisions given by decision support systems (that could otherwise be based on personal intuition and experience. Different decision analysis methods, including elementary methods, multiattribute utility theory, and outranking methods are also introduced and compared. Inclusion of an intelligent knowledge base seems to be required to give managers the ability to quantify the impacts of both technical (hard) and subjective (soft) constraints and improve managerial decision-making processes.

The third chapter describes the development of an e-commerce business satisfaction management model aimed at helping SMEs to effectively adopt e-commerce systems or evaluate e-commerce success. A completely managed process of evaluation of critical success factors helps to improve e-commerce success from a business perspective.

In the fourth chapter the authors deal with several development stages of managerial information systems designed for the purposes and needs of businesses as a support for management operations and decision-making processes. The authors describe methods for evaluating the performance of management information systems using calculation schemes that allow for the design and coding of computer programs for solving the above-mentioned problems automatically.

The purpose of the fifth chapter is to provide a comprehensive survey on e-marketplaces in terms of their use and customer satisfaction. An e-marketplace is a type of technology where people can buy and sell their items online, therefore it is perceived as part of the online business processes that enable the management of organizations, technology, and people.

The sixth chapter of the first section discusses digital leadership. Such agility is, in fact, an organizational capability, where a combination of internal and supplier/partner resources allows enterprises to quickly create customer value propositions and deliver value through digital services, e.g. services using advanced digitization. This chapter deals with the development of a 10-step methodology that shows how an innovative value proposition moves from concept to implementation using an agile system and business architecture. It also illustrates how this concept can help enterprises continually look at innovative opportunities and quickly design and deliver digital services that generate this value.

The second section is focused on human resources management and its use in practice.

In the seventh chapter the human resource information system responds more quickly to the changes and needs of managerial decision-making. Human resource management (HRM) provides guidance for an organization's workforce. The use of information technology can improve the information available to HR, facilitating HR processes and making them faster and more efficient in the processes of solving strategic issues of HRM.

In the eighth chapter the authors deal with the modeling system and the role of humans in a complex sociotechnical system as a human/machine system. The subject of research is the professional activity of personnel in the sociotechnical system, the structure of their professionally important qualities, the methods of assessing the professional suitability of a person, and the methods of training operational personnel. The use of the hierarchy analysis method and decision support systems allows multicriteria decision-making in a complex system. The use of the proposed model allows managers to implement a tool that will reduce the training costs of professionals and raise the level of professional skills of the operator. In addition, the HMC interface can be customized to accept individual operator portraits and their integrated estimation capabilities.

The ninth chapter analyzes the need for a correct understanding of information and the possibilities of effective implementation of information technologies as a rational attempt to harmonize the modern organizational environment, reduce the level of conflicts and improve efficiency indexes. The role of information management as a multifunctional decision-making system that determines the strategy, forms the normative basis for the regulation of innovation activities, ensures a continuous process of foresight, policy development, implementation, monitoring, and evaluation in different organizational environments, and considers the content and peculiarities of the conflict management process based on the implementation of communication scenarios is discussed.

The tenth chapter presents methodological proposals for organizing the activities of program teams in conditions of unstable development teams. The authors discuss the possibilities of implementing the technique of tuning using the Highsmith's Adaptive Software Development Approach as well as the role of the personal coordinator, which allows for risk mitigation of project failures based on the external evaluation study and critical analysis of existing approaches.

The last chapter of the second section is aimed at evaluating participatory management that will establish a dynamic of democratization of public administration, since it associates planning and widespread participation through political definitions and adjustments and changes. It will be a model for the management of the optimization of the public budget, whose objective is to provide the administrator with the tools necessary to optimize the application of available public resources, respecting the need for employment of increasingly scarce resources and an increasingly demanding and participatory population. Based on a case study solution, a model is presented that uses the methodology of the analysis of feasibility, the application of a multicriteria structured model, and mathematical programming.

The third section contains examples of the management of various information systems.

The twelfth chapter deals with the improvement of the management of professional English education and the methods of accessibility of training courses using IT support. Customer satisfaction levels with English e-learning websites used as support for education will be examined. The service quality model of Parasuraman, Zeithaml, and Berry and the technology acceptance model (TAM) are both used. The design of the study uses two specific aspects, perceived ease of use and perceived usefulness in TAM and their mutual relationship. This model examines the five elements of intangible service quality, namely, reliability, assurance, tangibles, empathy, and responsiveness, indicated in the SERVQUAL model, which will form the basis for assessing the level of satisfaction with the education system.

The thirteenth chapter presents a new proposal for supporting the management of research processes in universities and higher education centers (named CREAMINKA). The aim of this study is to develop a knowledge-based model that aims to address the innovative aspects of research. It is presented with a knowledge model of entrepreneurship (startups) as well as an analyzer of general and specific competencies based on data mining processes.

The fourteenth chapter describes the possibilities of the application of Geographic Information Systems (GIS) associated with Standard Penetration Test reports in civil engineering as a support tool for planning and decision-making in public and private spheres. Different possibilities of information management are discussed using two practical case studies.

The last chapter of the third section focuses on discussing the management of the performance of two types of data cache models where hardware and software methods for energy saving are proposed. This chapter closes the case studies section where various possibilities of management of information systems are discussed.

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Section 1

The Role of Information Technology as a Support of Management of Information Systems

Chapter 1

Management Functions of Information System Components as an Integration Model

Boy Subirosa Sabarguna

Additional information is available at the end of the chapter

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Abstract

Management functions develop first, as systematic steps to carry out management activities, while information components system follow later as part of management elements, where both must be integrated in order to make its practical implementation more clear. Management Functions and Information System Components as an integration model are (1) to explain Management Functions, Information System Components, Goals and Benefit related to Information System and (2) to explain integration process of Management Functions with Information System Component to get goals and benefits as an integrated model. Research method using expert method has done an integration of management function, which includes the cycle of P, O, A, C, E and I, to run management process, must be step by step, and as a cycle. Information components include S, H, F, B, and T and must have minimum requirement. Management of Information System needs goals and benefits that can be calculated clearly and specifically. To get goals and benefits in excellence performance are needed the integrated process to coordinate management functions and information system components, as an Integrated Model with an example in applications of software in Nosocomial Infection Control for Hospital, as the figure below.

Keywords: management functions, information system components, integration model, goal, benefit

1. Introduction

1.1. History of management functions and information system components

The function of management as a systematic step continues to grow since long time, and it began from

- POAC (Planning, Organizing, Actuating, and Controlling);

becomes,

- POACD (Planning, Organizing, Actuating, Controlling, Directing);

becomes,

- POACE (Planning, Organizing, Actuating, Controlling, Evaluating);

becomes,

- POACEI (Planning, Organizing, Actuating, Controlling, Evaluating, Innovation).

It provides a systematic, important step forward in order to implement practical management activities. Thus, running the management becomes easy using the systematic step.

In addition to management functions, there are also elements of management, which continues to grow as well, namely

- 5 M (Man, Money, Method, Material, Market);

becomes,

- 5 M + T (Man, Money, Method, Material, Market, Technology);

becomes,

- 5 M + T + I (Man, Money, Method, Material, Market, Technology, Information). This information is originally only data that are processed, as a material to perform step activities.

Today's complex organizational activities, and the changing times and rapid and sophisticated technologies are due to

1. increasingly difficult and expensive resources;
2. an era of competition that demands quality service;
3. the increasing demands and expectations of the community with the support of technology.

Moreover, in relation to a system of information that develops extraordinarily and is moving in disruption [1], it requires a past, present, and future study, in order to make adequate anticipation to avoid the agitation and destruction of the information system and at the same time the destruction of its organization.

The latest development of the management function and components of information systems requires integrated effort, due to resource constraints and the need to achieve effectiveness and efficiency significantly; then, the integration needs to explain the relationship between the management function with the components of information systems so that there is a clear integration. Based on the above, the aims of Management Functions of Information System Components as an Integration Model [2] are (1) to explain Management Functions, Goals and Benefits related to Information System Components; and (2) to explain integration process of Management Functions with Information System Components to get goals and benefits from integrated model.

There is a need to clarify the linkage between the management function and the information system components so as to illustrate linkages [3], as well as the linkages that can be measured in terms of the linkage having loads [4] which can be taken into account either qualitatively or quantitatively; then, the linkage is an integration that can easily be done both in terms of component and overall. With the three things: clarity, measurable linkages, and easy to implement, there is evidence of the need for integration, if not the two namely management functions and components information systems where efforts and goals run individually and as a whole which will not achieve the goal. Thus, the integration between the management function and the components of the information system will help achieve an integrated relationship so that it will achieve the goal more easily.

1.2. Management function

Management [5] in accordance with the classical definition is "coordination between various resources through the process of planning, organizing, there is control ability to achieve goals." While the important goal of management is to achieve effectiveness and efficiency, the achievement of this goal is an important characteristic of management [6]. The latest definition according to the recent times is strategic thinking to gain a competitive advantage [7]. Various experts put forward various management functions which include the following:

1. Is group of manager activities in performing their functions, namely planning, organizing, directing, and controlling [8]
2. the description of the classic management function is the POACE (Planning, Organizing, Actuating, Controlling, and Evaluating) function, as shown in the following explanation [9] **Table 1**.

The Management Functions shown in **Table 1** is the recurring cycle, meaning that after the evaluation is done, it will be an input for the next planning. When described with the latest view today, which is related to the development of communication and information technology, there is a new function called INNOVATING [10]; without any innovation, then the company will be left behind and sooner or later will die by itself. Based on this reason, the current POACEI management function is described in **Figure 1** as a cycle.

1.3. Information system component

In general, information systems-related subsystems include the following [11]:

1. inputs, which are facts and data that have not been processed;
2. process, which is related to efforts to transform or transform data into information;
3. output, which displays the result of changes of data that has been in though and useful form of information.

A complete picture about the interrelation of subsystem can be shown in **Figure 2** [12].

Feedback is a description showing the return or continuous return of information to data back, by a controlled process or not. Thus, a system that is a unity of various subsystems in order to produce information is called information systems. In this case, as the goal is to achieve greater benefits of existing data, it is important to note the existence of components, interconnected to achieve certain goals. Information systems will run when there are components that support, move, and sustain the system. The information system is an intangible concept, tangible is its supporting components, visible, and can be measured. Information System Component [13] is important such as hardware, software, and network. After expanded of explanation, so components become as below (**Table 2**).

Code	Function	Explanation
P	Planning	Plan activities for the future.
O	Organizing	Organize for each activity and resources to be organized as needed.
A	Actuating	Carry out activities with full responsibility and continue to adjust to the plans and situations that occur.
C	Controlling	Controlling for implementation to fit the plan and lead to the achievement of goals.
E	Evaluating	Assess whether the plan works well and the goals can be achieved, if there are deviations, why and how to resolve and how to avoid recurrence.

Table 1. Management functions explanation.

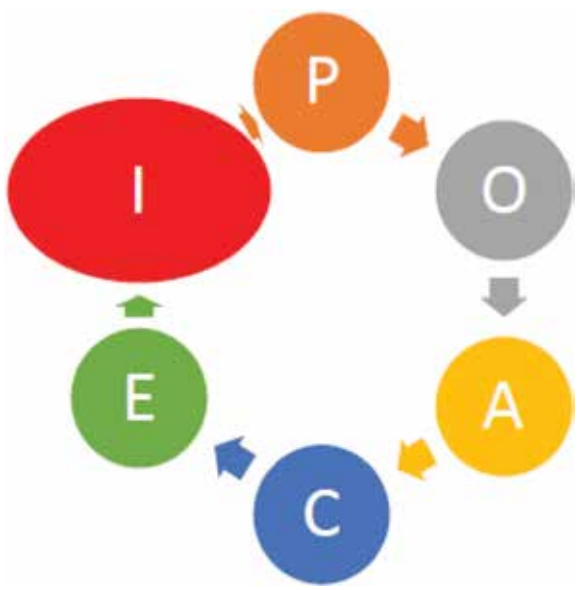

Figure 1. POACEI cycle.

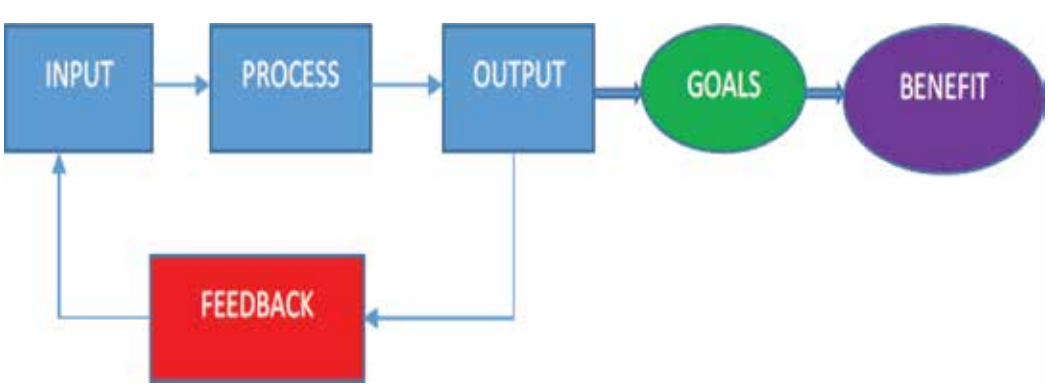

Figure 2. Information system.

No	Components	Subcomponents	Description
1.	Infrastructure	1. Room	Room for equipment and workplace
		2. Light	Electricity for power equipment
		3. Network	Base on Internet, online and offline, web-based, cloud system, smartphone related
2.	Hardware	1. Server	Hard disk with big capacity (SSD) as big data with Speed 4G
		2. Workstation	Amount sufficient, with the capacity as needed
3.	Software	1. Operating system	Compact, user friendly, developed gradually and continuously
		2. Help	There are facilities with sufficient explanation
		3. Trouble shooter	There are certain ways and options for some trouble conditions
4.	Brainware	1. User	Users who have received training on information systems and can use for decision making
		2. Training and guidance	There is a training module and user manual for correct telemedicine use, both hard and softcopy about the information system used
		3. Operator	Qualifications and competencies that suit your needs
5.	Technology	1. Cable	Using a wired system to funnel data
		2. Wireless	Use frequency to connect
		3. Satellite	Satellite-based for contacts

Table 2. Information system component.

2. Goals and benefits of integration

2.1. Goals

The classic goal of management is to achieve:

1. Effectiveness [14]; with the understanding of the results achieved in accordance with the expected target, in this case, the targeted target, and initial goals are important as a benchmark for success.
2. Efficiency is an achievement with cost-efficient but still achieves the expected quality value, so the cost is cheaper but the quality is maintained [15].

The two things above are important to provide information systems with the plan, the results achieved in accordance with expectations, the quality that is maintained and cost-efficient; thus, the information system can be smooth, well-performing, and ready to be continuously developed.

2.2. Benefit

Benefits to be achieved by the implementation of good management functions in managing information systems are the hope of disruptive situation [16] with characteristics including

1. high-quality achievement;
2. very low cost;
3. in the conditions of many new emerging competitors.

Number 3 is a key feature of the Disruptive Era, which needs to be anticipated; otherwise, it will not miss or die by itself.

3. Research method for integration model

The method used in order to develop an integrated model between management functions and information system components includes (1) literature study and (2) ask experts, as a

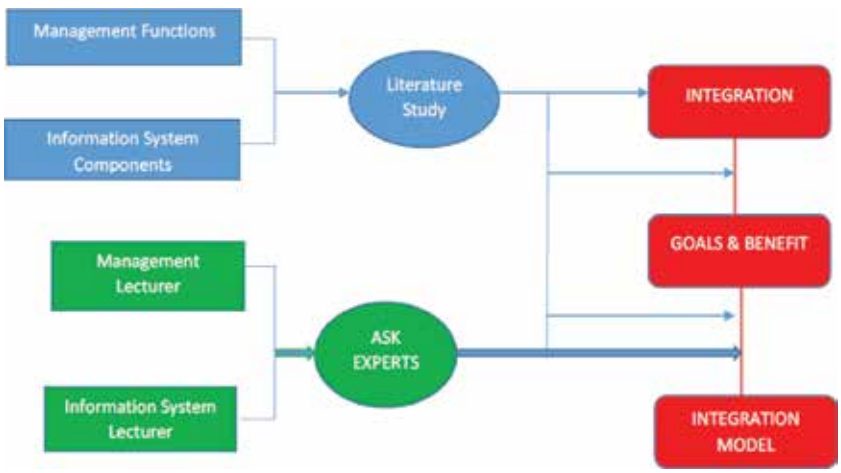

Figure 3. Research methods for integration.

qualitative research, conducted by action research [17]. Stages of activity include data collection, data analysis, and modeling [18]. This is described in **Figure 3**.

The description above shows a complete research process as a model that is ready to be done and implemented further, and follow three steps: (1) literature study for the collection of theoretical aspect; (2) ask expert, to get more input and more deep explanation; and (3) using a model in Nosocomial Infection Control in Hospital.

4. Integration model

4.1. Model

Management functions include cycle of P, O, A, C, E, and I, to run management process, must be step by step, and as a cycle, when P = Planning, O = Organizing, A = Actuating, C = Controlling, E = Evaluating, I = Innovating [19]. Information components include S, H, F, B, and T, must have a minimum requirement, when S = Infrastructure, H = Hardware, F = Software, B = Brain ware, T = Technology. Management of Information System needs goals and benefits that can be calculated clearly and specifically. The goals are effectiveness and efficiency and how the information system can be run. This model was developed by the asked expert method using the qualitative method by two experts, with the result of integration between Management Function and Information Components. The management function includes the cycle of P, O, A, C, E, and I, to run management process, must be step by step, and as a cycle, when P = Planning, O = Organizing, A = Actuating, C = Controlling, E = Evaluating, I = Innovating [19]. Information components include S, H, F, B, and T, must have a minimum requirement, when S = Infrastructure, H = Hardware, F = Software, B = Brain ware, T = Technology. Management of Information System needs goals and benefits that can be calculated clearly and specifically. The goals are effectiveness and efficiency and how the information system can be run to get these goals and benefits that must have a high quality and low price with many newcomers as competitors. To get goals and benefits of excellent performance need, the integrated process to coordinate management functions and information system components, as an Integrated Model, is shown in **Figure 4**.

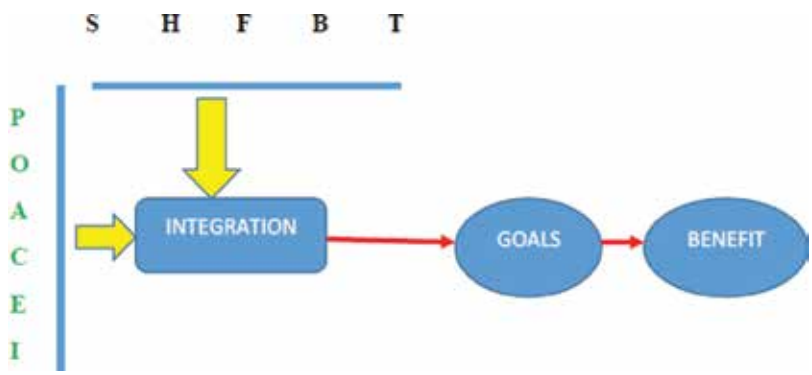

Figure 4. Integrated model of management functions and information system components.

Figure 5. Integrated model in Planning-1.

To use model, we should start with the order of management functions vertically from top to bottom, namely Planning, Organizing, Actuating, Controlling, Innovating; then directed to the horizontal are infraStructure, Hardware, Software, Brain ware, and Technology. Thus, the Planning link as part of the Management Function and Information System Component needs to be linked to the subsequent management process. The following illustrates, for example, the interrelationships between planning: infraStructure, Hardware, soFtware, Brain ware, and Technology, which must be described and should be a clear link to the achievement of effectiveness and efficiency. A clear and complete planning and accompanied by the achievement of effectiveness and efficiency will be the basis for achieving a high quality, low cost, and in the face of the abundance of existing and emerging competitor. Certainly, it is necessary that all the management functions be described completely and relevantly, the following related to planning only. This is shown in **Figure 5**.

A complete description, for example, overall integration in Planning-infrastructure, Planning-Hardware, Planning-software, Planning-Brain ware and Planning-Technology, is given. In **Table 3**,

M. F	**ISC**				
	Infrastructure	**Hardware**	**Software**	**Brain ware**	**Technology**
Planning	Procurement based on time and needs	Choice of appropriate specifications, including vendors and development plans	Determination to be used, including vendor to be selected and maintenance plan	User and Operator determination and required training program	Selection and linkage with anticipated development
Organizing					
Actuating					
Controlling					
Evaluating					
Innovating					

Note: ISC, Information System Components; MF, Management Functions.

Table 3. Integrated model in Planning-2.

Integrated Model in Planning is shown. This model has advantages due to integration, making it complete and systematic, with the weakness being the many actions that need to be done.

Organizing explanations include

1. organizing the position and the type of room, the need for electric power, and network settings;
2. organizing the location and type of hardware interspersed with servers and workstations to suit usage needs;
3. organizing software, related to Operating System, Help and Trouble Shooter required in operations;
4. organizing about Brain Ware related to the User regarding who and what criteria and training manuals and also guidelines for use that suit your needs;
5. organizing the use of technology that prospective related with data transfer, speed, cable, and satellite network as needed and relatively affordable.

Actuating explanations include

1. actuating on Infrastructure, indicating the existence of procedures of use, the operational procedures of the existing infrastructure, and linkages;
2. actuating on Hardware, related to hardware usage, use and maintenance procedures so that it clearly defines the standard used to prevent errors;
3. actuating on Software, encouraging proper execution with clear and easy to understand, and easy to understand guidelines and procedures;
4. actuating about Brain Ware, including the procedures and capacities necessary to be able to run the information system, including how to train and determine the authority of use;
5. actuating Technologies, including some guidelines and rules for the use and mapping of technologies, including the necessary development.

Controlling explanations include

1. controlling of Infrastructure, related to the benchmark used to measure the presence or absence of irregularities in the use of infractions such as space and electricity that need to be guaranteed to help;
2. controlling of Hardware, related to efforts to control servers and workstations to run in accordance with the objectives, and provide feedback for improvement;
3. controlling of Software, relating to various ways to be aware of any possible deviation, can provide alert, and can give an appearance of what happens to be understood as an error;
4. controlling of Brain Ware, in relation to the processes that occur as well as the behavior of users and operators in using information systems, so that they are ensured in the guidance;

5. controlling of Technologies, including monitoring and control of network and data transport, ensuring that there are no errors and flaws that interfere with interpretation results.

Evaluating explanations include

1. evaluating on Infrastructure, relating the results achieved in accordance with the planned activities with Room, Light, and Network, whether there are differences in the results of less or more;
2. evaluating about Hardware, related to hardware comparison in planning with existing, in terms of Server and Workstation, the difference seen or not;
3. evaluating about Software, discerning differences between Operational System, Help, and Trouble Shooter from planning to reality, whether adjustments or improvements are needed;
4. evaluating about Brain Ware, seeing the difference between a plan and a reality in terms of User and Operator, and the need to be spelled or customized;
5. evaluating Technology, examining the difference in terms of technology related to data transfer either with cable or wireless, between plans with reality, whether to be repaired or even to be replaced.

Innovating explanations include

1. innovating on Infrastructure is a present-day study into the future to see the possibilities of new things that arise, to anticipate and be prepared, related to Room, Light, and Network;
2. innovating about Hardware is a future thought to estimate the possibility of new things that need to be anticipated and prepared, especially with servers and workstations;
3. innovating about Software, rapid and sophisticated development, requires adequate anticipation, and follow-up will be able to keep up with the times;
4. innovating on Brain Ware, preparation, and anticipation, in relation to changes from the User and Operators, in order to obtain objectives and benefits, is intimidated by the changing of thoughts related to the Users and Operators;
5. innovating about Technology; this requires long-term thought and strong anticipation and possibly the existence of various alternatives, due to rapid progress and sophistication, resulting in a rapid technological obsolescence.

4.2. Example of nosocomial infection control for hospital

Applications of software in Nosocomial Control for Hospital, related to the notion of surveillance, include [20] "systematic, active and ongoing observation of the occurrence and spread of Nosocomial Infection in an event that causes increased or decreased risk." The activities undertaken are collection data, data analysis, and information dissemination. Required data related to the type of nosocomial infection, location, number of affected, analyzed causes

and spread, disseminated to the responsible team. Associated with Information System Components (ISC) with its control as part of the management function, [21] (1) Integration Model, (2) Goals, and (3) Benefit are seen, which are related like the following description in **Figure 6**.

ISC / MF	InfraStructure	Hardware	SoFtware	Brain ware	Technology
Planning	-	-	-	-	-
Organizing	-	-	-	-	-
Actuating	-	-	-	-	-
Controlling	Wireless Networks	Server in Hospitals and Workstations in the form of tablets at each officer	Data recording, Automated Monitoring and Early Warning System	Officers, related to duties and responsibilities	Web based
Evaluating	-	-	-	-	-
Innovating	-	-	-	-	-

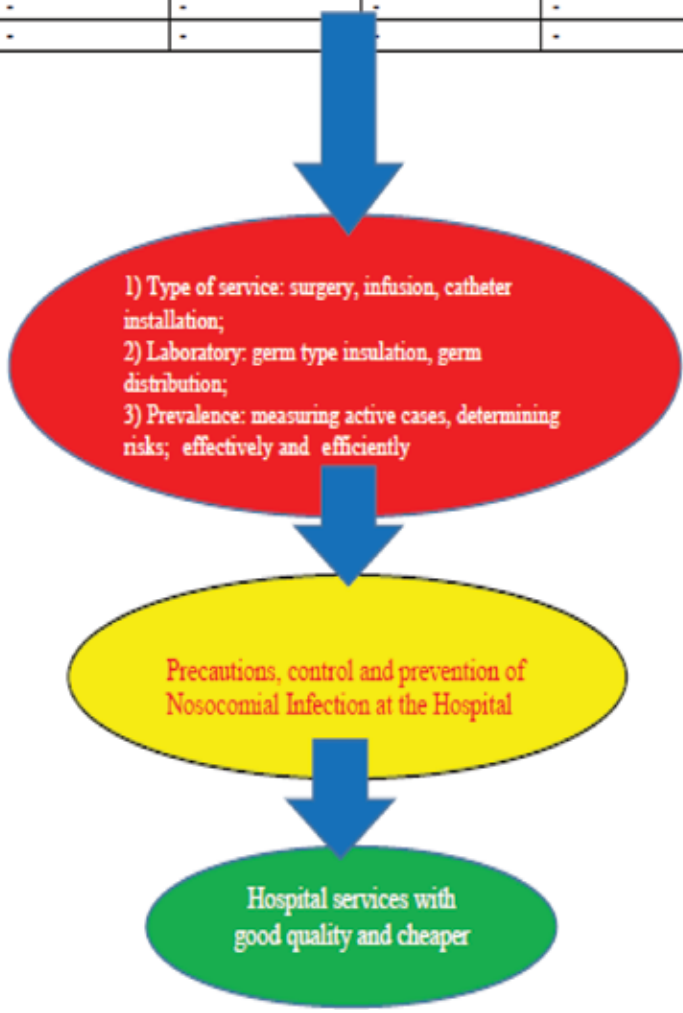

Figure 6. Nosocomial infection control for hospital in integrated model.

Explanation of the above figures, related to the relationship between Integration Model, with Goals to be achieved and Benefit to be obtained at the Nosocomial Infection Control for Hospital, is as follows.

4.2.1. Integration model

Explanation of Integration Model: related to process of control on

1. infrastructure: related to Wireless network,
2. hardware: related to Server in a hospital and workstation in the form of tablets at each officer,
3. software: related to Data Recording, Automatic Monitoring, and Early Warning System,
4. brain Ware: related to the officer related to duties and responsibilities,
5. technology: related to Web based.

As a complementary unity for the process of controlling activities related to the information system, the next is the nosocomial infection control activities in the hospital, which are related to

1. type of service: surgery, infusion, catheter installation;
2. laboratory: germ type insulation, germ distribution;
3. prevalence: measuring active cases, determining risks.

The above activities must be done effectively and efficiently.

4.2.2. Goals

The goals of nosocomial infection control activities in the hospital include

1. precautions,
2. control,
3. and prevention of nosocomial infection at the hospital

This can be done in a systematic and structured way by using information system, so that goals can be achieved clearly.

4.2.3. Benefit

To get continuous of goal achievements, then the benefit for Hospital Services will be obtained with good quality and cheaper as impact of using information system for Nosocomial Infection Control in Hospital.

The above illustration shows a clear link between the model with the objectives and benefits, which in general give the excess of ease in assembling the linkages in the implementation, although it requires a complete study from the beginning as a weakness.

5. Conclusion and suggestion

Integrated Model of Management Functions (MFs) and Information System Components (ISCs) will facilitate linking together in order to describe and integrated activities. Furthermore, it will directly facilitate demonstrating clear objectives and encouraging the making of relevant benefits. It is recommended to be used in the framework of education and training and to train the skills of managers in making programs or activity proposals related to information systems.

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Chapter 2

Decision Support Systems

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Additional information is available at the end of the chapter

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Abstract

The current decision-making problems is more complex than it was in the past, prompting the need for decision support. Most real-world decision-making situations are subject to bounded rationality; whereby the technical and economic evaluation of all solution alternatives (branches) is bounded by the consideration of dominant subjective constraints. The early definition of DSS introduced it as a system that intended to support decision makers in semi-structured problems that could not be completely supported by algorithms. DSSs were planned to be an accessory for managers to expand their capabilities but not to replace them. Decision support systems could provide the means to complement decision makers by quantitatively supporting managerial decisions that could otherwise be based on personal intuition and experience. In addition to the traditional DSS characteristics (i.e., data and model orientation, interactivity), the inclusion of an intelligent knowledge base would be required to quantify the impacts of both technical (hard) and subjective (soft) constraints.

Keywords: decision support system, decision analysis, decision alternatives, criteria, weight

1. Introduction

As a matter of fact, nowadays, decision-making is more complicated than it was in the past for two governing reasons. Firstly, growing technology and communication systems have spawned a greater number of feasible solution alternatives from which a decision-maker can select. Secondly, the increased level of structural complexity of today's problems can result in a chain reaction of magnification of costs if an error should occur [1].

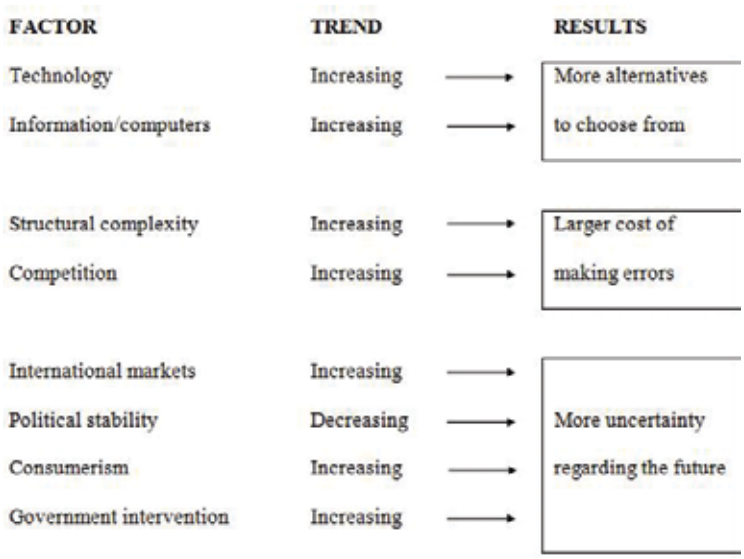

Figure 1. Factors affecting decision-making [2].

Turban and Aronson examined what they consider to be the major factors that affect decision-making, and have drawn conclusions regarding current trends and corresponding results/impacts on decision-making (**Figure 1**) [2].

In general, managerial decisions are derived from human judgment which includes deductive reasoning supported by experience, information and knowledge [3]. To compensate the effect of human error, the decision-making process can be partially supplemented by computer aided automation. The final system cannot be fully automated, unless perfectly processed information and an optimum model is provided.

DSS is used to model human reasoning and the decision-making process; both are capable of accepting facts from users, processing these facts, and suggesting the solutions that are close to the solutions that are presented by human experts [4]. DSS can considerably support in evaluating different maintenance decisions in order to select the most robust and cost-effective answers in a systematic and transparent way [5].

The growing level of decision support system accomplishment in organizations over the recent decades is strong proof that DSS is a viable and well accepted managerial tool.

2. Decision support systems

2.1. A brief history

Over the past fifty-plus years, the field of Information Systems (IS) has undergone a considerable progression of growth. Each expansion has built on its predecessors and supplemented them in the process [6].

Before 1965, it was extremely expensive to build a large-scale information system. Around this time, the establishment of the IBM System 360 and other more powerful processor systems made it more practical and cost-effective to build management information systems (MIS) in large corporations. The pre-specified reports (e.g., budget, cumulative cost and progress statements) output from MIS are data-oriented and restrict decision-makers to gathering the necessary information for making choices, but do not supply a framework to model decision problems. At that point, it was recognized that technological support for decision-making must facilitate ad hoc (problem-specific) recovery of data and managerial control over model manipulation. Decision-makers did not wish to be locked into systems they could not control [7].

In the late 1960s, model-oriented DSS or management decision systems became practical. Two DSS pioneers, Peter Keen and Charles Stabell, stated the concept of decision support which was extracted from the theoretical studies of organizational decision-making during the late 1950s and early 1960s and the technical work on interactive computer systems that mostly carried out in the 1960s [8].

In 1961, Michael S. Scott Morton published "Management Decision Systems: Computer-Based Support for Decision Making." Later, in 1968–1969, he studied the effect of computers and analytical models in critical decision-making. His research played a "key role in launching the DSS movement" [9].

In 1980, Steven Alter published an important book titled "Decision Support Systems: Current Practice and Continuing Challenge." His research founded a structure for identifying management DSS [10].

Bonczek et al. established a theory based on knowledge-based DSS [11]. Their research presented how Artificial Intelligence and Expert System technologies were applicable to developing DSS. They also introduced four essential "aspects" or components of all DSS [12], these are:

1. A Language System (LS) which includes all the recognizable messages.
2. A Presentation System (PS) for all messages emitted by DSS.
3. A Knowledge System (KS) addressing all the imbedded knowledge in a DSS.
4. A Problem-Processing System (PPS) that tries to diagnose and solve problems.

In the early 1990, business intelligence, data warehousing and On-Line Analytical Processing (OLAP) software began expanding the potential of DSS [10]. Around 1997, the data warehouse became the cornerstone of an integrated knowledge environment that granted a higher level of information sharing, facilitating faster and better decision-making [13].

Decision support systems have experienced a noticeable growth in scholarly attention over the past two decades. In according to Google Scholar (October 2007), the rate has increased from less than three publications per week in 1980 to over 20 publications per day twenty-five years later [14]. The Internet and Web have also accelerated developments in decision support and have provided a new way of capturing and documenting the development of knowledge in this research area [10].

2.2. DSS definitions

According to Mora et al., the decision maker employs computer technology to: (a) organize the information into problem factors, (b) attach all the attributes to a model, (c) use the framework/model to simulate alternatives, and (d) select the best course of action [15]. The outcomes are reported as parameter conditions, experimental forecasts, and/or recommended actions. A typical architecture of DSS provided by Mora et al. is shown in **Figure 2** [15].

2.3. DSS ideal characteristics and capabilities

Defining standard characteristics of DSS is not viable but the major features that distinguish DSS from other previously established systems can be summarized from Turban and Aronson as follows [2]:

- DSS assists decision makers in semi-structured and unstructured problems (which cannot be solved by standard procedural methods or tools), employing human judgment and computers.

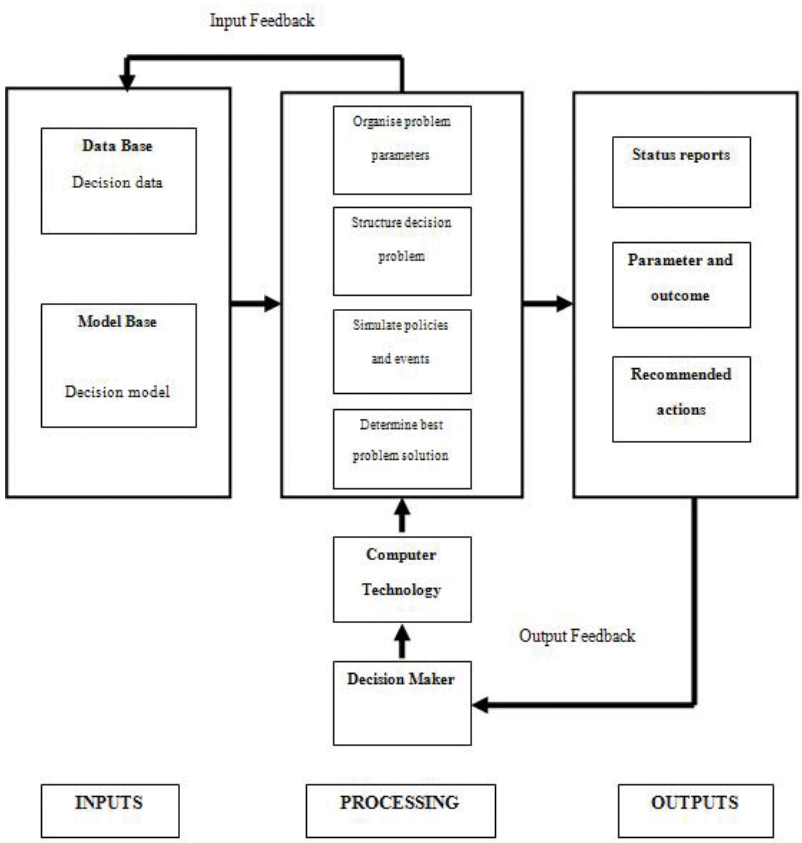

Figure 2. Typical architecture of decision support system (Mora et al., [15]).

- It covers a vast spectrum of managerial levels, from top executive to line managers.
- Support is provided to both individuals and groups. Less structured situations often require the intervention of several individuals from different divisions and organizational levels or sometimes even from different organizations.
- DSS facilitates several interdependent and/or sequential decisions that may be made once, several times, or repeatedly.
- DSS carries out all parts of the decision-making process: intelligence, design, choice and implementation.
- It covers a variety of decision analysis tools.
- DSS is adaptive and flexible, and so users can add, change, delete, or reorganize basic elements.
- DSS should be user friendly and have strong graphical interfaces.
- DSS tries to improve the effectiveness of decision-making (appropriateness and quality) rather than its efficiency (the cost of decision-making).
- DSS attempts to support the decision makers not to replace them. Therefore they will have control over all levels of the process.
- End users should be able to build (and modify) simple systems. Complicated systems can be constructed with assistance from information system (IS) experts.
- A DSS generally employs models for analysing problems since modeling enables experimenting with different strategies under different configurations.
- DSS should be able to supply access to a variety of data sources and formats.
- A DSS can be integrated with other systems and/or applications, and it can be distributed through networking and web technologies.

Figure 3 demonstrates an extension of an ideal set of DSS characteristics; based on the work of Turban and Aronson [2].

Lemass also emphasizes that a DSS should improve both the effectiveness and efficiency of decision-making [1]. Effectiveness is the degree to which identified goals are achieved, whilst efficiency is a measure of the application of resources to attain the goals. The effectiveness and efficiency of a DSS can be measured by its ability to enable decision-makers to:

- define difficult problems earlier;
- rapidly identify viable solutions;
- equitably compare the consequences of each solution;
- stylize an interface for displaying problem-specific (ad hoc) data collection and results presentation (e.g., tables, forms, graphics, etc.); and
- run sensitivity analyses to check model assumptions and hence help to defend proposed solutions more convincingly.

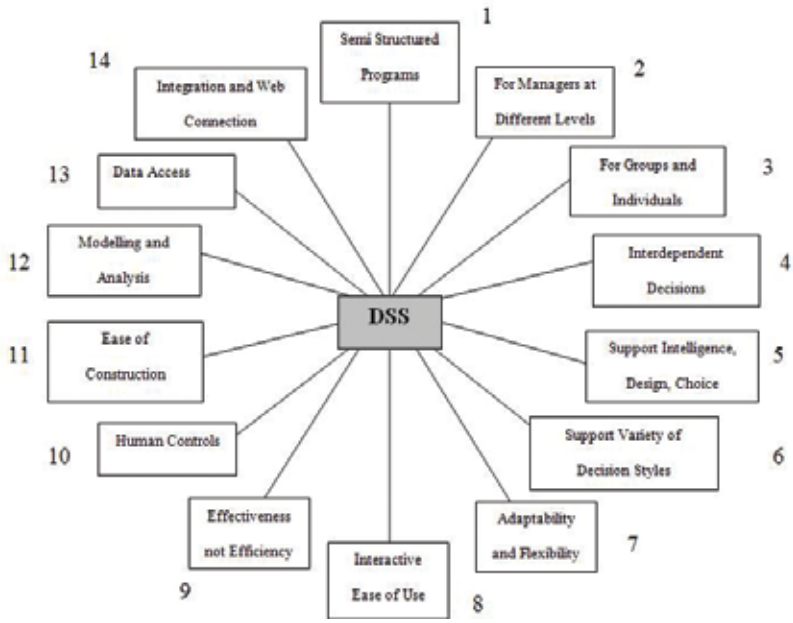

Figure 3. The desirable characteristics and capabilities of DSS.

3. An introduction to decision-making

Traditionally, a decision is defined as being a choice: a choice about a course of action [16], the choice of a strategy for action [17], a choice leading to a certain desired objective [18]. It can be clearly understood that decision-making as a non-random activity concluding in the selection of one course of action among multiple strategies and DSS is a prevailing system that can ease this process [6].

Simon stated that the process of making the decision includes three basic phases: intelligence, design, and choice [19]. Turban described how implementation, is also required over and above a "paper" solution, as the fourth phase, in order to solve the original problem [2].

The intelligence phase, or problem identification, involves gaining awareness that inconsistencies exist between the current state of a situation and the desired circumstances. At this level the decision maker tries to diagnose the problems that need to be addressed and/or opportunities that need to be tracked [20].

In the design phase, a decision maker attempts to generate alternatives, and analyses the options to provide knowledge about their relevant implications. During this phase, the decision maker may find that supplementary knowledge is required. This leads to a return to the intelligence stage to clarify the problems before continuing with the design activity [6].

During the choice phase, the decision maker selects one of the proposed alternatives that have been explored in the design phase. The outcome depends on the nature of the decision context

and the decision maker's own traits and idiosyncrasies. It may be that none of the alternatives are satisfying (return to the design phase), that several competing alternatives gain high scores, or that the state of the context has changed dramatically after analysis of alternatives (return to the intelligence phase). However, one option must be chosen for implementation [21].

The fourth and final step is implementation. This phase includes a set of chosen solutions that need to be approved by stakeholders and put into action over time [20]. This requires cautious planning and sensitivity to those involved in the process and/or those affected by it. The resolution must then be monitored to guarantee that the problem has been corrected. If the problem has been rectified, then the decision-making procedure is finalized [22]. Generally, the outcome of successful implementation is solving the real problem while any failure results in returning to a former phase of the process [2].

3.1. The structure of decisions

There is a variety of decision types which can be classified based on specific factors. An appreciation of decision types can assist decision makers understand what knowledge and knowledge manipulation features would be required in decision support system [6]. The level of "programmability" or structuredness is a helpful aspect for understanding and classifying decisions. Simon argued that decisions could be placed along a spectrum from highly structured to completely unstructured [23]. Decisions may also be further classified as single-stage and multiple-stage, with either risk, certainty or uncertainty of outcome.

Structured decisions are made when well-known procedures can be readily applied to all the phases of decision-making to provide standard solutions for repetitive problems. They are characterized by definite decision criteria, a limited number of precise alternatives whose consequences can be worked out without any complexity [24].

Structured decisions	**Unstructured decisions**
Routine, repetitive	Unexpected, infrequent
Established and stable context	Emergent and turbulent contexts
Alternatives clear	Alternatives unclear
Implications of alternatives straightforward	Implications of alternatives indeterminate
Criteria for choosing well defined	Criteria for choosing ambiguous
Specific knowledge needs known	Specific knowledge needs unknown
Needed knowledge readily available	Needed knowledge unavailable
Result from specialized strategies (i.e., procedures that explicitly pre-specify full set of steps to follow in order to reach decisions)	Result from general strategies (e.g., analogy, lateral thinking, brainstorming, synthesis used in the course of reaching decisions)
Reliance on tradition	Reliance on exploration, creativity, insight, ingenuity

Table 1. Decision structuredness [6].

A semi-structured decision is made when some, but not all, of the phases of decision-making are structured. While some standard solution procedures may be applicable, human judgment is also called upon to develop decisions which tend to be adaptive in nature [1].

When none of the phases of decision-making are structured, the resulting decisions are classified as unstructured. Lack of clear decision criterion and the difficulty in identifying a finite set of alternatives and high levels of uncertainty concerning the consequences of the known alternatives at most of the decision levels, are all symptoms of this unstructuredness [25].

Semi-structured and unstructured decisions are made when problems are ill-defined (ill-structured). Srinivasan et al. notes that most real-world problems fall towards the unstructured end of this spectrum [20]. **Table 1** demonstrates the characteristics of structured and unstructured decisions.

4. Multi attribute decision-making methods

Engineering or management decisions are generally made through available data and information that are mostly vague, imprecise, and uncertain by nature [26]. The decision-making process in bridge remediation is one of these ill-structured occasions, which usually need a rigorous approach which applies explicit subject domain knowledge to ill-structured (adaptive) problems in order to reformulate them as structured problems. Multi-attribute decision-making (MADM) is an efficient tool for dealing with uncertainties.

A standard feature of multi-attribute decision-making methodology is the decision matrix with m criteria and n alternative as illustrated in **Figure 4**. In the matrix C1,...,Cm and A1,.., An indicate the criteria and alternatives respectively: each row belongs to a criterion and each column describes the performance of an alternative. The score aij describes the performance of alternative Aj against criterion Ci. It has been conventionally assumed that a higher score value means a better performance [27].

As shown in **Figure 4**, weights W1,...,Wm are assigned to the criteria. Weight Wi reflects the relative importance of criteria Ci to the decision, and is assumed to be positive. The weights of the criteria are typically defined on subjective basis. The values X1,...,Xn related to the alternatives in the decision matrix are used in the Multi-Attribute Utility Theory (MAUT) methods.

		x_1	·	·	x_n
		$\mathbf{A}_1$	·	·	$\mathbf{A}_n$
w_1	$\mathbf{C}_1$	a_{11}	·	·	a_{m1}
·	·	·	·	·	·
·	·	·	·	·	·
w_m	$\mathbf{C}_m$	a_{m1}	·	·	a_{mn}

Figure 4. The decision matrix.

Generally, higher ranking value represents a higher performance of the alternative, so the item with the highest ranking is the best action item [27].

In addition to some monetary based and elementary methods, the two main families in the multi-attribute decision-making methods are those founded on the MAUT and Outranking Methods.

4.1. Elementary methods of MADM

These elementary approaches are characterized by their simplicity and their independence to computational support. They are suitable for problems with a single decision maker, limited alternatives and criteria which can rarely occur in engineering decision-making [28]. Maximin and Maximax methods, Pros and Cons analysis, Conjunctive and Disjunctive methods and the Lexicographic method are all in this category [29].

4.1.1. Maximin and Maximax methods

The Maximin method's strategy is to avoid the worst possible performance, maximizing the minimal performing criterion. The alternative, for which the score of its weakest criterion is the highest, is preferred. For example, a weight of one is given to the criterion which is least best achieved by that choice and a weight of zero to all other criteria. The strategy with the maximum minimum score will be the optimum choice. In contrast to the Maximin method, The Maximax method selects an alternative by its best attribute rather than its worst. This method is particularly useful when the alternatives can be specialized in use based upon one attribute and decision maker has no prior requirement as to which attribute this is [30].

4.1.2. Pros and cons analysis

Pros and Cons analysis is a qualitative comparison method in which positive and negative aspect of each alternative are assessed and compared. It is easy to implement since no mathematical skill is required [29].

4.1.3. Conjunctive and disjunctive methods

The conjunctive and disjunctive methods are non-compensatory screening methods. They do not need criteria to be estimated in commensurate units. These methods require satisfactory rather than best performance in each attribute, i.e., if an action item passes the screening, it is adequate [31].

In Conjunctive method, an alternative must meet a minimal threshold for all attributes while in disjunctive method; the alternative should exceed the given threshold for at least one attribute. Any option that does not meet the rules is deleted from the further consideration [28].

4.1.4. Decision tree analysis

Decision trees provide a useful schematic representation of decision and outcome events, provided the number of courses of action, ai, and the number of possible outcomes, Oij, not

large. Decision trees are most useful in simple situations where chance events are dependent on the courses of action considered, making the chance events (states of nature) synonymous with outcomes [25].

Square nodes correspond to decision events. Possible courses of action are represented by action lines which link decision events and outcome (chance) events. Circular nodes differentiate the outcome events from the decision events in order to underline that the decision-maker does not have control when chance or Nature determines an outcome [1].

The outcomes for each alternative, originates from the chance nodes and terminate in a partitioned payoff/expected value node. The expected value for each course of action is achieved by summing the expected values of each branch associated with the action [25].

A decision tree representation of a problem is shown below as an example. Three strategies (courses of action) are investigated (See **Figure 5**):

a1: replace the distressed bridge section (it would soon be unsafe)

a2: rehabilitate the bridge (repair costs will not be prohibitive)

a3: do nothing (the symptoms are more superficial than structural)

The estimated costs of replacement and rehabilitation are $6.3 M and $1.1 M respectively. If the road section is replaced, it is assumed that no further capital costs will be incurred. If the road is rehabilitated and repairs are not satisfactory, an additional $6.3 M replacement cost will result. If no action is taken and the road consequently requires major repairs or becomes totally unserviceable, respective costs of $6.3 M and $18 M will apply (Lemass [1]).

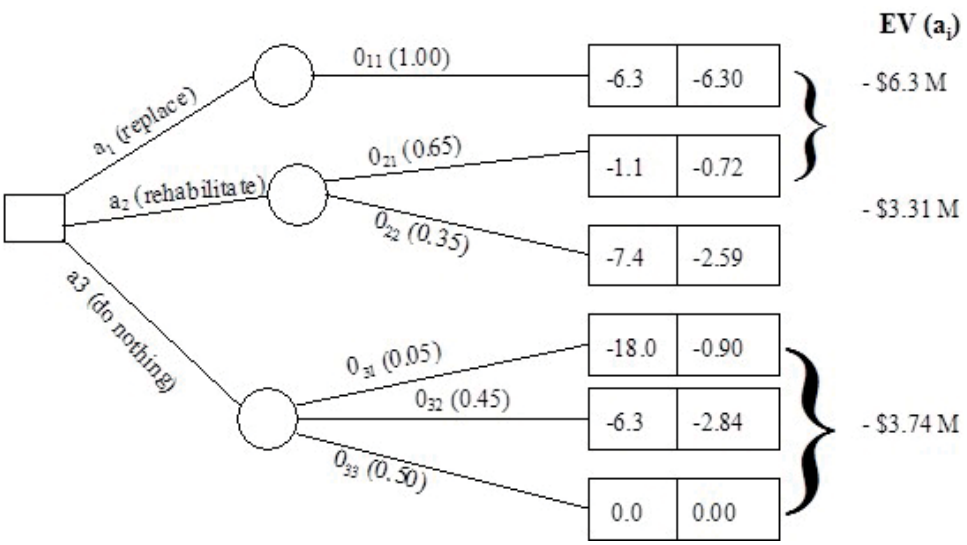

Figure 5. A decision tree for selecting the best remediation strategy of a bridge.

In this example, states of nature are the same as possible outcomes. The outcomes and associated negative payoffs (costs in millions of dollars) can be considered as follows:

Payoff		
S1 = O11:	the bridge section is successfully replaced	u11 = − $ 6.3
S2 = O22:	the repairs are satisfactory	u22 = − $ 1.1
S3 = O23:	the repairs are unsatisfactory	u23 = − $ 7.4
S4 = O34:	the bridge section fails, becoming unserviceable	u34 = − $ 18.0
S5 = O35:	the bridge section requires major repairs	u35 = − $ 6.3
S6 = O36:	the bridge section remains satisfactory	u36 = − $ 0.0

The expected value (cost) of action a2 is the lowest, based on the probability (likelihood of occurrence) assigned for each outcome, pij and this course of action can be followed [9].

4.1.5. Lexicographic method

In lexicographic analysis of problems, a chronological elimination process is continued until either a single solution is found or all the problems are solved. In this method criteria are first rank-ordered in terms of importance. The alternative with the best performance score on the most important criterion is selected. If there are ties related to this attribute, the performance of the joined option on the next most important factor will be compared until the unique alternative is chosen [31].

4.1.6. Cost-benefit analysis (CBA) and cost-effectiveness analysis (CEA)

The concept of cost–benefit analysis (CBA) originated in the United States in the 1930s where it was used to find a solution to problems of water provision. This method is used to estimate all the costs and benefits associated with a particular project which is usually defined in money terms, in order to weigh up whether a project will bring a net benefit to the public and to be able to compare the possible options for limited resources. It is one of the most comprehensive and at the same time the most difficult technique for decision-making [32].

According to Kuik et al. the application of CBA in an integrated assessment causes the following concerns [33]:

- First, CBA measures costs and benefits on the basis of subjective preferences given objective resource constraints and technological possibilities and should probably be evaluated on a case−by−case basis as an open question.
- Second, certain costs and benefits which are in the social and environmental domains might be difficult to quantify in monetary terms.

4.2. Multi attribute utility theory (MAUT)

MAUT is based upon the use of utility functions. Utility functions are employed to quantify the preference of the decision-maker by allocating a numerical index to different degrees of

satisfaction as the attribute under consideration takes values between the most and least defined limits [34]. They are considered a compliant tool of representing how much an attribute (or a measure) satisfies the decision-maker objectives to transform the raw performance values of the alternatives against diverse criteria, both factual (quantitative) and judgmental (qualitative), to a general dimensionless scale [35]. They represent a means to translate attributes units into utility units. Utility functions can be specified in terms of a graph, table or mathematical expression. Mathematical expressions of utility functions include: straight-line, logarithmic, or exponential functions [34].

The utility values are estimated by normalizing the output of the simulation tests. Normalization of performance measures is conducted utilizing the minimum and maximum limits that are obtained from the simulation. Moreover, they are commonly checked against the outputs and replaced if there are values beyond the limits. The utility functions can be monotonic in a way that the least desirable scenario corresponds to the lowest utility [U(xi) =0] while the most desirable scenario matches with the highest utility [U(xi) =1.0], the interval [0,100] can also be used for this purpose [34].

4.2.1. Simple multi-attribute rating technique (SMART)

Simple Multi Attribute Rating Technique (SMART) is a method that used to determine the weights of the attributes. This method was initially developed by Edwards [50] and is based on direct numerical ratings that are aggregated additively. There are many derivates of SMART, also including non-additive methods. In a basic format of SMART, there is a rank-ordering of action items for each criterion setting the worst to zero and the best to 100 and interpolating between [27]. By filtering the performance values with associated weights for all criteria a utility value for each option is estimated [36].

SMART is independent of the action items/alternatives. The advantage of this approach is that the assessments are not relative; hence shifting the number of options will not change the final outcomes. If new alternatives are likely to be added, and the action items are compliant to a rating model, then SMART can be a better option [37].

One of the limitations of this technique is that it disregards the interrelationships between parameters. However, SMART is a valuable technique since it is uncomplicated, easy and quick which is quite important for decision makers. In SMART, changing the number of alternatives will not change the decision scores of the original alternatives and this is useful when new alternatives are added [37]. He also argued that using SMART in performance measures can be a better alternative than other methods.

4.2.2. Analytical hierarchy process (AHP)

AHP is a multi-attribute decision-making technique which belongs to the class of methods known as “additive weighting methods” [28]. The AHP was suggested by Saaty and uses an objective function to aggregate various features of a decision where the main goal is to select the decision alternative that has the maximum value of the objective function [38]. The AHP is based on four clearly defined axioms (Saaty [39]). Similar to MAU/VT and SMART, the AHP is

classified as a compensatory technique, where attributes/criteria with low scores are compensated by higher scores on other attributes/criteria, but contrasting the utilitarian models, the AHP employs pair wise comparisons of criteria rather than value functions or utility where all criteria are compared and the end results accumulated into a decision-making matrix [40].

The process of AHP includes three phases: decomposition, comparative judgments, and synthesis of priority. Through the AHP process, problems are decomposed into a hierarchical structure, and both quantitative and qualitative information can be used to develop ratio scales between the decision elements at each level using pair wise comparisons. The top level of hierarchy corresponds to overall objectives and the lower levels criteria, sub-criteria, and alternatives. Users are asked to set up a comparison matrix (with comparative judgments) by comparing pairs of criteria or sub-criteria. A scale of quantities -ranging from 1 (indifference) to 9 (extreme preference) is used to identify the users priorities. Eventually, each matrix is then solved by an eigenvector technique for measuring the performance [41].

The comparisons are normally shown in a comparative matrix A, which must be transitive such that if, i > j and j > k then i > k where i, j, and k are action items; for all j > k > i and reciprocal, $a_{ij} = 1/a_{ji}$. Preferences are then calculated from the comparison matrix by normalising the matrix, to develop the priority vector, by A.W = λmax.W; where A is the comparison matrix; W is the Eigen vector and λmax is the maximal Eigen value of matrix A [42].

Through the AHP process, decision-makers' inconsistency can be calculated via consistency index (CI) to find out whether decisions break the transitivity, and to what extent. A threshold value of 0.10 is acceptable, but if it exceeds then the CI is calculated by using the consistency ratio CR = CI/RI where RI is the ratio index. CI is defined as $CI = (\lambda_{max} - n)/(n - 1)$; where λmax as above; n is the dimension [43]. **Table 2** shows the average consistencies of RI.

The advantages of the AHP method are that it demonstrates a systematic approach (through a hierarchy) and it has an objectivity and reliability for estimating weighting factors for criteria [45]. It can also provide a well-tested method which allows analysts to embrace multiple, conflicting, non-monetary attributes into their decision-making.

On the other hand, the disadvantages are that the calculation of a pair-wise comparison matrix for each attribute is quite complicated and as the number of criteria and/or alternatives increases, the complexity of the calculations increases considerably. Moreover if a new alternative is added after finishing an evaluation calculation, it is very troublesome because all the calculation processes have to be restarted again [46].

The limitations of AHP are of a more theoretical nature, and have been the subject of some debate in the technical literature. Many analysts have pointed out that, the attribute weighting questions must be answered with respect to the average performance levels of the alternatives. Others have noted the possibility for ranking reversal among remaining alternatives after one

N	1	2	3	4	5	6	7	8	9	10
R1	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

Table 2. Random inconsistency index, adapted from Ishizaka [44].

is deleted from consideration. Finally, some theorists go so far as to state that as currently practiced, "the rankings of (AHP) are arbitrary." Defenders of AHP, such as Saaty himself, answered that rank reversal is not a fault because real-world decision-making shows this characteristic as well [47].

4.3. Outranking methods

The most important outranking methods assume data availability roughly similar to what required for the MAUT methods. Fundamental problems with most MAUT and MAUT-related methods are handling uncertain or fuzzy information and dealing with information stated in other than ratio or interval scale. In some conditions, instead of quantitative measures descriptive expressions are frequently faced [48]. The outranking method acts as one alternative for approaching complex choice problems with multiple criteria and multiple participants. Outranking shows the degree of domination of one alternative over another and facilitates the employment of incomplete value information and, for example, judgments on ordinal measurement scale. They provide the (partial) preference ranking of the alternatives, not a principal measure of the preference relation [48]. Here the two most famous categories of the outranking methods, the ELECTRE and the PROMETHEE methods are briefly explained.

4.3.1. The ELECTRE methods

The ELECTRE method is a part of MCDA (multi criteria decision-aid). The main aim of the ELECTRE method is to choose alternative that unites two conditions from the preference concordance on many evaluations with the competitor and preference discordance was supervised by many options of the comparison. The starting point is the data of the decision matrix assuming the sum of the weights equals to 1 [49]. As shown in Eq. (1), for an ordered pair of alternatives (Aj, Ak), the concordance index Cjk is the sum of all the weights for those attributes where the overall performance of Aj is least as high as A_k.

$$C_{jk} = \sum_{a_{ij} \geq a_{ik}} w_i \qquad j, k = 1, \ldots, n, \qquad j \neq k \tag{1}$$

The concordance index must lies between 0 and 1.

The calculation of the discordance index djk is more complex. If Aj performs better than Ak on all criteria, the discordance index will be zero. Otherwise, as per Eq. (2):

$$d_{jk} = \max \frac{a_{ik} - a_{ij}}{\max a_{ij} - \min a_{ij}} \qquad j, k = 1, \ldots, n, \qquad j \neq k \tag{2}$$

Therefore for each attribute where Ak outperforms Aj, the ratio is computed between the variance in performance between Ak and Aj and the maximum difference in score on the attribute/criterion concerned between the alternatives. The maximum of these ratios (must be between 0 and 1) is the discordance index [27].

This method determines a partial raking on the alternatives. The set of all options that outrank at least one other alternative and are themselves not outranked.

4.3.2. The PROMETHEE methods

This method was introduced by Brans and Vincke [47], Brans et al. [17], and Edwards [50]. The scores of the decision table need not necessarily be normalized or transformed into a dimensionless scale. Higher score value indicates a better performance. It is also assumed that a preference function is associated to each attribute. For this aim, a preference function PFi(Aj, Ak) is defined showing the degree of the preference of option A_j over A_k for criterion C_i:

$0 \leq PFi(Aj, Ak) \leq 1$ and

PFi(Aj, Ak) = 0 no indifference pr preference,

PFi(Aj, Ak) ≈ 0 weak preference,

PFi(Aj, Ak) ≈ 1 strong preference, and

PFi(Aj, Ak) = 1 strict preference.

In most realistic cases, Pi is a function of the deviation d = aij-aik, i.e., PFi(Aj, Ak) = PFi(aij-aik), where PFi is a non-decreasing function, PFi(d) = 0 for $d \leq 0$ and $0 \leq PFi(d) < 1$ for $d > 0$. The main benefit of these preferences functions is the simplicity since there are no more than two parameters in each case.

As shown in Eq. (3), multi criteria preference index π (Aj, Ak) of Aj over Ak can then be calculated considering all the attributes:

$$\pi(A_j, A_k) = \sum_{i=1}^{m} w_i \, P_i \, (A_j, A_k) \tag{3}$$

The value of this index is between 0 and 1, and characterises the global intensity of preference between the couples of choices [27].

For ranking the alternatives, the following outranking flows (Eq. (4) and Eq. (5)) are classified:

Positive outranking flow:

$$\varphi^{+}(A_j) = \frac{1}{n-1} \sum_{k=1}^{n} \pi \, (A_j, A_k) \tag{4}$$

Negative outranking flow:

$$\varphi^{-}(A_j) = \frac{1}{n-1} \sum_{k=1}^{n} \pi \, (A_k, A_j) \tag{5}$$

The positive outranking describes how much each option is outranking the other items. The higher $\varphi^{+}(A_j)$, the better the alternative. The negative outranking flow shows the power of A_j its outranking character.

The negative outranking flow shows how much each alternative is outranked by the others. The smaller $\varphi^{-}(A_j)$, the better the alternative. $\varphi^{-}(A_j)$ depicts the weakness of A_j its outranked character (ibid).

4.3.3. TOPSIS methods

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) which was firstly proposed by Hwang and Yoon (1981) is one of the mostly used multi-criteria decision-making techniques [45]. The basic concept of TOPSIS is that the selected option should have the shortest distance from the positive ideal solution and the farthest distance from the negative-ideal solution in a geometrical sense. Within the process an index called "similarity index" is defined to the positive-ideal option by combining the proximity to the positive-ideal and the remoteness from the negative solution- ideal option. Then the method selects a solution with the maximum similarity to the positive-ideal solution. The default assumption is that the larger the outcome, the greater the preference for benefit attributes and the less the preference for cost attributes [51]. The idea of TOPSIS can be expressed in a series of steps:

Step 1: Identify performance data for n alternatives over m attributes. Raw measurements are normalized by converting raw measures xij into normalized measures rij as follows (please see Eq. (6)):

$$r_{ij} = \frac{x_{ij}}{\sqrt{x_{ij}^2}} \qquad i = 1, \ldots, m, \;\; j = 1, \ldots, n \tag{6}$$

Step 2: Estimate weighted normalized ratings as per Eq. (7):

$$\text{Weighted} \;\; r_{ij} = w_j r_{ij} \tag{7}$$

w_j is the weight of the jth attribute. The basis for the weights is usually an ad hoc reflective of relative importance. If normalizing was accomplished in Step 1, scale is not an issue.

Step 3: Obtain the positive-ideal alternative (extreme performance on each criterion) A+.

Step 4: Find the negative-ideal alternative (reverse extreme performance on each criterion) A−.

Step 5: Create a distance measure for each decisive factor to both positive-ideal (Si+) and negative-ideal (Si−).

Step 6: For each option/alternative, find out a ratio Ci + equal to the distance to the negative-ideal divided by the summation of the distance to the positive-ideal and the distance to the negative-ideal (as shown in Eq. (8)):

$$C_{i^+} = \frac{S_{i^-}}{\left(S^{i^-} + S^{i^+}\right)} \tag{8}$$

Step 7: Rank order all the options by maximizing the ratio (specified) in Step 6.

4.4. Sensitivity analysis

Sensitivity analysis is the method used to find whether a particular utility or probability is essential in determining the preferred alternative. There are always some uncertainties for the

weights of the criteria and the scores of the alternatives against the subjective (judgmental) criteria [52]. As a result an important question is how the final ranking or the ranking values of the alternatives is sensitive to the changes of some input parameters of the decision model [27].

4.5. Summary

This chapter covers the definition of decision support system, its ideal characteristics and its background history. Different decision analysis methods including elementary methods, multi attribute utility theory and outranking methods have also been introduced and compared.

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Chapter 3

Developing the EBS Management Model to Assist SMEs to Evaluate E-Commerce Success

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Abstract

In the literature, a lack of strong consensus or well-known theoretical research framework exists to defining and evaluating e-commerce success among small to medium enterprises (SMEs). Exploring more effective methods to describe and evaluate e-commerce success becomes a challenging task. This research seeks to help fill the gap by proposing a new model to evaluate e-commerce success from a business perspective. This measure has been termed e-commerce business satisfaction (EBS). A total of 2401 surveys were successfully sent to SMEs. The usable response rate for the surveys was 7.54%. Principal component analysis with varimax rotation method was then adopted within the factor analysis. Using the 15 critical success factors (CSFs) obtained from previous research as a foundation, an EBS management model was finally simply developed to assist SMEs business managers in effectively adopting e-commerce systems or evaluating e-commerce success, which was categorised into five components including *Marketing, Management Support and Customer Acceptance, Website Effectiveness and Cost, Managing Change* and *Knowledge and Skills*. Further research is needed to determine the weighting of each CSF so that a yardstick measurement method might be further developed to assist SMEs in adopting e-commerce successfully.

Keywords: E-commerce satisfaction, E-commerce success, evaluation, management model, SMEs

1. Introduction

Electronic commerce (e-commerce) is not a new concept, but it has had increasing and unpredictable developments [1]. The fact is that the number of small to medium enterprises (SMEs) adopting e-commerce has increased significantly in recent years. It has been proved that

successful e-commerce/IS use can create net benefits concerning financial and operational performance for SMEs, even in developing countries [2]. A significant number of SMEs have, however, failed in adopting e-commerce while many businesses are not satisfied with their e-commerce systems. The research stated, therefore, that quantifying the value contribution of e-commerce has become an issue for managers seeking to justify the enormous expenditures involved in new IT investment [3].

Among the research methods, the evaluation has been one of the five top research areas on the adoption of e-commerce along with trust, technology acceptance and technology application, e-commerce task-related application, and e-markets, which resulted from the analysis of a total of 1064 e-commerce-related articles and 33,173 references published in leading e-commerce journals between 2006 and 2010 [4]. Researchers have also enunciated the need for evaluating e-commerce success as avoiding failure again, learning from experience, indicating actual business benefits, the requirement for adoption guidelines, and for further improvement and development [5].

Investigation to date does not clearly show how to evaluate the success of e-commerce systems [6]. In the investigation of e-commerce, many research studies use the IS success model to evaluate e-commerce systems [7]. For example, the original or updated DeLone and McLean model have been widely used for evaluating the degree of IS/e-commerce success [8]. The Technology Acceptance Model (TAM) and its extensions have also been used as reliable and robust models for predicting the user acceptance of e-commerce [9].

IS success approach may not, however, be methodologically and theoretically feasible in e-commerce among SMEs [10]. The literature has noted that the difficulties existed in using such IS models and its extensions [5]. The main difficulty has been highlighted that the determinants of e-commerce might be dissimilar to the concepts in IS success studies [5, 10]. Other difficulties could be focused on the involvement of top management, beyond Internet technology and lack of experiences [5].

In the literature, no strong consensus or well-known comprehensive and integrated theoretical framework currently exists [10–12]. Research frameworks also lack a theoretical approach to defining and evaluating e-commerce success among SMEs [10–12]. Exploring more effective methods to describe and evaluate e-commerce success, thereby, becomes a challenging task [13, 14]. This research seeks to help fill the gap by proposing a new model to evaluate e-commerce success from a business perspective.

2. CSFs and E-commerce success

2.1. Using business satisfaction for evaluating e-commerce success

In the literature, satisfaction is a very important element for a successful long-term relationship with e-commerce adoption/success [9]. Research highlighted that satisfaction rather than system use was adopted as an appropriate measure of e-commerce success [15]. Any

unsatisfactory performance regarding this criterion could not be compensated for by better performance concerning one or more other criteria [16]. Satisfaction study is, therefore, being used widely for a better understanding of e-commerce success.

This research proposed that the term e-commerce business satisfaction (EBS) would be a better measure of e-commerce success where e-commerce satisfaction was discussed from a business perspective, which has been previously defined as 'the overall satisfaction that a business has with an e-commerce system meeting its requirements and expectations' [17].

2.2. Using CSFs for understanding EBS to evaluate e-commerce success

The concept and approach of CSFs have been studied and applied successfully in a broad range of contexts in many areas of IS/IT research including identifying system needs [11, 18]. Research states that satisfaction with e-commerce is significantly affected by organisational determinant critical success factors (CSFs) [10].

Using a set of CSFs identified as one of the key implementation strategies employed in the context of performance analysis and strategic management, SMEs may focus on and manage the few key areas in the implementation process to measure their e-commerce systems, judge the efficacy of e-commerce systems, improve their e-commerce systems, and predict e-commerce usage, which could contribute to the success of these experiential-driven initiatives and help achieve a successful implementation outcome of e-commerce [14, 18–22]. Identifying CSFs that impact the adoption of e-commerce will also make it possible to assess its future growth [21].

Over the past decade, therefore, a large number of investigations have focused on determining what CSFs affected the adoption of e-commerce successfully [23, 24]. Despite the increasing work on e-commerce, however, the investigation indicated that there were still very few studies that attempted to investigate the effect of proposed CSFs on the implementation of e-commerce [18] and also lack of an integrated approach for the development of a well-established e-commerce CSFs model [25]. This research adopted the CSFs identified in previous work for understanding business satisfaction associated with e-commerce success.

3. Research methodology and the survey results

A blend of research methods consisting of focus group studies, pilot tests, and surveys have been used and discussed.

3.1. Focus group studies

A focus group study involves a formalised process of bringing a small group of people together for an interactive and spontaneous discussion or interview of one particular topic or concept [26]. With origins in sociology, focus group study became widely used in market

research during the 1980s and was used for more diverse research applications in the 1990s [27]. Focus group studies might help prepare for a survey by providing sufficient information about the survey objective, by defining and improving indicators and about preventing possible errors [28].

Most experts agree that the optimal number of participants in any type of focus group interview is from six to 12 members in nondirective interactive communications facilitated by a moderator who prepares and uses a loosely constructed set of relevant questions [27–29]. In this research, a target of 18 SMEs business managers (nine for each in Australia and China) were formed to define and improve indicators preventing possible errors.

3.2. Pilot tests

A pilot test is an important and essential step in checking the rigour of the survey instrument and the need for any final modification before conducting the survey proper [28, 30–32]. The objectives of this step were to examine the validity of each item in the survey and to avoid any misleading cultural differences due to inaccurate translation [33], as it is extremely difficult even for experienced social scientists to write a questionnaire [30].

Research advises that a pilot test of 20–50 cases is usually sufficient to discover the major flaws in a questionnaire before they damage the main study [30]. Research further suggested that researchers use open questions in pilot tests and then develop closed-question responses from the answers given to the open questions for large-scale surveys [26].

Twenty businesses were involved in pilot tests (10 for each in Australia and China) in this research, which were carried out with open questions to modify the proposed questionnaires and any errors.

3.3. Surveys and survey results

The survey samples were selected first. Since most computer programs use standard error algorithms based on the assumption of simple random samples, the standard errors reported in the literature often underestimate sampling error [34]. The goal of the sampling is to collect data representative of a population within the limits of random error, which the researcher then uses to generalise findings from a drawn sample back to a population [35]. It is critical that the chosen respondents are representative of the study population [31]. The random sampling method was chosen in this research to select samples [26] as follows:

- Stage 1: random sampling of big clusters.
- Stage 2: random sampling of small clusters within each selected big clusters.
- Stage 3: the sampling of elements from within the sampled small clusters.

Research recommends a mailing sequence for sending the survey questionnaire followed by a reminder sent about 1 week later [36]. Two follow-up reminder letters should then be sent

to those not responding while the first should arrive about 1 week after sending the questionnaire and the second a week later [26]. If the higher response rate is necessary, phone calls can be made to the non-respondents about 2 weeks after two reminders [36]. Follow-up notices with personally requesting non-responders' participation may increase response rates to some extent [36, 37]. This research adopted the following data collection sequence represented based on research advice [32, 36–38]:

- Step 1: sending survey forms with an invitation letter.
- Step 2: 2 weeks later, sending the first e-mail reminder to non-respondents.
- Step 3: another 2 weeks later, sending a second e-mail reminder to non-respondents.
- Step 4: followed 2 weeks later, making phone calls to remaining non-respondents.

In this research, a total of 2401 surveys were successfully sent to SMEs in Australia and China including Australian SMEs (1528) and Chinese SMEs (873). The usable response rate for the surveys was 7.54% (181 out of 2401) including Australian SMEs (69) and Chinese SMEs (112) [39]. Consequently, a total of 15 items from item 1 to item 15 were finally identified (**Table 1**).

Items	Description
Item 1	CEO IT/e-commerce/e-commerce marketing knowledge
Item 2	Senior staff IT/e-commerce knowledge
Item 3	Regular staff training in the appropriate or relevant IT skills
Item 4	Flexibility of e-commerce systems to change depending on the business process
Item 5	Ability to keep up with the rate of technology change (externally)
Item 6	The response time effectiveness/performance of an e-commerce website
Item 7	Trust in the interface design and information displayed on a website
Item 8	Support from top management/decision-maker
Item 9	Support from senior management
Item 10	Customer pressure/acceptance/ interest
Item 11	Cost associated with keeping up to date or upgrade of e-commerce system
Item 12	Decision-maker's effective e-commerce marketing plan
Item 13	Effective e-commerce marketing strategy
Item 14	Adoption of different e-commerce marketing strategies based on different business requirements/ needs
Item 15	The consistency of graphics and backgrounds with business culture used on a website

Source from [39].

Table 1. The 15 items identified.

4. Data analysis

During the data analysis procedures, this research conducted an initial reliability analysis and validity analysis first. Principal component analysis with varimax rotation method was then adopted within the factor analysis.

4.1. Reliability analysis

Reliability is the extent to which a question yields the same responses over time, or a scale produces consistent results when repeated measurements are made [36, 40]. Any summated scale should be first analysed for reliability to ensure its appropriateness before proceeding to an assessment of its validity [41]. In this research, reliability was assessed using internal consistency analysis [36]. The earliest and simplest measure of the internal consistency of a set of data items is the split-half reliability of the scale [40, 41]. On assessing split-half reliability, the total set of items is divided into two equivalent halves—if the two scales correlate highly, they should produce similar scores [42, 43]. The total scores for the two halves are then correlated, and this is taken as the measure of the reliability of the survey [42, 43].

In practice, the approach for assessing internal consistency is the coefficient alpha (a.k.a., 'the reliability coefficient') or Cronbach's alpha popularised in a 1951 article by Cronbach based on the work in the 1940s by Guttman and others and is the most common measure of internal consistency of items in a scale [32, 36, 42, 44, 45], which is the most commonly applied estimate of a survey's reliability [40, 43]. It provides a summary measure of the inter-correlations that exist among a set of items [40, 42, 45, 46].

At the initial reliability analysis stage, Cronbach's alpha should be considered as the critical characteristic. Cronbach's alpha varies from 0 to 1 [40, 46]. The higher the correlations among the items is the greater the Cronbach's alpha values which imply that high scores on one question are associated with high scores on other questions [36]. If the value of Cronbach's alpha is low and if the item pool is sufficiently large, this suggests that some items do not equally share in the common core and should be eliminated [42]. Research also indicates that a value is considered to have very good reliability between 0.80 and 0.95, good reliability between 0.70 and 0.80, fair reliability between 0.60 and 0.70 and poor reliability below 0.60 [43].

In the test of reliability in this research, Cronbach's alpha is 0.837. The results showed strong evidence of meeting the reliability standards of exploratory research and are considered to have very good reliability.

4.2. Validity analysis

The validity of a survey instrument may be defined as the extent to which it accurately measures what it is supposed to measure [36, 40]. There are three basic approaches to establishing validity namely content validity, criterion validity, and construct validity [36, 40, 43].

4.2.1. Content validity

Content validity, sometimes called face validity, measures the extent to which a survey's content logically appears to reflect what was intended to be measured [43]. It typically involves a

systematic review of the survey's contents to ensure that it includes everything it should and nothing that it should not [46]. Although there does not yet exist a scientific measure of the content validity for a survey instrument [46], content validity is often assessed practically by approaches such as focus groups, and/or pilot test studies [41, 46, 47].

In this research, content validity was assessed subjectively but systematically to establish the appropriateness of the variables used—items not considered appropriate were rejected by two focus group studies (one for each in Australia and China) and 20 pilot tests (10 for each in Australia and China).

4.2.2. Criterion validity

Criterion validity addresses the ability of a measure to correlate with other standard measures of similar established criteria [43]. Criterion validity may be classified as either concurrent or predictive depending on the time sequence in which the new measurement scale and the criterion measure are correlated [40, 43] as follows:

- Concurrent criterion validity—if there is an existing instrument that one can compare with a newly devised questionnaire [40, 46], or if the new measure is taken at the same time as the criterion measure and is shown to be valid, then it has concurrent validity [43].
- Predictive criterion validity is established when a new measure predicts a future event [36, 43].

However, no method for assessing criterion validity is foolproof while none can conclusively show if a concept is truly measuring what it should [36]. As the concern is more about the validity of the use of the survey instrument than its own inherent validity [36], most researchers appear to more commonly use construct validity as discussed below. In this research, criterion validity analysis was not conducted, as no similar established surveys were available with which to compare it, and the measure is not being used to predict a future event.

4.2.3. Construct validity

Construct validity addresses the question of what constructor characteristic the survey is measuring and how an instrument 'behaves' when it is used [40, 46] as follows:

- Convergent validity is the extent to which the survey correlates positively with other measures of the same construct [40]. It assesses the extent to which different data collection methods produce similar results [46]. Convergent validity is also another way of expressing internal consistency as highly reliable scales contain convergent validity [43].
- Discriminant validity is the extent to which a survey result does not correlate with other constructs from which it is supposed to differ and represents a measure of its distinctiveness [40, 43]. When two item values are correlated above 0.75, discriminant validity between items may be questioned and the items rejected [43].
- Nomological validity is the extent to which the summated scale makes accurate predictions of other concepts in a theoretically based model [40, 41].

In this research, convergent validity was being assessed actually through reliability analysis. Technically, discriminant validity was being indirectly established through the following factor analysis. Nomological validity was not analysed as no similar established relationships appeared to exist in the literature.

4.3. Factor analysis

The basic rationale of factor analysis is that the variables are correlated because they share one or more common components, and if they did not correlate, there would be no need to perform factor analysis, which operates on the correlation matrix of the variables to be factored [36]. For the ease of interpretation, principal component analysis with varimax rotation method was conducted within the factor analysis. In practice, principal component analysis can be conducted using SPSS software through factor analysis.

Table 2 shows that the criteria for evaluating a matrix of the factor loading for each variable onto each component are quite good that the 15 items are grouped into five components with the suppression of loadings not less than 0.4. Items with factor loadings less than 0.4 have not been displayed for clarity [48].

Factors	Components					Cronbach's Alpha	Items
	1	2	3	4	5		
F15	0.792					0.743	Item 13
F14	0.788						Item 14
F13	0.67	0.492					Item 12
F12		0.818				0.661	Item 9
F11		0.705					Item 8
F10		0.461					Item 10
F9			0.771			0.696	Item 15
F8			0.738				Item 11
F7			0.522	0.43			Item 6
F6			0.439				Item 7
F5				0.805		0.578	Item 5
F4				0.753			Item 4
F3					0.785	0.662	Item 1
F2					0.782		Item 2
F1					0.606		Item 3

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 7 iterations.

Table 2. Rotated component matrix.

Component	Initial eigenvalues			Extraction sums of squared loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.759	31.730	31.730	4.759	31.730	31.730	2.031	13.537	13.537
2	1.505	10.036	41.766	1.505	10.036	41.766	2.008	13.388	26.925
3	1.256	8.371	50.137	1.256	8.371	50.137	1.943	12.954	39.879
4	1.185	7.899	58.036	1.185	7.899	58.036	1.907	12.712	52.591
5	1.021	6.807	64.843	1.021	6.807	64.843	1.838	12.252	64.843
6	0.851	5.676	70.519						
7	0.751	5.004	75.523						
8	0.635	4.232	79.755						
9	0.603	4.019	83.774						
10	0.523	3.485	87.260						
11	0.471	3.143	90.402						
12	0.465	3.097	93.499						
13	0.404	2.693	96.192						
14	0.319	2.124	98.317						
15	0.253	1.683	100.000						

Extraction method: Principal component analysis.

Table 3. Total variance explained.

Any components with a variance (represented by the eigenvalue) less than 1.0 were rejected as they contribute less than other factors to the model [36]. **Table 3** shows that all eigenvalues are over 1.0 of component 1, component 2, component 3, component 4, and component 5. According to research, the components accepted should account for at least 60% of the cumulative variance [36, 40]. In this research, cumulative percentage of the variance for the four components accounts for 64.843% which satisfies the normally accepted measure (see **Table 3**).

5. Results and discussion

Based on the above analysis, the 15 CSFs were categorised into five components by the strength of relationship:

- Component 1: for the three items grouped including F15, F14 and F13, there is a single focus on *Marketing*.

Figure 1. The EBS management model.

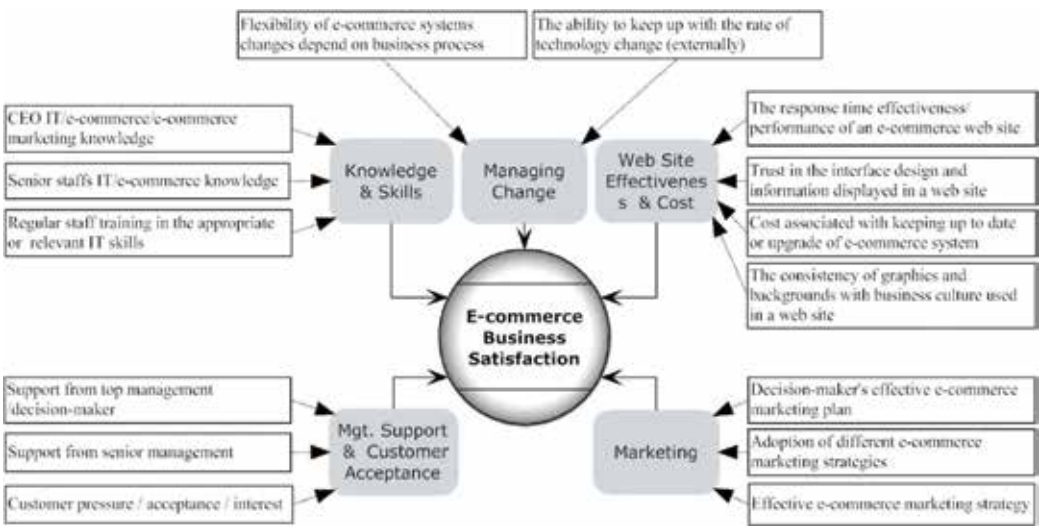

Figure 2. Fifteen CSFs categorised into the EBS management model.

- Component 2: for the three items grouped including F12, F11 and F10, the centre points are *Management Support and Customer Acceptance*.
- Component 3: for the four items grouped including F9, F8, F7 and F6, the focuses are *Website Effectiveness and Cost*.

- Component 4: for the two items grouped including F5 and F4, the common factor is *Managing Change*.
- Component 5: for the three items grouped including F3, F2 and F1, the common focus is on *Knowledge and Skills*.

Thus, an EBS model for business managers—EBS management model—can be simply developed encompassing the above five components (see **Figure 1**) [13].

By superimposing the 15 CSFs onto the above EBS management model, SMEs Business Managers might effectively adopt or evaluate e-commerce satisfaction and success from a business perspective (see **Figure 2**).

6. Conclusions, limitation and further research

This research seeks to explore a new method to describe and evaluate e-commerce success from a business perspective. An EBS management model with 15 CSFs as a foundation was finally simply developed to assist SMEs business managers in effectively adopting e-commerce systems or evaluating e-commerce success, which was categorised into five components including *Marketing, Management Support and Customer Acceptance, Website Effectiveness and Cost, Managing Change* and *Knowledge and Skills*.

The major limitation is that the investigation just focuses on SMEs in Australia and China. This implies to conduct further research in other counties. Further research is also needed to determine the weighting of each CSF so that this EBS management model might be further updated and extended as a yardstick measurement method to assist SMEs in adopting e-commerce successfully.

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Chapter 4

Some Methods for Evaluating Performance of Management Information System

Khu Phi Nguyen and Hong Tuyet Tu

Additional information is available at the end of the chapter

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Abstract

Recently, several kinds of information systems are developed for purposes and needs of business and play an important role in business organizations and management operations. Management information system, or MIS for short, is a kind of information system. It is a key factor to facilitate and attain efficient decision-making in an organization. Its performance relates to many other information systems, for instance, DSS or decision support system, SIS or strategic information system, etc. Methods of testing statistical hypotheses concerning the performance of MIS are absolutely essential to support management activities and decision-making.

Keywords: management information systems, information theory, rough set theory, decision-making process, ANOVA

1. Introduction

A *system* is a set of interrelated components assembled to accomplish certain objectives or goal. Basic characteristics of a system are highlighted as boundaries, interfaces, input-outputs, and methods of making outputs from inputs. The environment of a system includes people, organizations, and other systems that supply data to or receive data from the system.

Solving problems comes from a system that usually uses the method of *systems approach* taking into account the goals, environment, and internal workings of the system. This method involves the following steps:

i. Define the problem and collect data for the problem.

ii. Identify and evaluate feasible solutions.

iii. Select the best solution and determine whether the solution is working.

An *information system* (IS) consists of components such as hardware, software, databases, personnel, and procedures that managers can use to make better decisions in control business operations. ISs are also used to document and monitor the operations of some other systems, called target systems that are prerequisite for the existence of ISs. On side of infrastructure, information system is an integration of diverse computers, displays and visualizations, database, storage systems, instruments, sensors, etc. via software and networks to share data and to provide aggregate capabilities.

In business operation, the activities of an organization equipped with IS are usually of three kinds: operational, tactical, and strategic planning. In this context, a *strategy* is meant as determination of the basic long-term goals and objectives of an enterprise and the adoption of courses of action and the allocation of resources necessary for achieving these goals. *Operational tasks* are the daily activities of the firm in consuming and acquiring resources. These daily transactions produce basis data for the operational systems.

ISs that provide information for allocation of efficient resources to achieve business objectives are known as *tactical systems*. Tactical systems provide middle-level managers with the information they need to monitor and control operational tasks and to allocate their resources effectively. The time frame for tactical activities may be monthly, quarterly, or yearly. Alternatively, ISs that support the strategic plans of the business are known as *strategic planning systems*. These systems are designed to provide top managers with information that assists them in making long-term planning decisions.

Both of the strategic planning information systems and tactical information systems may use the same data source, so the distinction between them is not always clear. For example, middle-level and top managers use budgeting information to allocate reasonable resources or to plan the long-term or short-term activities, budgeting becomes a tactical decision activity or a strategic planning activity, respectively. Hence, the differences between systems are attributed to whom and what the budgeting data are used.

The top management of the organization carries out strategic planning based on results of operational tasks, tactical systems, and related external information to decide whether to build new plants, new products, facilities, or invest in technology. For making these decisions, strategic planners have to address problems that involve long-range analysis and prediction. The time frame for strategic activities may be months or years.

Some basic business systems that serve the operational level of the organization are called *transaction processing systems* or TPS for short. A TPS that records the daily routine transactions necessary to the conduct of the business monitor and control system physical processes is called *process control system* or PCS. For example, a wastewater treatment plan uses electronic sensors linked to computers to monitor wastewater processes continually and control the water quality process [1]. Similarly, a petroleum refinery uses sensors and computers to monitor chemical processes and make real-time controls to the refinery process. A process control system comprises the whole range of equipment, computer programs, and operating procedures [2].

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Knowledge-based IS that supports the creation, organization, and dissemination of business knowledge to employees and managers throughout a company is named as *knowledge management system*. In such a case, knowledge management is the deployment of a comprehensive system that enhances the growth of knowledge. Expert systems are the category of artificial intelligence which has been used most successfully in building commercial applications. An expert system is also considered as a knowledge-based system that provides expert advice and act as expert consultants to users.

A decision support system (DSS) is a computer-based system intended for use by a particular manager or a team of managers at any organizational level in making a decision in the process of solving a semi-structured decision. Database-based management system and a user interface are major components of a DSS. The database consists of information related to production information, market and marketing information, research data, financial transactions, and so forth.

The decision-maker must have suitable knowledge and skills on mining these systems of DSS to address the problem arising and make effective decisions. In traditional approaches to decision-making, usually scientific expertise together with statistical descriptions is needed to support decision-making. Recently, many innovative facilities have been proposed for decision-making process in enterprises with huge databases, together with several heuristic models.

Management information systems (MIS) are a kind of computer ISs that could collect and process information from different sources to make decisions in level of management [3]. This level contains computer systems that are intended to assist operational management in monitoring and controlling the transaction processing activities that occur at clerical level. MIS provides information in the form of prespecified formats to support business decision-making. The next level in the organizational hierarchy is occupied by low-level managers and supervisors. Therefore, MIS takes internal data from the system and summarized it to meaningful and useful forms as management reports to use it to support management activities and decision-making.

MISs encompass a complex and broad topic, that is why, MIS boundaries need to be defined to reduce difficulties in system managing. Firstly, MIS contains a vast number of related activities, so it is hard to review all of them. It may discuss on a selected sample of activities, depending on objectives and viewpoint of researcher. Alternatively, it only focuses on farm levels or on some lesser extent systems enough for researchers addressing problems. Secondly, MISs can be defined and described in several frameworks. Only a few of these frameworks are used to discuss important subject matters. Lastly, MISs are developed as a sense of how these systems have evolved, adapted, and been refined as new technologies have emerged, changing economic conditions, etc.

To evaluate performance of MIS, its output data must be characterized in a set of basic *features* appropriate to functions, objectives, and goals of the system. These output data need to be observed repetitively to evaluate the extent to which MIS is implemented to make successful decisions in organization. Using these observations, methods of data mining in rough set point of view, statistical analysis, etc. can be applied to evaluate the extent to which MISs are used to make effective decisions in planning purposes [4–7].

2. Evaluation of features and making decision rules

In mathematical modeling, an IS can be modeled by a sample $\Omega = \{\omega_1, \omega_2, \ldots, \omega_n\}$ of n objects ω_i where i = 1,2,…, n. The ith object ω_i is observed by instances of m *conditional features* $f_1, f_2,\ldots, f_m$, valued as $f_j(\omega_i)$ j = 1,2,…, m. Additionally, a feature d characterizes a specific effect of ω_i denoted by $d(\omega_i)$, the so-called *decision feature*. In case of having s effects for a decision, d is represented by values $d(\omega_i) = d_k$ with $k \in \{1,2,\ldots, s\}$.

Let $F = \{f_1, f_2,\ldots, f_m\}$, then $(\Omega, F \cup \{d\})$ is a *decision information table* or DIT with $n = |\Omega|$ objects, $m = |A|$ conditional features, and a decision d. Objects ω and ω' are *indiscernible* if and only if the following binary relation R_F on Ω with respect to (w.r.t.) F is satisfied:

$$R_A: f_j(\omega) = f_j(\omega') \; j = 1, 2, \ldots, m \tag{1}$$

This is an *equivalence relation*. Equivalent class of $\omega \in \Omega$ with respect to (w.r.t.) F is:

$$[\omega]_F = \{\omega' \in \Omega \mid f_j(\omega') = f_j(\omega) \;\; j = 1, 2, \ldots, m\} \tag{2}$$

Assume that there are r such equivalence classes and named by $C_1, C_2,\ldots, C_r$. They are disjoint subsets and form a partition of Ω by R_F. Similarly, for the decision feature d, another partition of Ω is $D_1, D_2,\ldots, D_s$ defined by the following equivalence relation:

$$R_d : d(\omega) = d_k, k = 1, 2, \ldots, s \tag{3}$$

Here, $D_k = \{\omega' \in \Omega \mid d(\omega') = d_k\}$ is an equivalence classes called the kth *decision class* of the DIT. If $f(D_k) = |D_k|/n$ be frequency of D_k w.r.t Ω, *information entropy* H(d) of decision feature d is

$$H(d) = -\sum_{k=1}^{s} f(D_i) \log_2 f(D_k) \tag{4}$$

On the other hand, let $f(C_i) = |C_i|/n$ be frequency of C_i and $f(D_k \mid C_i) = |D_k \cap C_i|/|C_i|$ conditional frequency of D_k conditioned C_i. The *conditional entropy* H(d|F) of the decision feature d w.r.t condition F is determined by

$$H(d|F) = -\sum_{i=1}^{r} f(C_i) \sum_{k=1}^{s} f(D_k|C_i) \log_2 f(D_k|C_i) \tag{5}$$

From Eqs. (4) and (5), the *mutual information* I(F, d) between F and d is given by

$$I(F, d) = H(d) - H(d|\, F) \tag{6}$$

The mutual information is nonnegative and symmetric, i.e. I(F, d) = I(d, F). In this case, the *significance* of feature $f \in F$ w.r.t d is defined as

$$Sgnf(f, d) = I(F, d) - I(F - \{f\}, d) \tag{7}$$

The significance of feature a represents the dependency of decision attribute d relative to condition attribute f. This measure reflects the discrimination ability of condition attributes.

The larger Sgnf(f, d), the more stronger of dependency relationships between a and decision attribute d. if Sgnf(f, d) > 0, then f is a *core feature* of DIT or f satisfies

$$I(F - \{f\}, d) < I(F, d) \tag{8}$$

Any core feature is significant and may not be eliminated in mining DIT. Let CFs be a set of all core features, CFs ⊆ F. To find CFs, each feature in F must be verified using Eq. (8) to whether or not include it to CFs.

Example 1: To analyze some features of a service, **Table 1** illustrated a DIT consists of evaluations of nine clients on four features of the service. In which, d is the decision feature, f_1: capacity for innovation; f_2: service capability; f_3: product technologies; and f_4: solution, are conditional features. Values in **Table 1** mean, 0: unpleased, 1: acceptable, and 2: very pleased.

Here, F = {f_1, f_2, f_3, f_4}. Using Eq. (1), four equivalence classes w.r.t F are C_1 = {ω_1, ω_8}, C_2 = {ω_2, ω_7}, C_3 = {ω_3, ω_5, ω_9}, C_4 = {ω_4, ω_6} and from Eq. (3) two decision classes D_0 = {ω_2, ω_5, ω_7, ω_9}, D_1 = {ω_1, ω_3, ω_4, ω_6, ω_8}. From Eq. (4), the information entropy of decision feature d is H(d) = 0.9911 and H(A) = 0.4976. From Eq. (5), the conditional entropy of d is H(d|F) = 0.3061, so the mutual information between F and d is I(F, d) = 0.6850.

	f_1	f_2	f_3	f_4	d
(a) Original data table					
ω_1	1	1	1	0	1
ω_2	0	1	1	0	0
ω_3	1	0	1	2	1
ω_4	1	2	0	1	1
ω_5	1	0	1	2	0
ω_6	1	2	0	1	1
ω_7	0	1	1	0	0
ω_8	1	1	1	0	1
ω_9	1	0	1	2	0
(b) Sorted data table					
ω_2	0	1	1	0	0
ω_5	1	0	1	2	0
ω_7	0	1	1	0	0
ω_9	1	0	1	2	0
ω_1	1	1	1	0	1
ω_3	1	0	1	2	1
ω_4	1	2	0	1	1
ω_6	1	2	0	1	1
ω_8	1	1	1	0	1

Table 1. A decision information system for evaluation service quality.

If the first feature a_1 is eliminated, it is obtained the same H(d), but $H(F - \{f_1\}) = 0.5144$ and $H(d|F - \{f_1\}) = 0.7505$. These imply $I(F - \{f_1\}, d) = 0.2405 < I(F, d)$ and the a_1, capacity for innovation is a core feature. But, $Sgnf(f_4, d) = Sgnf(F, d) - Sgnf(F - \{f_4\}, d) = 0$, so f_4 may be eliminated since it is not significant.

The features F, d can be considered as random quantities with values are represented in rows of a DIT. In theory of information, the mutual information is a measure of average information this random quantity receives from that one in all one's conditions and vice versa. Therefore, I(F, d) measures quantity of average information that the decision feature d receives from conditional features w.r.t. decisional value of d. That is why, it is concerned to the problem of removing redundant conditional features so that the reduced set provides the same effect, e.g., the same quality of classification or decision as the original.

A *coeffect reduced set* R of conditional features set is a subset of A so that I(R, d) = I(F, d), i.e., R contains some conditional features having the same effect as F. Any coeffect reduced set or *reduced set* of F for short can be used as the whole F. An algorithm to find a reduced set R based on mutual information is as follows:

ALGORITHM MIBR // *Mutual Information Based Reduced set.*

// Input: DIT = $(\Omega, F \cup \{d\})$.

// Output: R // *a reduced set of* F.

$S := \emptyset$; $R := CFs$; // *set of core features.*

Repeat.

$S := R$; for any $f \in F - R$, if $I(R \cup \{f\}, d) > I(S, d)$ then $S := R \cup \{f\}$;

$R := S$; // *reassign before doing the next iteration.*

Until I(R, d) = I(F, d);

Example 2: Using data in **Table 1**, the above algorithm is done as follows.

Firstly, $R = CFs = \{f_1\}$, S = R then

i. $f_2 \in F - R$, then $I(R \cup \{f_2\}, d) = 0.6850 > I(S, d) = 0.3198$, so $S = R \cup \{f_2\} = \{f_1, f_2\}$;

ii. $f_3 \in F - R$, $I(R \cup \{f_3\}, d) = 0.6850 = I(S, d)$, S does not change;

iii. $f_4 \in F - R$, $I(R \cup \{f_4\}, d) = 0.6850 = I(S, d)$, S does not change;

$R = S = \{f_1, f_2\}$. By checking, $I(R, d) = 0.6850 = I(F, d)$, the iteration is terminated. It is obtained $R = \{f_1, f_2\}$ is a reduced set of F.

It is noticed that, if the two steps i and ii of the previous treatment are permuted, then the set $R = \{f_1, f_3\}$ is another reduced set of F.

Remark: As shown above, reduced set R of DIT is not unique. Finding minimum reduced set of DIT is an optimization problem. Several algorithms have been proposed to solve this problem, e.g., algorithm of rough set-based feature selection based on ant colony optimization (RSFSACO) in [8], cf. [9], for more detail.

Given X, a subset of Ω in a DIT, *low-approximation* or *upper-approximation* of X w.r.t. F respectively named as $L_F X$ or $U_F X$, is defined by:

$$L_F X = \{\omega \in \Omega \mid [\omega]_F \subseteq X\}, U_F X = \{\omega \in \Omega \mid [\omega]_F \cap X \neq \varnothing\} \tag{9}$$

It can be shown that $L_F X \subseteq X \subseteq U_F X$. Some other relations between these approximations have been illustrated, e.g., in [5]. The difference set $B_F X = U_F X - L_F X$ is called a *boundary* of X and $\Omega - U_F X$ is the outside region of X. X is a *rough set* if $B_F X \neq \varnothing$, otherwise a *crisp set*.

Example 3: In Example 1, let $X = \{\omega_1, \omega_3, \omega_5, \omega_7, \omega_9\}$. Then, the approximations of X are $L_F X = \{\omega_3, \omega_5, \omega_9\} = C_3$ and $U_F X = \{\omega_1, \omega_2, \omega_3, \omega_5, \omega_7, \omega_8, \omega_9\} = C_1 \cup C_2 \cup C_3$. The boundary $B_F X = \{\omega_2, \omega_8, \omega_9\}$ differs from empty set, so X is a rough set and C_4 is the outside region of X. **Figure 1** shows all these sets w.r.t in Ω.

Any decision class Ω_k in Ω/R_d is subset of Ω, so it has a low approximation $L_F \Omega_k$. Hence, *positive region* in Ω w.r.t d, f is the following subset:

$$P_i(F) = \cup_{k=1}^{s} L_F \Omega_k \tag{10}$$

In data analysis, the dependence between attributes is important. The *dependency* of the decision feature d on the conditional features F is defined by the following ratio:

$$\mathrm{Dep}(d, F) = |P_d(F)|/|\Omega| \tag{11}$$

By definition, $0 \leq \mathrm{Dep}(d, F) \leq 1$ and if $\mathrm{Dep}(d, F) = 1$, d depends *totally* on F. If $\mathrm{Dep}(d, F) = 0$, i.e., $P_d(F) = \varnothing$, then d does not depend on F. In case of $0 < \mathrm{Dep}(d, F) < 1$, d depends *partially* on F.

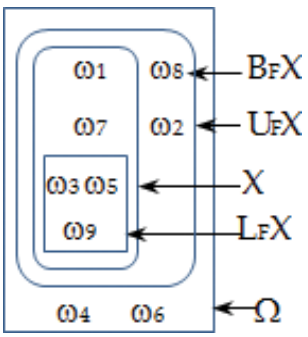

Figure 1. *Approximations of* X.

Using the degree of dependency, a coeffect reduced set R of conditional features in a DIT can also be found by meaning of Dep(d, R) = Dep(d, F).

Example 4: Example 1 gives two decision classes $D_0 = \{\omega_2, \omega_5, \omega_7, \omega_9\}$, $D_1 = \{\omega_1, \omega_3, \omega_4, \omega_6, \omega_7, \omega_8\}$; low approximations of these classes are $L_FD_0 = \{\omega_2, \omega_7\}$, $L_FD_1 = \{\omega_1, \omega_4, \omega_6, \omega_8\}$ thus $P_d(F) = \{\omega_1, \omega_2, \omega_4, \omega_6, \omega_7, \omega_8\}$ and the degree of dependency or quality of approximation is Dep(d, F) = 1/3. Using the coeffect reduced set $R = \{f_1, f_2\}$, it can be shown that all equivalence classes w.r.t R are the same ones in Example 1. Therefore, the above low approximations and positive region are also the same, i.e., $L_RD_0 = L_FD_0$, $L_RD_1 = L_FD_1$ and $P_d(R) = P_d(F)$.

So far, problems of inducing rules from DITs have been studied and developed. The rough set method can be applied to the problems with several advantages [5]. For instance, the lower and upper approximations are applied to describe the inconsistency of a DIT and to induce corresponding rules dynamically from decision systems [6]. These methods of approximation can be used to address incomplete input data for inducing decision rules [7]. Such rules can be applied to partition a set of objects into classifications [10].

Given a DIT, let V_f be the range of $f \in F$, for a $v \in V_f$, $\omega \in \Omega$ a proposition like $f(\omega) = v$ or $f = v$ for short, takes a logic value true or false depending on ω. Assignment, $\phi := f = v$ is to define a logic variable ϕ w.r.t the proposition $f = v$. Then, ϕ is true if there exists $\omega \in \Omega$ so that $f(\omega) = v$ or false in vice versa. Set of logic variables on F and logical operations, like ~: not; ∧: and; ∨: or; set up a set of logic expressions called *decision language* from F, denoted by $\mathcal{L}(F)$. The meaning of ϕ in $\mathcal{L}(F)$, denoted by $\langle\phi\rangle$, is a set of ω in Ω so that the proposition ϕ is true. Additionally, if $\phi := f = v$ then $\langle\phi\rangle = \{\omega \in \Omega / f(\omega) = v\}$, so ϕ takes the set $\langle\phi\rangle$ as its *description*.

A *decision rule* allows individual, team workers, and organization choose effectively specific course of action in response to opportunities and threads and help. Formally, a decision rule is a logic expression defined by proposition $\phi \rightarrow \psi$, read "*if* ϕ *then* ψ", where $\phi \in \mathcal{L}(F)$ and $\psi \in \mathcal{L}(d)$ referred to as *condition* and *decision* of the rule, respectively. A decision rule $\phi \rightarrow \psi$ is true if $\langle\phi\rangle \subseteq \langle\psi\rangle$. Both ϕ andψ are equivalent written as $\phi \leftrightarrow \psi$, if and only if $(\phi \rightarrow \psi) \wedge (\psi \rightarrow \phi)$.

Assume that $\langle\phi\rangle$ and $\langle\psi\rangle$ are nonempty. The *support* of the rule $\phi \rightarrow \psi$ is defined as

$$\mathrm{Supp}(\phi \rightarrow \psi) = \left|\langle\phi\rangle \cap \langle\psi\rangle\right| \tag{12}$$

The larger Supp($\phi \rightarrow \psi$), the more power of the rule in DIT. When $|\langle\phi\rangle| \neq \varnothing$, the *certainty* or *accuracy* of $\phi \rightarrow \psi$ denoted by Cert(ϕ,ψ) is

$$\mathrm{Cert}(\phi \rightarrow \psi) = \left|\langle\phi\rangle \cap \langle\psi\rangle\right| / \left|\langle\phi\rangle\right| \tag{13}$$

This is a percentage objects of $\langle\psi\rangle$ presented in $\langle\phi\rangle$ or percent of objects having property ψ in the set of objects having property ϕ or Cert($\phi \rightarrow \psi$) shows the *confidence* of the rule. In consequences, Cert($\phi \rightarrow \psi$) = 1 is equivalent to $\phi \rightarrow \psi$ is true, the rule is certain or accurate. Alternatively, if $|\langle\psi\rangle| \neq \varnothing$ the *coverage* of $\phi \rightarrow \psi$ is also defined:

$$\mathrm{Covg}(\phi \to \psi) = \left|\langle\phi\rangle \cap \langle\psi\rangle\right| / \left|\langle\psi\rangle\right| \tag{14}$$

The smaller of $\mathrm{Covg}(\phi \to \psi)$, the less power of the rule. Finally, the popularity of $\phi \to \psi$ is measured by the *strength* of the rule:

$$\mathrm{Strg}(\phi \to \psi) = \left|\langle\phi\rangle \cap \langle\psi\rangle\right| / \left|\Omega\right| \tag{15}$$

In a given DIT, a coeffect reduced set R of conditional features and corresponding positive region $P_d(R)$ are set up. Then, the DIT is restricted to a new table with features R, d and $P_d(R)$. Such a table is called *decision support table* or DST. Based on the above measures, decision rules extracted from DST are verified before using them in prediction decisions.

It is noted that, there may be pairs of *inconsistent* or *conflicting* decision rules which have the same conditions but different decisions. Such conflicting rules must be excluded. In general, set $\Re$ of τ decision rules $\phi_\alpha \to \psi_\alpha$ selected need to meet the properties:

1. Each $\phi_\alpha \to \psi_\alpha$ in $\Re$ is *admissible*, $\mathrm{Supp}(\phi_\alpha \to \psi_\alpha) \neq 0$,
2. $\Re$ *covers* Ω or $\left|\cup_{\alpha=1}^{\tau}\langle\phi_\alpha\rangle\right| = \left|\cup_{\alpha=1}^{\tau}\langle\psi_\alpha\rangle\right| = |\Omega|$,
3. $\Re$ consists of pairs *mutually independent*, i.e., for $\phi_\alpha \to \psi_\alpha$, $\phi_\beta \to \psi_\beta \in \Re$, it is obtained that $\langle\phi_\alpha\rangle \cap \langle\phi_\beta\rangle = \varnothing$ and $\langle\psi_\alpha\rangle \cap \langle\psi_\beta\rangle = \varnothing$,
4. $\Re$ preserves the *consistency*: $\cup_{i=1}^{\tau} L_F D_i = \left\langle \vee_{\alpha=1}^{\tau} \phi_\alpha \right\rangle$.

Example 5: A coeffect reduced set, e.g., R = {f_1, f_2}, and positive region determined by $P_d(R)$ = {ω_1, ω_2, ω_4, ω_6, ω_7, ω_8} as in Example 4. Some decision rules are extracted from **Table 1** and measures of obtained rules are presented in **Table 2**. The supports of the 2nd and 3rd rules are 2, their certainties and strengths are equal to 1 and 22.2%. So, they can be combined together:

$$(f_1 = 1) \wedge [(f_2 = 1) \vee (f_2 = 2)] \to d = 1 \tag{16}$$

The support of this rule is raised to 4, coverage of 100% and strength 44.4%. This rule is supported by the classes C_1, C_4, and can be deduced as follows: "if capacity for innovation is acceptable and service capability is unpleased then the system activity is still acceptable".

The class C_3 = {ω_3, ω_5, ω_9} is not in $P_d(R)$, and a rule like (f_1 = 1) and (f_2 = 0) → (d = 0 or 1) may not be considered. Because, when it was used, this rule would be useless, since it receives nothing in decision.

Decision rules	Coverage (%)	Supported by
1. (f_1 = 0) ∧ (f_2 = 1) → (d = 0)	50.0	C_2: ω_2, ω_7
2. (f_1 = 1) ∧ (f_2 = 1) → (d = 1)	40.0	C_1: ω_1, ω_8
3. (f_1 = 1) ∧ (f_2 = 2) → (d = 1)	40.0	C_4: ω_4, ω_6

Table 2. List of extracted decision rules.

The method of decision-making is also applied to build up decisions for risk warning based on processing historical data. Risk management model includes three sequential basic steps, that are risk identification, risk measurement, and risk warning. Risk identification should be objective itself, all risk levels are assessed by experts based on their work experience, this method ignores the role of historical data. That model does not have enough consideration on the uncertain and imprecision of risk. Alternatively, that method will unavoidably lead to some faulty judgments.

Data to identify risk factors often come from the operation, policy, environment, and management of a system. Collected data including a feature to assess risks are described by the feature d in a DIT. This decision feature d is often of six levels, 0: no risk, 1: little, 2: low-grade, 3: middle-grade, 4: distinct, and 5: dangerous. The historical data are collected factually, so there will be some data fields or features which have less impact on the final risk level. If these redundant features are removed, then there will be produced a simplified feature set which will have a positive impact on risk judgment. Where is the place of finding reduced feature set to ignore unnecessary information while the nature of collected data is still unchanged.

Based on fact-finding of conditional features and observed risk levels on DIT, decision rules to predict risk levels are extracted. This process is only a step of the training stage in machine learning. To improve quality of risk prediction, more observations on DIT and verifications of rules must be done repeatedly.

Example 6: To evaluate security risks of a system, three conditional feature types of the system come from environmental impact, management structure, and control equipment are taken into account. These conditional features are notated as E, M, and C, respectively, and the decision feature d is simplified at two levels, either 1: risk-warning or 0: no-warning. Data are shown in **Table 3**.

From **Table 3**, there are five equivalence classes $C_1 = \{\omega_1\}$, $C_2 = \{\omega_2, \omega_5\}$, $C_3 = \{\omega_3\}$, $C_4 = \{\omega_4\}$, $C_5 = \{\omega_6\}$ and two decision classes $D_1 = \{\omega_4, \omega_5\}$, $D_2 = \{\omega_1, \omega_2, \omega_3, \omega_6\}$.

Using Eqs. (4)–(6), the information entropy of F = {E, M, C} is H(F) = 2.2516, H(d) = 0.9183 and mutual information between F and d I(F, d) = 0.5850. From Eq. (6), $I(F - \{C\}, d) = 0.1258$ less than I(F, d), then a_3 is a core feature with a significance of Sgnf(C, d) = 0.4591.

	E	**M**	**C**	**d**
ω_1	0	1	1	1
ω_2	1	0	1	1
ω_3	1	1	2	1
ω_4	0	1	0	0
ω_5	1	0	1	0
ω_6	0	1	2	1

Table 3. Risk warning data.

Consider F-{M} = {E, C}, from Eq. (5), H(d|F − {M}) = 0.3333 implies to I(F − {M}, d) = 0.5850 = I(F, d). Therefore, {E, C} is a coeffect reduced set of F. Hence, there are formally two decision rules:

$$[(E = 0) \wedge (C = 0)] \vee [(E = 1) \wedge (C = 1)] \rightarrow (d = 0) \tag{17}$$

$$[(E = 1) \wedge (C \# 0)] \vee [(E = 0) \wedge (C \# 0)] \rightarrow (d = 1) \tag{18}$$

It is noticed that the first expression of the second disjunction is an implication of the second one in the first rule. Therefore, maybe [(E = 1) ∧ (C = 1)] → [(d = 0) or (d = 1)] happens. Alternatively, the second rule can be written as (C # 0) → (d = 1). However, if E = 1 and C = 1, the first rule gives d = 0 contrary to the just deduced rule. For these reason, the above rules are chosen reasonably as [(E = 1) ∧ (C = 2)] ∨ [(E = 0) ∧ (C≠ 0)] → (d = 1).

Similarly, F-{E} = {M, C} gives I(F − {E}, d) = I(F, d), thus {M, C} is also a reduced set of F. Then,

$$[(M = 1) \wedge (C = 0)] \vee [(M = 0) \wedge (C = 1)] \rightarrow (d = 0) \tag{19}$$

$$[(M = 1) \wedge (C \neq 0)] \vee [(M = 0) \wedge (C = 1)] \rightarrow (d = 1) \tag{20}$$

It is also noticed that the second expressions of the above disjunctions are identical and it is necessary to ignore them. Because, if (M = 0) ∧ (C = 1) is true, these rules simultaneously imply d = 0, 1 hard to decide.

Consequently, the second and fourth rules in **Table 4** may be used for risk warning w.r.t the collected data in **Table 3**.

The difficulties in choosing decision rules will be increasing with large-scale datasets. To reduce in part this shortcoming and make decision rules more efficiently, techniques of machine learning should be used. For instance, in [11], a back propagation neural network was used for training data in DIT, verifying decision rules in a number of steps to minimize errors in prediction based on decision rules.

Decision rules for risk warning	Coverage (%)	Strength (%)
1. [(E = 0) ∧ (C = 0)] → (d = 0)	50.0	20.0
2. [(E = 1) ∧ (C = 2)] ∨ [(E = 0) ∧ (C ≠ 0)] → (d = 1)	75.0	60.0
3. [(M = 1) ∧ (C = 0)] → (d = 0)	50.0	20.0
4. [(M = 1) ∧ (C≠ 0)] → (d = 1)	75.0	60.0

Table 4. List of extracted decision rules for risk warning.

3. Evaluation of the extent of MIS using ANOVA

For the outcome extent of an MIS, it is assumed that a reduced set of m features, namely f_1, f_2, …, f_m, is considered and evaluated with real numbers. The probability distribution of f_i is assumed that normal $N(\xi_i, \sigma_i^2)$ with expected mean ξ_i and variance σ_i^2.

ANOVA or analysis of variance was derived based on the approach in which the statistical method uses the variance to determine the expected means whether they are different or equal. It assesses the significance of factors, the so-called features here, by comparing the response means of observation samples at different features. In this chapter, ANOVA with single stage and multiple stages are introduced to evaluate features from the extent of an MIS.

In doing ANOVA, it is also assumed that all m features f_i are of the same variances. In a course of consideration, m observation samples at different features are randomly drawn. The ith sample is denoted by $\{\omega_{ij}\}$, j = 1, 2,…, n_i, a manifestation of a random variable f_i from the population of f_i values. Basic characteristics of the ith sample are:

$\overline{\omega}_i = \left(\sum_{j=1}^{n_i} \omega_{ij}\right)/n_i$—sample average, is an estimate for μ_i,

$s_i^2 = \left(\sum_{j=1}^{n_i} \left[\omega_{ij} - \overline{\omega}_i\right]\right)^2 / df_i$—sample variance, estimate for σ^2 with degree of freedom $df_i = n_i - 1$.

These calculations are done by using the following three basic sums:

Sum:

$$S_i = \sum_{j=1}^{n_i} \omega_i \tag{21}$$

Sum of squares:

$$SS_i = \sum_{j=1}^{n_i} \omega_i^2 \tag{22}$$

Sum of squares of derivations:

$$SS_i = \sum_{j=1}^{n_i} \left[\omega_{ij} - \overline{\omega}_i\right]^2 \tag{23}$$

Then, it is implied that $\varpi_i = S_i/n_i$ and $SSD_i = SS_i - S_i^2/n_i$, so $s^{*2}_i = SSD_i/df_i$.

To verify condition that all variance σ_i^2 are equal to the same value σ^2, the Bartlett test based on the χ^2 probability distribution is used at a level of significance α valued from 1 to 5%. If the hypothesis on the equality of all variances is correct, m > 1 and $n_i > 1$ for all i, Bartlett has shown that the statistic χ^2_{cal} has approximately a χ^2-distribution with df = m−1:

$$\chi^2_{cal} = 2.3026\left(df \times \log s^2 - \sum_{i=1}^{m} df_i \log s_{*i}^2\right)/c \tag{24}$$

Here, $df = \sum_{i:1..m} df_i$, $c = 1+(\sum_{i:1..m} 1/df_i - 1/df)/[3(m-1)]$, $s^2 = (\sum_{i:1..m} df_i \times s_{*i}^2)/df = (\sum_{i:1..m} SSD_i)/df$ is the pool variance, an estimate for σ^2. If a calculated χ^2_{cal} is less than $\chi^2_{1-\alpha}$-percentile, it is unreasonable to deny that all variances are the same. It is noticed that the approximation χ^2-distribution is a poor one for $df_i \leq 2$.

In case of $n_1 = n_2 = \ldots = n$, then df = n−1 and Eq. (21) can be quite simple. Indeed, because of $\log s^2 = \log\sum_{i:1..m} SSD_i - \log(df)$ and $\log s_i^2 = \log SSD_i - \log(df_i)$, a shortened form of Eq. (24) is

$$\chi^2_{cal} = 2.3026\left(m \times \log s^2 - \sum_{i=1}^{m} \log s^2_{*i}\right) df/c \tag{25}$$

where, $c = 1 + (m + 1)/(3\,m[n-1])$. The value χ^2_{cal} in Eq. (25) is calculated by using only all SSDs.

Setting $n = \sum_{i:1..m} n_i$, $\omega_o = (\sum_{i:1..ni} n_i\varpi_i)/n$, $\xi_o = (\sum_{i:1..ni} n_i\xi_i)/n$ and $\eta_i = \xi_i - \xi_o$. It is shown the following partitions

$$\begin{aligned}\sum_{i=1}^{m}\sum_{j=1}^{n_i}\left[\omega_{ij} - \xi_i\right]^2 &= \sum_{i=1}^{m}\sum_{j=1}^{n_i}\left[\omega_{ij} - \overline{\omega}_i\right]^2 + \sum_{i=1}^{m} n_i[\overline{\omega}_i - \xi_i]^2 \\ &= \sum_{i=1}^{m}\sum_{j=1}^{n_i}\left[\omega_{ij} - \overline{\omega}_i\right]^2 + \sum_{i=1}^{m} n_i\left[\overline{\omega}_i - \omega_o - \eta_i\right]^2 + n[\omega_o - \xi_o]^2\end{aligned} \tag{26}$$

According to the χ^2-partition theorem, the sums in the rightmost side of Eq. (26) are of χ^2-distribution with degrees of freedom $n-m$, $m-1$, 1, respectively.

If the expected means of m populations are the same, $\xi_i = \xi_o$ and $\eta_i = 0$ for all i. The two first terms of Eq. (26) are variations *within* or *between* samples and determined in turn as follows:

$$s_1^2 = \left(\sum_{i=1}^{m}\sum_{j=1}^{n_i}\left[\omega_{ij} - \overline{\omega}_i\right]^2\right)/(n-m) = \left(\sum_{i=1}^{m} SSD_i\right)/(n-m) \tag{27}$$

$$s_2^2 = \left(\sum_{i=1}^{m} n_i[\overline{\omega}_i - \omega_o]^2\right)/(m-1) = \left(\sum_{i=1}^{m} S_i^2/n_i - \left[\sum_{i=1}^{m} S_i\right]^2/n\right)/(m-1) \tag{28}$$

The statistics s_1^2, s_2^2 and $s_3^2 = n[\omega_o - \xi_o]^2$ are unbiased estimates of σ^2. In this case, the total variance between observations and population is determined as follows:

$$s^2 = \left(\sum_{i=1}^{m} n_i\left[\omega_{ij} - \omega_o\right]^2\right)/(n-1) = \left(\sum_{i=1}^{m} SS_i - \left[\sum_{i=1}^{m} S_i\right]^2/n\right)/(n-1) \tag{29}$$

In such a case, the variance ratio $v^2_{cal} = s_1^2/s_2^2$ is of the Fisher probability distribution with $df_{s1} = n - m$, $df_{s2} = m - 1$. Therefore, the hypothesis about equality of m expected means is tested using the Fisher distribution with a given level of significance α valued from 1 to 5%. If $v^2_{cal} > F_{1-\alpha}(df_{s1}, df_{s2})$, the hypothesis of equal means would be rejected, in which $F_{1-\alpha}(df_{s1}, df_{s2})$ is the $100(1-\alpha)$% percentile of the Fisher distribution.

It is noticed that the condition $m > 1$ and, for all i, $n_i > 1$ are essential not only for Bartlett test, but also for doing ANOVA [12]. Conversely, the analysis is trivial when $n_i = 1$ for some i. Also, if $m = 1$, the analysis is pure inference from single population [13].

Example 7: Assume that there are four features need to be tested at the 5% level of significance with data in **Table 5**. Calculations are given in **Table 5**.

Using Eq. (24), $\chi^2_{cal} = 1.328$ is far less than $\chi^2_{0.95}(3) = 7.815$, the 95% percentile in the table of χ^2 probabilities with df = 3. Therefore, the hypothesis on equality of variances is accepted. The variation between dataset is estimated by the pool variance, Eq. (29), $s^2 = 36.3/9 = 4.037$. Using the underlined numbers in **Table 5**, the ANOVA table is presented in **Table 6**.

Features f_i	f_1	f_2	f_3	f_4	
ω_{i1}	7	5	8	7	
ω_{i2}	3	4	3	4	
ω_{i3}	4	6	5	2	
ω_{i4}				5	
{1}. ni.	3	3	3	4	13
Si	14	15	16	18	*63*
SSi	74	77	98	94	343
Si^2/fi	65.33	75	85.33	81	306.67
SSDi	8.667	2	12.67	13	*36.333*
{2}. dfi.	2	2	2	3	9
1/dfi	0.5	0.5	0.5	0.333	1.833
$\underline{si}^2$	4.333	1	6.333	4.333	
$\log(\underline{si}^2)$	0.637	0	0.802	0.637	
$df_i.\log(\underline{si}^2)$	1.274	0	1.603	1.91	4.787
$s^{2:}$	4.037	c.:	1.157	χ^2_{cal}:	*1.328*
$df.\log(s^2)$	5.455	$\Sigma(Si^2/ni)-(\Sigma Si)^2/n$:			*1.359*

Table 5. Calculations for single-stage ANOVA.

Variation sources	**SSD**	**df**	$\mathbf{s^2}$	v^2
Between features	1.359	3	0.453	0.11
Within features	36.333	9	4.037	
Total	37.692	12	$F_{0.95}(3,9) = 3.86$	

Table 6. Single-stage ANOVA table of Example 7.

The calculated basic sums in the first part of **Table 5** are used to set up an ANOVA in **Table 6**. It is shown that $v^2_{cal} = 0.453/4.037 = 0.112 < 3.86$, the 95% percentile in the table of Fisher probabilities w.r.t $\alpha = 5\%$. The hypothesis on equality of the expected means would be accepted at the 5% significance level.

If the hypothesis $\xi_i = \xi_2 = \ldots = \xi_m$ is rejected, all possible differences of these means in form of linear combinations are estimated by using confidence intervals. In such a case, there is a probability of $1 - \alpha$ that all comparisons simultaneously among the expected means satisfy:

$$-\lambda < \sum_{i=1}^{m} \delta_i \overline{\omega}_i - \sum_{i=1}^{m} \delta_i \xi_i < \lambda \tag{30}$$

Here, $\sum_{i=1\ldots m} \delta_i = 0$ and $\lambda^2 = s^2 \times F_{1-\alpha}(m-1, n-k) \times (m-1) \times \sum_{i=1\ldots m} (\delta_i^2/n_i)$, $F_{1-\alpha}(m-1, n-k)$ is the $100(1-\alpha)\%$ percentile of the Fisher probability distribution.

For instance, if m = 3, n = 4, $\varpi_1 = 2.25$, $\varpi_2 = 4.0$, $\varpi_3 = 4.5$ and $s^2 = 4.41$, then $F_{0.95}(2,3 \times 4 - 3) = 4.26$. Using Eq. (30), some 95% confidence intervals are calculated as follows:

$-\delta_1 = 1 = -\delta_2$, $\delta_3 = 0$, $\lambda = 4.33$; the confidence interval of $\xi_1 - \xi_2$ is -1.75 ± 4.297 or $(-2.55, 6.47)$.

$-\delta_1 = 0$, $\delta_2 = 1 = -\delta_3$; similarly, the confidence intervals of $\xi_2 - \xi_3$ is -0.5 ± 4.297 or $(-3.797, 4.797)$.

$-\delta_1 = ½ = \delta_2$, $\delta_3 = -1$, $\lambda = 3.721$. The 95% confidence interval of $½\xi_1 - ½\xi_2 - \xi_3$ is $(-2.436, 5.096)$.

When having several stages need to be tested on equality with expected means of features, multiple-stage ANOVA is applied. This is the case of evaluating the same given m features in k different stages, denoted by $\Gamma_\nu \nu = 1, 2, \ldots, k$. To simplify in presentation, without loss generality, it is assumed that all observed samples in stages have the same size, i.e., $n_i = n$ for all i, and Eq. (25) is used for Bartlett test.

The notations are similar, but an index ν added to the observations in each νth stage. The sums in Eqs. (21)–(23) are renotated as $S_{\nu i}$, $SS_{\nu i}$, $SSD_{\nu i}$. Since, $\varpi_{\nu i} = S_{\nu i}/n$, $s_{\nu i}^2 = SSD_{\nu i}/(n-1)$ are the average and variance of sample of the νth stage. All computations with multistage are similar to the single-stage ANOVA. Then, the results from stage computations are combined as shown at the end part of **Table 7**, to form multistage ANOVA table.

Example 8: Given a two-stage dataset of three features in five first rows of **Table 7**, calculations are illustrated in the parts, notated as {1} and {2}, of the table which aim at presenting schemes for finding basic sums and terms of Bartlett test and ANOVA.

fi	**Stage 1**			**Stage 2**			**Sizes**
	f_1	**f_2**	**f_3**	**f_1**	**f_2**	**f_3**	
$\omega_{\nu\ ij}$ 1	5	7	6	9	8	10	k = 2
2	8	4	7	8	7	8	m = 3
3	6	6	5	8	5	7	n = 3
{1} S_{ij}	19	17	18	25	20	25	124
SS_{ij}	125	101	110	209	138	213	896
S_{ij}^2/n	120.33	96.33	108.00	208.33	133.33	208.33	874.67
SSD_{ij}	4.67	4.67	2.00	0.67	4.67	4.67	21.33
$logSSD_{ij}$	0.67	0.67	0.30	−0.18	0.67	0.67	2.80
{2}	Bartlett test:			ANOVA:			
(ΣlogSSDi)/(km)−log(n−1):			0.166	$S^2/(mn)$:		868.44	
S^2/df_i	874.67	$logs^2$	0.250	$S^2/(kmn)$:		854.22	*14.222*
SSD	21.333	c.	1.194	$(\Sigma(S_1i + S_2i)^2)/(km) - S^2/(kmn)$:			*4.778*
logSSDi	2.80	χ^2_{cal}	*1.945*	$SS_1 + SS_2 - S^2/(kmn)$:			*41.778*

Table 7. Calculations for Two-stage ANOVA.

Calculations for the Bartlett test in {2} of **Table 7** show that $\chi^2_{cal} = 1.194 < \chi^2_{0.95}(5) = 11.07$, the hypothesis that population variance is the same for all features is accepted at $\alpha = 5\%$. An estimate of the population variance is $s_1^2 = 21.33/(2 \times 3 \times [3–1]) = 1.778$, cf. **Table 8**. The part {3} of **Table 7** is the calculation scheme for the terms in **Table 8**, where Subtotal equals Total minus Within stages or the sum of Between features within stages, Between stages, and Interaction.

The ratio of the variation between stages to within features is $v^2 = s_3^2/s_1^2 = 14.222/1.778 = 8.0$ which by far exceeds the 95% percentile of Fisher distribution $F_{0.95}(1,12) = 4.75$. That means the difference of the expected means between stages is different significantly. In other words, the effects between stages are significantly discriminated.

Similarly, in comparison of the variation within features and between features within stages, **Table 8** shows that $v^2 = s_2^2/s_1^2 = 3.105/1.778 = 1.747 < F_{0.95}(2,12) = 3.89$. This shows that the difference between the expected means of features within stages is not significant or the effects between features within stages are almost the same.

Beside the above effects, the interaction between stages and features is also a factor need to be considered. The ratio $v^2 = 0.006/0.012 = 0.50$ gives that such an interaction is not present in given dataset. Thus, both the lines labeled "*Interaction*" and "*Within stages*" give the same unbiased estimates of σ^2, since a combination of these lines can improve the estimate of σ^2. The residual mean square is a sum of variations between the Interaction and Within stages. This leads to an updated population variance is 1.525 less than $s_1^2 = 1.778$ in **Table 8**, but obviously increases v^2 ratios. **Table 9** analyzes the interaction without stage of Example 8.

Variation sources	**SSD**	**df**	$\mathbf{s^2}$	$\boldsymbol{v^2}$
Between stages	14.222	1	14.222	8.0
Between features within stages	6.210	2	3.105	1.747
Interaction	0.012	2	0.006	0.50
Subtotal	20.444	5		
Within stages	21.333	12	1.778	
Total	41.778	17		

Table 8. Two-stage ANOVA table of Example 8.

Variation sources	**SSD**	**df**	$\mathbf{s^2}$	$\boldsymbol{v^2}$
Between stages	14.222	1	14.222	9.328
Between features within stages	6.210	2	3.105	2.036
Residual mean square	21.345	14	1.525	
Total	41.778	17		

Table 9. ANOVA table—two-stage without interaction.

The ratio $v^2 = s_2^2/s_1^2 = 3.105/1.525 = 2.036 < F_{0.95}(2,14) = 3.74$ or the effects between features within stages are the same. While, $v^2 = s_3^2/s_1^2 = 14.222/1.525 = 9.328$ which also by far exceeds $F_{0.95}(1,14) = 4.60$, the effects between stages are also significantly discriminated, cf. **Table 8**.

4. Case studies

To evaluate the extent to which MIS is being used to attain achievements of long-term planning, short-term planning in the South-West Nigerian universities [14], all selected features are f_1: Construction of building in the university, f_2: Student enrolment projection, f_3: Manpower projection, f_4: Staff recruitment exercises, f_5: Establishment of new faculties and department, f_6: Designing university academic program, f_7: Stock library with books and journals are considered in long-term evaluation. For short-term, f_1: Promotion of Staff, f_2: Staff Training and Development, f_3: Appointment of Deans or Heads of Departments or Divisions, f_4: Appointment of Committee Members, f_5: Allocation of offices to staff, f_6: Allocation of Residential Quarters, f_7: Allocation of Lecture room/theaters, f_8: Full-time equivalent or Teacher-Students Ratio, and f_9: Maximum Teaching Load are considered.

In evaluation of the extent of our university for a 5-year strategy planning, the following features are used f_1: Effectuation rights and obligations of students, f_2: Promotion of international cooperations, f_3: Library, equipment and material facilities, f_4: Potential of Scientific R&D and transfer of technology, f_5: Capacity of organization and management, f_6: Design of university academic programs, f_7: Promotion of academic operations, f_8: Capacity of manpower projection, f_9: Management of finance and resources. These basic features are factors to evaluate whether the university attains its goal and objectives. Each basic feature is evaluated in the scale of 100 but here it is illustrated in the one of 20 points.

Example 9: Let f_i, i = 1, 2,…, 9 be features characterized as the extent of an MIS as above. ω_{ij}, j = 1, 2,…, 12 is a value that is evaluated as the ith feature by the jth evaluator in a shorten marking scheme of 20. Calculations for the single-stage ANOVA table are shown in **Table 10**.

The calculated value $\chi^2_{cal} = 9.432$ in **Table 10** does not exceed $\chi^2_{0.95}(8) = 15.51$, the hypothesis on equality of variances is accepted. The population variance is estimated as $s^2 = 1185.58/99 = 11.976$. The corresponding ANOVA table for this dataset is given in **Table 11**.

Here, as variance ratio $v^2 = 8.907$ far exceeds $F_{0.95}(8,99) = 2.06$, it is unreasonable to assume that all the expected means of features are the same. This can also be seen from **Table 10**, where all sum of features from f_1 to f_4 are less than the ones of features from f_5 to f_9.

A more detailed examination revealed that the nine features can be partitioned into two groups, namely A = {f_1, f_2, f_3, f_4} with the first four features and B = {f_5, f_6, f_7, f_8, f_9} with the remainders. Each group of features can be seen as a treatment and its observation sample includes all observations in the same group. Since, it would be reasonable to consider the variation between features into three portions between: the features from A, the features from B, and between group A and B. Calculations in this consideration are extracted from **Table 10** and illustrated in **Table 12**.

	f_1	f_2	f_3	f_4	f_5	f_6	f_7	f_8	f_9
ω_{i1}	13	2	10	2	14	10	9	9	11
ω_{i2}	1	1	3	13	11	10	10	10	14
ω_{i3}	7	5	0	11	13	7	11	15	15
ω_{i4}	9	15	2	17	10	7	11	13	15
ω_{i5}	3	8	9	7	17	9	7	17	20
ω_{i6}	6	2	5	5	14	10	11	15	17
ω_{i7}	7	2	7	2	13	11	15	11	5
ω_{i8}	10	3	10	10	11	13	13	11	15
ω_{i9}	8	13	7	7	10	11	11	8	17
ω_{i10}	11	6	9	8	9	9	10	14	15
ω_{i11}	5	2	7	8	3	14	7	10	15
ω_{i12}	7	3	3	10	9	15	11	13	11
{1} Si	87	62	72	100	134	126	126	146	170
SSi	753	554	556	1038	1632	1392	1378	1860	2566
Si^2/ni	630.75	320.33	432	833.3	1496.3	1323	1323	1776.3	2408.3
SSDi	122.25	233.67	124	204.7	135.67	69	55	83.667	157.67
logSSDi	2.087	2.369	2.09	2.311	2.133	1.839	1.740	1.923	2.20
{2} Bartlett		df:8				Anova			
$\Sigma logs_i^2/k$:		1.036	c:	1.034	ΣSi:	1023	$\Sigma SSDi$:		*1185.58*
$log.s^2$:		1.078	χ^2_{cal}	*9.432*	$\Sigma Si^2/fi$:	10,543	$\Sigma Si^2/n - S^2/nm$:		*853.33*

Table 10. Calculations for single-stage ANOVA dataset.

Variation sources	**SSD**	**df**	s^2	v^2
Between feature	853.333	8	106.667	8.907
Within features	1185.583	99	11.976	
Total	2038.917	107		

Table 11. Single-stage ANOVA table of Example 9.

In comparison with the variance within features s^2, the variance ratios v^2 = 23.243/11.976 = 1.941 < $F_{0.95}(3,99)$ = 2.66 and v^2 = 113.60/11.976 = 2.371 < $F_{0.95}(4,99)$ = 2.43 in **Table 13** show that there is no essential difference between features in the same group. Since the third ratio v^2 = 183.33/11.976 = 15.309 is far greater than $F_{0.95}(1,99)$ = 3.9, the features in group A and B do have different expected mean.

Example 10: Assume that in an MIS, there are two stages that need ANOVA with the same set of features. In each stage, samples of evaluations in marking scheme of 20. Let ω_{vij} be an integral value in marking scheme of 20 that evaluates the ith feature given by the jth evaluator

	Group A		Group B		n = 12	
n_*	4 × 12		5 × 12		108	
ΣS_i	321	6.6875	702	11.7	1023	
$\Sigma S_i^2/n_i$		2216.4		8327		10,360
$S^2/\underline{S}(ni)$		2146.7		8213.4		9690.1
SSD		*69.729*		*113.6*		*183.33*
Ave.:	6.688		11.7		9.472	

Table 12. Calculations for ANOVA between group A and B.

Variation sources	SSD	df	s^2	v^2
Between features from A	69.729	3	23.243	1.941
Between features from B	113.60	4	28.40	2.371
Between features in A and B	183.33	1	183.33	15.309
Total	853.33	8		

Table 13. ANOVA table of two groups A and B.

from the νth stage, ν = 1, 2, i = 1, 2,…, 7, j = 1, 2,…, 8. This dataset is in **Table 14** including calculation for ANOVA.

Using Bartlett test in {3}, $\chi^2_{cal} = 9.507$ not exceed $\chi^2_{0.95}(15) = 22.36$, so population variances are the same with the pool variance of $s^2 = 1185.58/96 = 2.105$. **Table 15** shows this ANOVA.

The ratio $v^2 = s_2^2/s_1^2 = 3.932/2.063 = 1.906$ is less than $F_{0.95}(6,98) = 2.15$, the difference between the expected means within stages is not significant. Similarly, $v^2 = s_3^2/s_1^2 = 37.723/2.063 = 18.29 > F_{0.95}(1,98) = 3.96$, the expected means between stages are discriminated.

Since $v^2 = 0.057/0.339 = 0.167$ less than the 95% percentile of Fisher distribution, any interaction does not exist. Thus, "Interaction" and "Within stages" variation sources are combined to $s_1^2 = (202.125 + 0.339)/104 = 1.947$ a better estimation for σ^2 than 2.063 in **Table 15**.

The case of m = 1 and k = 2 has been presented in the previous subsection with group A, B. In [15], ANOVA has been used to specify whether a statistical relationship exists between human development index and security index. The authors in [16] have used the ANOVA combined with regression analysis to assess and evaluate student MIS of a university.

In this subsection, the student test is presented in comparison with the effects of f from the two stages or treatments. Let $\{\omega_{ij}\}$ i = 1, 2 and j = 1, 2,…, n_i be two observation samples of sizes n_i drawn from the two treatments of the feature f. Using Eqs. (21)–(23), the means ϖ_1, ϖ_2 and variances s_1^2, s_2^2 are calculated with $df_1 = n_1–1$, $df_2 = n_2–1$.

The equality of population variances is tested using Fisher distribution with $v^2 = s_1^2/s_2^2$. If $v^2 < F_{\alpha/2}(df_1, df_2)$ or $v^2 > F_{1-\alpha/2}(df_1, df_2)$, it is unreasonable to assert that the population

	f_1	f_2	f_3	f_4	f_5	f_6	f_7	
ω_{1i1}	16	15	17	14	14	13	14	k = 2
ω_{1i2}	13	14	11	12	10	13	12	m = 7
ω_{1i3}	14	16	15	14	15	14	16	n = 8
ω_{1i4}	12	14	13	12	14	12	15	
ω_{1i5}	13	15	14	10	13	14	13	
ω_{1i6}	10	12	11	13	12	10	12	
ω_{1i7}	12	14	13	14	13	13	12	
ω_{1i8}	13	14	13	15	13	14	13	
{1} S_1i	103	114	107	104	104	103	107	742
SS_1i	1347	1634	1459	1370	1368	1339	1447	9964
S_1i^2/ni	1326	1625	1431	1352	1352	1326	1431.1	9843
SSD_1i	20.88	9.5	27.88	18	16	12.88	15.88	121
$logSSD_1i$	1.32	0.978	1.445	1.255	1.204	1.11	1.201	8.512
	f_1	f_2	f_3	f_4	f_5	f_6	f_7	
ω_{2i1}	16	17	18	14	15	14	15	
ω_{2i2}	14	15	13	12	11	13	14	
ω_{2i3}	15	18	15	14	16	15	16	
ω_{2i4}	13	14	14	15	14	13	14	
ω_{2i5}	14	16	15	13	15	14	13	
ω_{2i6}	13	14	13	15	14	14	15	
ω_{2i7}	14	15	16	14	13	15	14	
ω_{2i8}	13	14	14	16	14	15	15	
{2} S_2i	112	123	118	113	112	113	116	807
SS_2i	1576	1907	1760	1607	1584	1601	1688	11,723
S_2i^2/ni	1568	1891	1741	1596	1568	1596	1682	11641.9
SSD_2i	8	15.88	19.5	10.88	16	4.875	6	81.125
$logSSD_2i$	0.903	1.201	1.29	1.036	1.204	0.688	0.778	7.101
$(S_1i + S_2i)^2$	46,225	56,169	50,625	47,089	46,656	46,656	4973	343,149
{3} Bartlett					Anova		$S=S_1 + S_2$	1549
$\Sigma logSSDi./(km) - log(n-1)$:				0.270	$S^2/(mn)$:		21460.9	
$\Sigma SSDi$:		*202.1*	$logs^2$:	0.314	$S^2/(kmn)$:		21423.2	*37.723*
$\Sigma logSSDi$:		15.61	c:	1.051	$\Sigma(S_1i + S_2i)^2/(km) - S^2/(kmn)$:			*23.589*
			χ^2_{cal}:	*9.507*	$SS_1 + SS_2 - S^2/(kmn)$:			*263.77*

Table 14. Calculations for two-stage ANOVA dataset.

variances are equal. Otherwise, the pool variance of these treatments is $s^2 = (SSD_1 + SSD_2)/(df_1 + df_2)$.

Variation sources	SSD	df	s^2	v^2
Between stages	37.723	1	37.723	18.290
Between features within stages	23.589	6	3.932	1.906
Interaction	0.339	6	0.057	0.167
Subtotal	61.652	13		
Within stages	202.125	98		
Total	263.777	111		

Table 15. Two-stage ANOVA table of Example 10.

The equality of the expected means from treatments is tested by the student distribution based on the difference $\varpi_0 = \varpi_1 - \varpi_2$. If this hypothesis is correct, there are two cases:

- If the variances in each treatment are equal, the statistics $t_{cal} = \varpi_0/s_o$ with $s_o^2 = s^2[1/n_1 + 1/n_2]$ has the student distribution $df = df_1 + df_2$ degrees of freedom,
- If the variances of treatments not equal, $t_{cal} = \varpi_0/s_o$ with $s_o^2 = s_1^2/n_1 + s_2^2/n_2$ approximate the student distribution with $df = c^2/df_1 + (1-c^2)/df_2$, where $c = (s_1^2/n_1)/(s_1^2/n_1 + s_2^2/n_2)$.

The hypothesis that the two expected means of the feature f from the treatments are equal is rejected at a level of significance α when $|t_{cal}| > t_{1-\alpha/2}(df)$. Otherwise, the confidence interval of the difference η between the two means is

$$\varpi_0 + t_{\alpha/2}(df)s_o < \eta < \varpi_0 + t_{1-\alpha/2}(df)s_o \tag{31}$$

where $t_{1-\alpha/2}(df)$ is the $100(1-\alpha/2)\%$ percentile of the student distribution, $t_{1-\alpha/2}(df) = -t_{\alpha/2}(df)$.

For instance, from **Table 12**, the variances in groups $s_A^2 = 69.729/47 = 1.484$ and $s_B^2 = 113.60/59 = 1.925$ give $v^2 = s_A^2/s_B^2 = 1.30$ less than $t_{0.995}(106) = 2.35$. It is accepted the variances in group A and B are equal. The pool variance is estimated by $s^2 = (SSD_1 + SSD_2)/(df_1 + df_2) = 113.60/106 = 1.729$. Also, **Table 12** gives $s_o^2 = s^2.[1/47 + 1/59] = 0.06611$ and $t_{cal} = (11.7–6.6875)/s_o = 19.68$, this so far exceeds $t_{0.995}(106) = 2.606$. The student test for these two treatment shows the expected mean of group B so far exceeds the one of A. The 99.5% confidence interval of the difference between these expected means is $11.7 - 6.6875 \pm 2.606 \times \sqrt{0.06611}$ or (4.342, 5.683).

Similarly, **Table 15** shows that there is no difference in evaluating features by evaluators within stages in Example 10. It is reasonable to group features in each stage to each other and using the method of comparison between two treatments of a feature as above.

5. Conclusion

It is dealt with this chapter the useful methods for choosing important features and supporting decisions of a given decision information system, presented in Section 2. The methods of ANOVA are introduced in Section 3 to evaluate features from the extent of an MIS.

The demonstrations of using such methods, through examples and case studies in Section 4 at our Faculty of Information System—University of Information Technology, showed that the efficiency of the proposed methods. The illustrated calculating schemes allow designing and coding computer programs for solving the above problems automatically.

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Chapter 5

An Enterprise Computer-Based Information System (CBIS) in the Context of Its Utilization and Customer Satisfaction

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Additional information is available at the end of the chapter

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Abstract

Information systems is the study of technology, organizations, and people. An enterprise computer-based information system (CBIS) is type of technology where people can buy and sell their items online, therefore, it is a part of the online business process. This relationship has resulted in the reengineering of the information systems' model, the formulation of new requirements for training and education, and opening new investment windows for the development of new technologies at both the computer hardware and software application level to meet the needs of newly emerging business models. The aim of this chapter is to provide a comprehensive survey on enterprise CBISs in the context of its utilization and customer satisfaction.

Keywords: enterprise CBISs, information systems, customer satisfaction, online systems

1. Introduction

An enterprise computer-based information system (CBISs) have an important role to play in the digital economy as well as being a vibrant research area. It is considered to be a unique online platform that offers tools and capabilities for marketing, communication and retention of consumers [1]. Unlike supply chains, an enterprise CBIS can be defined as an inter-organizational technological and online information system that permits the contributing purchasers and vendors in a number of markets to exchange information about cost and goods assistance and carry out business transactions. It assists possible trading partners to find each other and transact. In addition to being significant from a practical perspective, enterprise CBISs have

made a key impact on the electronic business (eBusiness) area from both the company and the customer's perspectives, as both have benefited from the emergence of enterprise CBISs with its main goal being to facilitate business transactions using an efficient and effective approach. It is clear that enterprise CBISs offer a more practical and well-defined business model for organizations to compete in the contemporary digital economy [2, 3]. Despite the rapid development of enterprise CBISs, it is noted that in many cases, they are under-utilized and face early closure due to various technical or cultural obstacles [4, 5].

In general, enterprise CBISs can be categorized from various perspectives relating to their utilization: the independent enterprise CBIS, the buyer-oriented enterprise CBIS, the supplier-oriented enterprise CBIS, the vertical enterprise CBIS, the horizontal enterprise CBIS and the hybrid enterprise CBIS.

This chapter aim is to provide a comprehensive survey on enterprise CBISs in the context of its utilization and customer satisfaction. It covers the concept of the enterprise CBIS, including its background, definitions, challenges, motivations, importance, types and enterprise CBISs research trends. The rest of the chapter is structured as follows: 1) Section 2 provides the background of enterprise CBISs, Section 3 reviews definitions of enterprise CBISs, Section 4 presents the importance enterprise CBISs, Section 5 identifies the strengths and limitations of enterprise CBISs and Section 6 discusses the categories of enterprise CBISs.

2. Background of enterprise CBIS

The utilization of the digital economy in the late '90s caused the disappearance of intermediaries between customers and vendors. A vendor could sell company goods and services directly to a customer without the need for a middle man [6, 7]. Beside the advance in the growth of the digital economy technologies, novel types of enterprise CBISs were established which contributed new value-added services, attracting many new customers and vendors with extra services that facilitate the required business transactions [4, 8, 9]. The development of enterprise CBISs has changed the way traditional business is performed, resulting in new business models, which were developed in the late 1990s. The enterprise CBIS is the result of employing innovative technology in business processes. Overall, the deployment of enterprise CBISs is associated with the eBusiness process of reengineering, linking IT/IS technologies with traditional businesses [10, 11]. It requires a change of management principles and practical alignment between IT/IS technologies and business processes, all of which should be considered for the successful implementation of enterprise CBISs.

While there are many advantages and opportunities for enterprise CBISs [4, 12], cases of the ineffective employment of enterprise CBISs, from both the customers' and vendors' side are reported [6]. If the services of an enterprise CBIS contractor do not add any value to the customer/vendor, in the long term, they will decide that the enterprise CBIS is not the best way for them to conduct business. Lacking an adequate critical mass of customers will lead to the eventual shutdown of that particular enterprise CBIS. Similarly, an insufficient number of buyers in the enterprise CBIS will reduce the incentive for vendors to join the enterprise CBIS, as there will not be enough customers to whom they could advertise their goods or services.

The contemporary literature on enterprise CBISs describes many different eBusiness models of enterprise CBISs [12]. Today's enterprise CBIS practices support many different processes between a customer and a vendor. A number of enterprise CBISs support only the aggregation of supply and demand, and the searching and matching of customers or vendors [13]. In addition, different enterprise CBISs support different types of auctions and negotiations. On the other hand, not many enterprise CBISs support the entire trade process such as contracting, logistics, insurance, finances, legal and payments [6].

3. Definitions of enterprise CBIS

In today's advanced technological world, the problem of eBusiness implementation and utilization remains one of the top concerns of business and IT executives in an organization. There are various definitions of enterprise CBIS in the existing literature, the most prominent ones from the following authors [11, 14–29].

In this chapter, we use the definition of the enterprise CBIS provided by Reynolds et al., who defined it as "a single set of hardware, software, databases, networks, people, and procedures that are configured to collect, manipulate, store, and process data into information" [30]. This definition of the enterprise CBIS is apt for a number of reasons. Firstly, it highlights all the factors involved in the enterprise CBIS research area, representing both 'what' and 'why'. Secondly, it refers to the purpose of these enterprise CBIS factors, including their aims and objectives. Lastly, the definition involves different important players participating in the utilization of enterprise CBISs together with the consideration of its different transactions.

4. Importance of enterprise CBIS

It is anticipated that no business today will remain untouched by the emergence of the digital economy. The main role of enterprise CBISs in today's rapidly changing business environment is to bring market players together to execute real-time exchange transactions, for example cost and product stipulations, and facilitating teamwork and network synchronization. The key idea is that a group of customers and vendors transact in a single online platform, allowing member organizations to take advantage of greater economies of scale and liquidity; and to purchase or sell anything easily, quickly and cost effectively. In addition, enterprise CBISs can help companies transcend geographical barriers, and grow globally to attain profits in emerging markets that were once unattainable [18–20].

Furthermore, the promising roles of enterprise CBISs include aggregating and matching customers and venders and providing inter-business organizational market information [31]. It performs similar business transactions to conventional marketplaces, such as matching buyers and venders, facilitating transactions, providing institutional infrastructure and offering capability, but with increased effectiveness and reduced transaction expenditure.

The main function of B2B enterprise CBISs is to enable information about the market and transactions to flow more efficiently. Usually, a buyer has to set up connections and associations with

many suppliers, who frequently use different IS and technologies, and vice versa. By utilizing an enterprise CBIS, the customer needs to create only one link with the enterprise CBIS, which provides a link to all the vendors on a system that shares similar standards. The enterprise CBIS offers a virtual space where customers and venders can come together to discover new business opportunities. The objective of the enterprise CBIS is to draw together as many buyers and venders as possible. Buyers bring purchase requirements while venders offer products or services. The enterprise CBIS will then match purchase requirements against selling offers, enabling the participants to undertake new exchanges [27, 32–35] Strengths and limitations of enterprise CBIS.

The development of IT/IS technologies and telecommunication allow the digital economy to flourish, allowing its customers to transact with a minimized cost. The ongoing improvement of IT/IS technologies and telecommunication increases the efficiency of enterprise CBISs. For instance, many recent developments in ICT have focused on improving the security of enterprise CBIS payments, which increase customers' confidence carry out business transactions on enterprise CBISs all over the globe [19, 20].

There is no doubt that the Internet has had an unprecedented impact on the digital business world. This is because of the noticeable advantages for both vendors and customers in comparison with conventional means of engaging in commercial activities. Despite these advantages, there are also disadvantages of conducting digital business on the Internet, such as security breaches to communication or confidentiality [36, 37].

4.1. Strengths of enterprise CBIS

Through the utilization of enterprise CBISs, SMEs stand a better chance of competing with larger organizations. Simply being connected to the Internet 'highway' provides the exposure that SMEs are otherwise unable to achieve [38]. In addition, unlike a physical organization which employs 'bricks and mortar' employees who need salaries, a work schedule, holidays, etc., an enterprise CBIS can offer their goods 24 hours a day, 7 days a week with lower costs [6, 32, 33]. Consumers are not restricted to particular business house and are thus able to attain information and place orders anytime, anywhere [12, 32].

Another advantage of enterprise CBISs is the facilitation of International transactions. The networked enterprise CBISs are not restricted by borders, nor do they belong to anybody and access and publication material costs are extremely low. Communication between a customer/vendor located at the opposite ends of the world is as simple as one click. Any vendor now can trade goods globally with less effort via the utilization of enterprise CBISs [12, 39].

In addition, the reduction of execution costs is also considered an advantage of enterprise CBISs. With reduced personnel required in enterprise CBISs, the costs of running an enterprise CBIS will also be lowered. This can provide an opportunity for businesses utilizing the enterprise CBIS to better optimize their assets [36, 37]. Furthermore, enterprise CBISs can offer comparison shopping. Customers are able to utilize online search engines and compare prices to select a product at the best price possible.

Another advantage of enterprise CBISs is their ability to provide detailed product information. There are limits to the amount of information that can be displayed in physical stores.

Customers may need detailed information about certain products that is difficult to provide. Providing such detailed information has been made easy with enterprise CBISs [40]. Moreover, enterprise CBISs can also create more efficient and targeted advertising to attract consumers. Compared to physical marketplaces, enterprise CBISs are able to keep detailed data on consumers as well as information on their shopping preferences to direct future communication and provide relevant offerings based on the customer's data. Customer information can be obtained by using all available data for example, customer location, the type of browser and operating system, the website they use to access the enterprise CBIS and their online behaviors/activities. This can help enterprise CBIS vendors maintain efficient communication with customers [25–27].

The facilitation of transactions is also considered an important advantage of enterprise CBISs [2, 10, 41]. This involves the process of matching the customers and vendors, for example, a customer with specific interests could easily establish a relationship with a vendor who supplies the desired products. This relationship can be long-term and the customer of the enterprise CBIS will have the opportunity to receive updates on the desired product. For example, a customer interested in a specific mobile make and model can register on the enterprise CBIS of the vendor who supplies that specific model to establish a relationship and initiate a transaction. The customer in this scenario will have the advantage of reviewing the product information prior to purchasing, before finalizing the transaction. On the other hand, the vendor will be able to record the customer's interests, provide the required services and send future updates. Thus, the ability of enterprise CBISs to facilitate transactions in this way could have the potential to build stronger relationships between customers and vendors, thereby resulting in the better utilization of enterprise CBISs [3, 8, 15].

4.2. Limitations of enterprise CBIS

Fraud is a rising concern when utilizing enterprise CBISs. It is widely accepted that the use of the Internet and enterprise CBIS systems has created new fraudulent possibilities [16, 17]. This is due to a lack of a direct contact, and in some cases, a customer may deliberately provide an incorrect identity and details to the vendor. Identity theft incidents in 2006, as a result of providing false information on the Internet, cost an estimated $50 billion US dollars to businesses in the USA. It was also found that with the increased number of online users, it has become difficult to report every incident in a timely manner.

The utilization of enterprise CBISs' also raises issues related to security, especially the security of the user's data. Unlike physical markets, enterprise CBISs are required to keep customer data safe from being exposed. Similar concerns are raised in relation to connecting to a community network where other users can possibly access private data. It is difficult for new companies which are utilizing enterprise CBISs to handle such threats unless they are supported by experienced employees or partners in this field. In addition, the costs involved in employing skilled IT staff and purchasing the hardware/software required to maintain a safer enterprise CBIS may be prohibitive for some vendors [2, 10, 12]. According to Al-Otaibi and Al-Zahrani [42], 70% of consumers in the Kingdom of SA are of the view that security is their major concern when it comes to buying or selling online [42]. This is especially so given the fact that to buy from the enterprise CBIS, personal details such as name and account details

are needed. Of major concern is the disclosing of credit card details. Another study found that the majority of online customers believed that current advancements in security features, including encryption and other techniques, are not sufficient to lower their security concerns [3, 9]. Furthermore, potential enterprise CBIS customers might be worried that vendors can gather sensitive information without their knowledge that could be used in the future to cause discomfort and frustration.

Uncertainty regarding the reliability of enterprise CBISs was also found to be a disadvantage for customers. With a lack of human contact (such as feeling and touching the products being offered), reliability in this sense means the dependability of enterprise CBISs, where customers believe that information about the product being offered is accurate and precise. Gommans et al. [43] added that such uncertainties could prevent prospective enterprise CBIS customers from engaging in and transacting with the enterprise CBIS. Therefore, it is important to consider such concerns in order to gain customers' confidence and meet their expectations.

5. Categories of enterprise CBIS

The literature discusses several different categories of enterprise CBISs. An independent enterprise CBIS is typically a B2B online platform purposed by a third party, which is open to sellers in a specific industry. The B2B enterprise CBIS involves a wide range of communications between businesses, including sales as well as the purchase of services, business resources, IT, manufactured parts and mechanisms and capital equipment. In order to set up an efficient purchasing environment, an association of buyers may choose to run a buyer-oriented enterprise CBIS. If buyers are looking to purchase or participate in enterprise CBISs' activities, this type of enterprise CBIS can help lower administrative costs and assist them to obtain the best price from suppliers. A supplier-oriented enterprise CBIS is set up and operated by a number of suppliers who are seeking to create an efficient sales waterway via the Internet to a large number of buyers. A vertical enterprise CBIS provides online access/contact to businesses vertically up and down each segment of an industry sector, for example, automotive, chemical, textiles or construction. A horizontal enterprise CBIS is a set of assorted business and government entities assembled according to a universal need for selected goods and services. **Table 1** presents a summary of these categories of enterprise CBISs [10, 41, 44–62].

Authors	Category of enterprise CBIS	Focus
Laudon and Traver (2007), Lucking-Reiley and Spulber (2001)	Independent	B2B transactions eliminate those involving homes, such as trade sales, inter customer exchange, and service.
Nepal et al. (2011)	Independent	By registering on an independent enterprise CBIS, companies can access top-secret requests for quotes or bids in the business industry.
Popovic (2002), Bakos and Bailey (1997), Yoo et al. (2013)	Independent	The authors categorized B2B enterprise CBISs according to their ownership arrangement and their industry focus.

Authors	Category of enterprise CBIS	Focus
Kaplan & Sawhney (2000), Campbell et al. (2013)	Independent	In disparity, independent enterprise CBISs are built by a small number of business industry agents (purchasers or sellers), typically leaders that dictate their particular industries.
Evans (2003)	Independent	The idea of two-sided enterprise CBISs refers to circumstances where one or many competing platforms give services that are employed by two types of trading business partners to interrelate and facilitate an exchange.
Bakos and Bailey (1997), Mancini et al. (2006)	Independent	Classifies web intermediary services into four categories: aggregation of purchasers and sellers, trust improvement between participants, market facilitation, and matching of purchasers and sellers.
Turban et al. (2002), L. Xiao et al. (2014).	Buyer oriented	A buyer-oriented enterprise CBIS is usually run by an association of buyers in order to set up an efficient purchasing environment.
Kösling (2001), Sila (2013), Mesaros (2010)	Buyer oriented	Procurement cycles can be abbreviated and also be supported by auctions and buy volume can be packaged up from interior business departments and from partner business organizations.
Smart and Harrison (2003)	Buyer oriented	Minimizing process costs is the maximum potential of eProcurement.
Singh et al. (2005), Turban et al. (2002)	Supplier oriented	A supplier-oriented enterprise CBIS is set up and operated by a number of suppliers who are seeking to create an efficient sales waterway via the Internet to a great number of buyers.
Turban et al. (2002)	Supplier oriented	Products can be sold directly to the consumer without any need for intermediaries.
Bierregaard (2002), McCuiston et al.(2001)	Supplier oriented	Companies sell extra products and business consumers can therefore realize huge discounts.
Bakos and Bailey (1997)	Vertical	Vertical enterprise CBISs provide online access/contact to businesses vertically up and down each segment of an industry sector, for example automotive, chemical, textiles or construction.
Bygdeson and Gunnarsson (2000)	Vertical	A vertical enterprise CBIS spans up and down each segment of one specific industry sector.
Kaplan and Sawhney (2000)	Horizontal	A horizontal enterprise CBIS is a set of assorted business and government entities assembled according to a universal need for selected goods and services.
Reinking (2000), Andoh-Baidoo et al. (2012)	Hybrid	In this category of enterprise CBISs, researchers combine both the vertical enterprise CBIS and the horizontal enterprise CBIS to add further value to businesses.
Lee et al. (2014)	Horizontal	In a horizontal enterprise CBIS, industries can be used for functions for example distribution, management, material, purchasing services etc.
Lee et al. (2014)	Vertical	In a vertical enterprise CBIS, professional information should support industry work process.

Table 1. Categories of enterprise CBISs.

Due to the dynamic business environments, enterprise CBISs are not strictly categorized according to **Table 1**. For instance, hybrid enterprise CBISs that combines both the vertical enterprise CBISs and horizontal enterprise CBISs can add further value to businesses.

6. Discussion and implication of CBIS

Despite all the possible advantages of IS in the context of online businesses today, the research in CBIS has narrowly focused on the cost related aspects. For instance, lack of customer satisfaction and unmet customer expectations are important inhibitors for online business growth. Trust is also another important aspect of CBIS utilization. Possible risks related to the opportunistic behavior of traders are a traditional reason of higher transaction costs in the CBIS environment, and demonstrates the need for CBIS techniques that build trust.

Two major contributions can be derived from this chapter. Firstly, for CBIS researchers, this chapter presents a detailed survey and useful background information on CBIS. Secondly, for CBIS stakeholders, this chapter suggests that for CBIS utilization and customer satisfaction, the three main pillars, i.e. customers, companies and CBIS regulators are needed. This study also categorized CBIS into several categories namely, independent CBIS, buyer oriented CBIS, supplier oriented CBIS, vertical CBIS, horizontal CBIS and the hybrid CBIS. Depending on the specific needs of the companies, they can employ any type of these CBIS. For example, large organizations that have sufficient resources would own say, a vertical CBIS with a multi-tiered system comprising many suppliers. On the other hand, a group of buyers may choose a buyer-oriented CBIS as a platform for finding the best procurement options. However shorter product life cycles and the demand for a larger number of derivatives have driven companies to be adaptive as well as responsive to the volatile environment. This suggests that they may need to consider a hybrid type of CBIS, which provides the benefits of both say the vertical and horizontal CBIS. Research on CBIS categories also ignores important aspects of customer needs and activities that may neutralize many of the hypothesized competitive benefits of fundamental firms. For instance, consumers who need instantaneous satisfaction may be unenthusiastic to rely on CBIS vendors who ship products by courier. Therefore, in this context the hybrid CBIS category involving the use of both virtual and physical presence to attain the needs of purchasers may be a better option.

Without any of the three pillars of CBIS as mentioned earlier, it is unlikely that the CBIS will be sustainable. A CBIS regulator plays a major role in the CBIS industry as they set the rules and regulations in order to control the CBIS applications. In some countries such as Saudi Arabia where there are many regulations relating to culture and religion, CBIS regulators have a huge effect on the sustainability of CBIS. Hence CBIS owners (or operators) need to consider the influence of this pillar. Obviously, the customer as a second pillar of CBIS also plays a very important role for its sustainability, without these pillars the CBIS will not function. Earlier customer focused CBIS research were mainly on the operational, implementation and adoption aspects of CBIS. However, with the introduction of Service Science Management and Engineering (SSME) by IBM, there is a now a focus on value (customer perspective) and value co-creation between stakeholders. Similarly, the company as the third pillar is also equally important. Together these three pillars should work together to co-create value for the stakeholders.

7. Conclusion and future trend

The existing literature in the field of the enterprise CBIS has indeed left doors open to identify the benefits and opportunities that may be gained in the future [2, 10, 12–14, 31, 38].

The current literature presents numerous cases of both the successful and unsuccessful employment and utilization of the enterprise CBIS, for both end purchasers and vendors. Unsuccessful employment of the enterprise CBIS might be caused by unsuitable service and/or support from suppliers. If the services provided by enterprise CBIS systems do not add value for both the purchaser and vendor, in the long term, the enterprise CBIS may not be the desired platform for a successful business operation, and the organization may be forced to face early closure if it does not have the desired volume of business. This also applies to purchasers. If there are only a small number of buyers, vendors are likely to lose interest in joining the enterprise CBIS, as they will not be compensated for their business investment.

Practically, future research directions should consider the intelligent agents in CBIS. The association between the IT and intelligent agents can assure new ways for customers to search and participate in CBIS. These technological applications can improve the ability of customers to search, select, negotiate, and transact for goods that align their preferences. Certainly, software-based intelligent agents present both organizations and customers with the possibility of "artificial life"–based demonstration in dealing with online transaction complexity, crowded, increasing demand of online business markets. They also have the ability to change market structure and CBIS performance. Thus, further research on these intelligent agents is needed in order to better understand their effectiveness on obtaining the satisfaction of CBIS' users. Moreover, there should two distinct practical aspects that need to be further examined. These practical perspectives are functional and technical. The functional perspective is basically focuses in the functionality of CBIS systems and specifically required experts with business background to develop and improve the business processes. The technical perspective focuses in the programming and improvements of CBIS as software and require experts with IT background to assist in maintaining proper running of CBIS in the long terms. Therefore, both practical perspectives require independent research to avoid any confusion and assist CBIS to flourish with respects to the desired utilization.

This chapter has presented a detailed review of enterprise CBIS research. In the review, different types of enterprise CBISs were identified. Categorizing enterprise CBISs into different types can assist business owners to make informed decisions as to which is the most appropriate type for their business needs. The hybrid enterprise CBIS is probably the most flexible type of enterprise CBIS which utilizes interrelated online marketing multi-dimensional channels. It maintains transactions between enterprise CBIS platforms in different ways where every channel communicates with each other.

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Chapter 6

Digital Leadership

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Additional information is available at the end of the chapter

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Abstract

Customers are demanding services using evolving technologies, and firms need agility in the way systems are designed and delivered to quickly meet customer expectations. Such agility is in fact an organizational capability where a combination of internal and supplier/partner resources allow firms to quickly create customer value propositions and deliver value through digital services, that is, services using advanced digitization. Leadership that enables such a customer-centric and service-driven culture using technology is referred to as digital leadership. This chapter develops a 10-step methodology not only to show how an innovative value proposition moves from conception to implementation using an agile system and business architecture, but also to lead to the next set of innovations for review. This methodology, developed over four years iteratively using over 100 graduate student projects, is briefly illustrated through two case examples.

Keywords: digital leadership, system architecture, business architecture, agility, organizational capability, digital services

1. Introduction

Business transformation in an evolving digital environment calls on firms to operate at two different speeds [1]. Firms must continue to operate at the traditional speed to meet their established business market needs, while using a faster speed to explore new opportunities enabled by advanced digitization. When operating at a faster speed, firms must use entrepreneurial thinking to generate innovative ideas that create value for customers, design digital or IT-enabled services quickly using advanced technologies, and build organizational capability to deliver such services to meet customer expectations. Faster design and delivery of these digital services requires agility within the IT system and business architectures under the co-leadership of IT and business executives. This is in essence the definition of *digital leadership*—a process that

is essential to developing and sustaining a culture of innovation by bringing ideas to fruition quickly using an agile IT and business architecture. This chapter proposes a 10-step structured methodology that is customer-centric, service-driven, and agility-focused. It helps translate innovative customer value propositions into digital services that are modular to address evolving customer expectations, while ensuring that the firm has the organizational capacity to quickly deliver these services to the market with an agile business architecture.

Information technology and business leaders working together to build an agile system and business architecture is not a new phenomenon. Agility through modular software design was a critical feature of system architecture when the business focus was on seeking operational process efficiencies through digitization in the late 1970s and 1980s. The design, development, and subsequent maintenance of modular software systems has enabled "system-level" agility.

With the introduction of personal computers in the 1980s, the focus of agility became critical in the development of systems that support business decision-making. Managers were able to evaluate alternative scenarios with varying assumptions to address decision uncertainty using modularization of data, decision models (algorithmic and heuristic), and configurable user interfaces. The design of such user-driven and IT-enabled modular decision support systems enabled "decision-level" agility.

When markets demanded operational efficiencies and effectiveness to address external stakeholder expectations (e.g. faster responses to customer order fulfillment and better off supply chain management) in the 1990s, agility to share data and integrate processes across departmental boundaries became critical. The modular design of processes across the enterprise, using best practices and enterprise software, provided organizations with "process-level" agility.

With Internet and web-based technologies extending business processes into customer and supplier operations in the early twenty-first century, organizations needed agility to build better relationships with customers (e.g. tracking orders and addressing design flaws or service complaints) and suppliers (e.g. gaining access to inventories and addressing supply chain disruptions). By separating business policies or decision rules sensitive to environmental changes from the rest of business operations using customer relationship and supply chain management systems, organizations were able to build "business-level" agility.

In summary, organizations over the last four decades have used modularity in software, decisions, processes, and policies/business rules to build agility to address changing market conditions. Today, customers are demanding value creation at each of their interfaces with the organization (i.e. service encounters), face-to-face or virtual, as they make decisions related to the purchase of a product or service. Organizations therefore need modularity at the service encounter level so that they can adapt the business to changing customer expectations. In other words, organizations need the capacity to build "service-level" agility to address customer value creation through advanced digitization.

The agility built at the software, decision, process, and policy levels to meet customer needs is defined with an internal focus, that is, how best to structure an organization to deliver the final product or service. Service-level agility, however, requires an external

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and a much more granular focus, especially in a virtual environment where customers engage in their decision-making process. Each of their service encounters—as they search, review, and evaluate products before they decide to purchase, and as they address all their service needs post purchase—become critical to gain customer loyalty. Such service-level agility calls on an organization to build its capability to adapt quickly and even reconfigure its customer value proposition as customer expectations change. Any change in their expectations can cause customers to shift allegiance and move to a competitor. This makes successful completion of each service encounter (i.e. a micro-service or business) a critical organizational capability, with all such micro-services or businesses leading to the customer ultimately purchasing a product. One characteristic of this capability is the ability to mix and match organizational resources, internal and partner, to keep customers successfully engaged [2]. This chapter discusses how service-level agility can be proactively supported using a modular system and business architectures with a 10-step structured methodology.

2. A methodology to build agility in systems and business architecture

The growing use of mobile communication, social media, and the Internet is empowering customers to seek information, evaluate competitive products and services, and shift allegiances among competing firms to maximize their value. Firms have been using artifacts such as an "innovation sandbox" to allow employees, partners, and customers to develop innovative product/service ideas, and to use focused organizational resources to assess their commercial viability [3]. Such an entrepreneurial mindset often calls on a firm to "pilot test" ideas with customers before institutionalizing them as a part of the firm's regular business model. However, firms today have to move beyond the "pilot test" approach and use a sustained two-speed approach to support business agility. The two-speed approach calls for use of a "faster speed" to continually look for innovative value propositions to support the current business model or create new business models, or both. The sustained use of a "faster speed" requires agility in both system and business architectures to realign organizational resources for the design and delivery of digital services.

IT and business leaders need and entrepreneurial mindset today to develop the digital quotient [4] or organizational capability to take advantage of advanced digitization opportunities and build a high performing digital enterprise [5]. McKinsey proposes six building blocks for creating a digital enterprise: *strategy and innovation, customer decision journey, process automation, organization, technology, and data analytics*. Data analytics helps generate innovative value propositions to support the customer decision journey. These value propositions lead to digital services, that is, a mix of manual and automated processes using advanced digitization. Organizational structure and effective strategy help deliver these digital services to the market quickly to meet customer needs. While these building blocks identify several elements of system and business architecture, they do not provide a systematic approach to building service level agility using module system and business architectures.

This chapter proposes a structured approach to build agility in the design and delivery of digital services. The 10-step methodology, shown in **Figure 1**, uses five distinct "service-level" components that create and sustain value throughout the design and delivery process.

1. Service innovation and delivery (steps 1 and 10): Develop innovative customer value propositions, often co-created with customer engagement, which are reviewed/refined after implementation to sustain innovation.
2. Service operations (steps 2 and 3): Identify customer service encounters that incrementally and collectively influence customer engagement in value creation, and map these encounters to specific processes/work-flows that will operationalize these service encounters.
3. Digital service design (steps 4 and 5): Leverage advanced technology to automate select processes/work-flows to develop digital services, and build a data warehouse to analyze value created and delivered and gain keen insight into customer decision processes.
4. Service strategy (steps 6 and 7): Strategically position digital services to address a customer's competitive strategy.

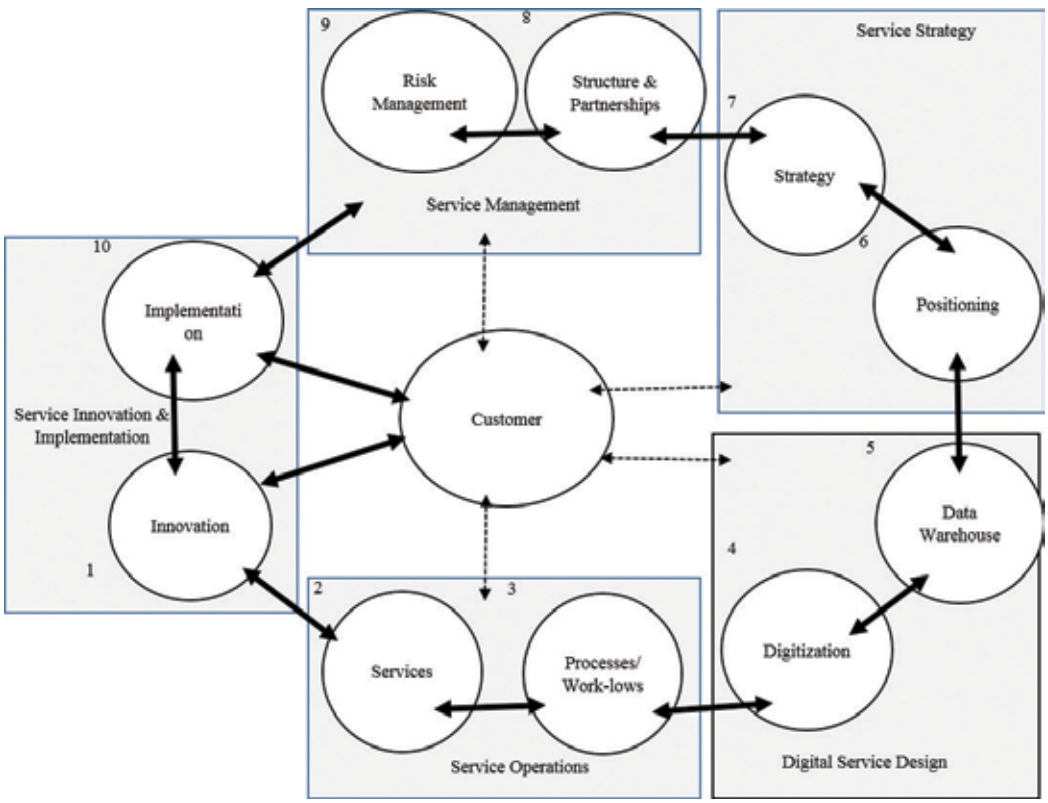

Figure 1. Digital leadership: customer centric, service driven and agility focused.

5. Service management (steps 8 and 9): Structure the management team that includes both internal employees and external suppliers/partners to deliver digital services for customer use while mitigating customer risks.

The customer focus is at the center of each of these service components. The service operations will meet evolving customer value propositions, and digital services designed will support customer engagement. The service strategy positions digital services to meet customer strategy, and service management ensures that a team of internal and external partners will deliver digital services to mitigate customer risk. In addition, as discussed earlier, service level agility is supported at each service encounter with modular system (service operations and digital service design) and business architecture (service strategy and management) to address changes in customer expectations or technologies all through the customer engagement in the purchase, design, and delivery process. This methodology is *customer-centric* in value creation, service-driven and evolving as customer expectations and technologies change and agility-focused to support configurability in both the design and delivery of the services.

2.1. Research methodology

The methodology proposed and used in teaching digital leadership is based on a combination of inductive and project-based learning.

- In 2014, a course called "IT-Enabled Innovation" was taught to graduate students that focused on how innovations supported by advanced digitization require changes to business processes and organizational capability. Twenty-one projects by a mix of full-time and working professionals led to the first change in the methodology.
- In 2015, an IT-enabled innovation was taught to 60 graduate students in France and the US, as they completed 21 projects, with half of the projects applied to real-world context. A balance scorecard was used that allowed innovation to be viewed as a by-product of a firm finding an opportunity to create customer value and studying its impact on a firm's financial performance, business processes, and people. Feedback from this experience led to the next change.
- In 2016, digital innovation to create customer value was viewed from two different and yet interdependent perspectives: technology that designs a "service" to create this value and business strategy (in all its forms: marketing, finance, operations, etc.) that delivers this value. This approach was used by 76 graduate students in France and the US in 30 different projects, with over half of the projects applied to a real-world context. Feedback from this experience finally led to the 10-step methodology discussed earlier.
- In 2017, this method was used by 26 graduate, 80 under-graduate and 14 executive MBA students in the US in 39 projects, half from real-world businesses, to further improve the methodology.

As new technologies continue to transform the way organizations (commercial, non-profit, and governmental) service their customers in all the roles they play as consumers, patients, citizens, members, and so on, some of the nuances of various steps used in the methodology will continue to be refined (e.g. how to position a service and how to mitigate risks). The next section discusses two example cases that describe this methodology.

3. Illustration of the methodology

Two example cases that provide a high-level summary of this methodology came out of the author's five-year experience in applying some of these concepts in the health care field. The health care industry is going through a significant transformation since patients have begun using advanced technologies such as the Internet, smart phones, wireless technologies, and social media to seek information and self-manage their health conditions. Hospitals in the US have also had to adapt to some of the reimbursement changes introduced by the Affordable Care Act (ACA)—with increased focus on improving patient satisfaction, reducing patient readmission, and providing sustained care under accountable care models. Continuity of care after discharge of patients from the hospitals has become essential to helping patients self-manage their health and allowing post-discharge care providers (e.g. pharmacies and rehab centers) to interact with patients and physicians in monitoring patients remotely when needed. Technologies that have shown some success inside a patient room in a hospital can be extended and integrated with systems in these external care facilities as well as "wearable technologies." This section illustrates the methodology in two cases: one at a pharmacy and the other within a patient room, with potential use at extended care facilities.

1. A smart phone that seniors can use to order prescriptions and have them delivered to their home—Prescription@Home
2. An integrated patient room technology (referred to as a "patient room robot") that can support a number of patient room activities often supported by disparate technologies such as "call bells" (to communicate with nurses), EMR (to remind nurses on medication administration and moving patients for specific lab tests), and other hospital systems (to connect patients with food service and nurses)—Robot@Hospital

3.1. Prescription@Home

Patients traditionally take their prescriptions to drugstores to have them filled by pharmacists. A pharmacist has discovered that several patients are older citizens who are often unable to come to the pharmacy to pick up their prescriptions for many reasons.

Step 1: Innovation

Consultations with older patients, physicians, and family members led the pharmacist to explore the design of a digital service (a mobile or a web-based app). This service will allow a senior and/or his family to submit their prescriptions online and have these delivered to their home. Let us refer to this digital service as Prescription@Home.

Step 2: Services

To support this service, the pharmacy should determine various customer touchpoints or service encounters. Each encounter by itself is crucial to ensure continued patient engagement and satisfaction with the pharmacy. With digital services supported remotely by apps, patients can easily move from one app to another when there are service response difficulties. For these reasons, each service encounter is evaluated using specific metrics to ensure it meets customer needs. For Prescription@Home, **Figure 2** shows the service encounters and metrics.

Step 3: Processes/workflows

Fulfilling each service encounter requires that the pharmacy design a set of processes and define workflows that move work and/or information among these processes to complete the service encounter. Each service encounter may require multiple additional interactions with the customer to accomplish the goal. For example, the "collect prescription" service encounter may be slightly different for a patient requesting a refill than for a new patient, when a patient may have to provide both a patient profile and the new prescription. For the three service encounters at Prescription@Home, **Figure 3** shows the processes/work-flows, along with the interactions with any external partners (e.g. physicians, insurance firms, etc.).

Step 4: Digital services

While the goal of digital services is to automate all the processes/workflows that support a service encounter, automation is not a prerequisite. Digitization may not support some processes/workflows (e.g. fill prescription). Therefore, the goal in this step is to decide on the type of digitization that will meet the customer's value proposition, fully realizing that there is a cost and complexity associated with each digitization. Some of these digitization opportunities may use established technologies such as access to databases and online communication, while others may use newer technologies such as sensors or mobile-based interfaces. **Figure 4** shows the digitization proposed for processes/workflows associated with Prescription@Home.

Step 5: Data warehouse

One of the expected outcomes of automation is the generation of data that is not only used to support faster communication among various processes and customer interactions (operational support), but is also used to help analyze the data against the targets associated with the service metrics (e.g. 99.99% accuracy of payment recording, 95% delivery of prescriptions within two days, etc.). In addition, the pharmacy may want to gather information about

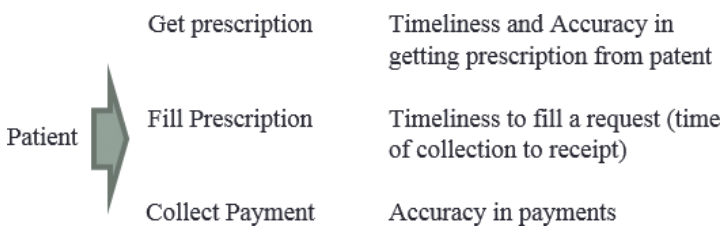

Figure 2. Patient encounter with pharmacy and metrics.

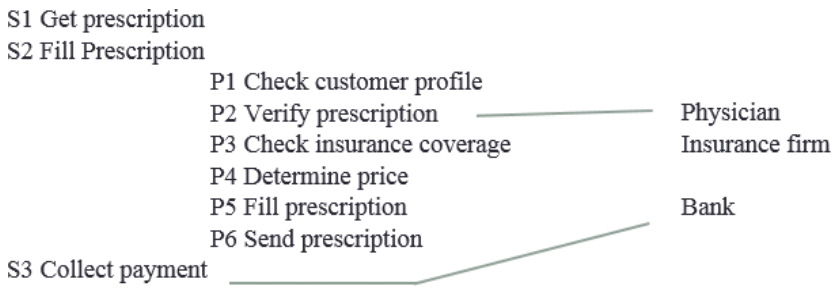

Figure 3. Service encounters with processes and workflows.

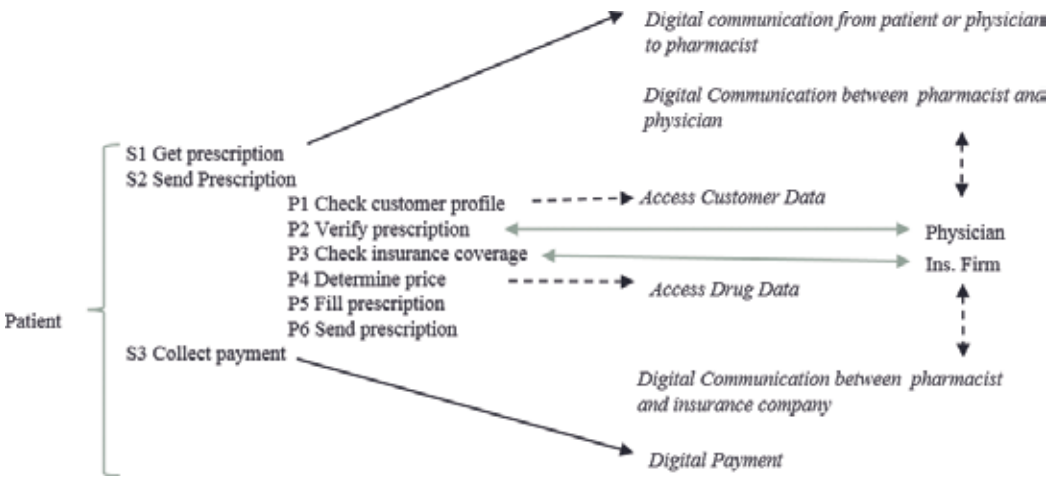

Figure 4. Digitization strategies for Prescription@Home digital service (in italics).

customer service encounters and demographic data to better segment the patients, alter service delivery times, or improve service innovations for the future.

The data gathered may be stored using relational database or other database architectures, and multiple data analytic techniques can help the organization gain insight into the decision process of customers. For Prescription@Home, **Figure 5** shows the data model used to store relevant prescription and other information needed for performance evaluation. The data items shown in blue help gain insight into patient and physician behavior, and the red data items help assess pharmacy performance against its stated metrics. The rest of the items shown in black helps support pharmacy operations.

Step 6: Positioning

Data analyzed from patients will not only help evaluate service delivery effectiveness but also address potential segmentation of customers to create additional value. In addition, the services can support select patient populations either in whole or in part, and select services can help individual patients or pharmacies. For example, Prescription@Home, in various forms, can support individual patients, nursing homes, or even physicians and nurse managers who

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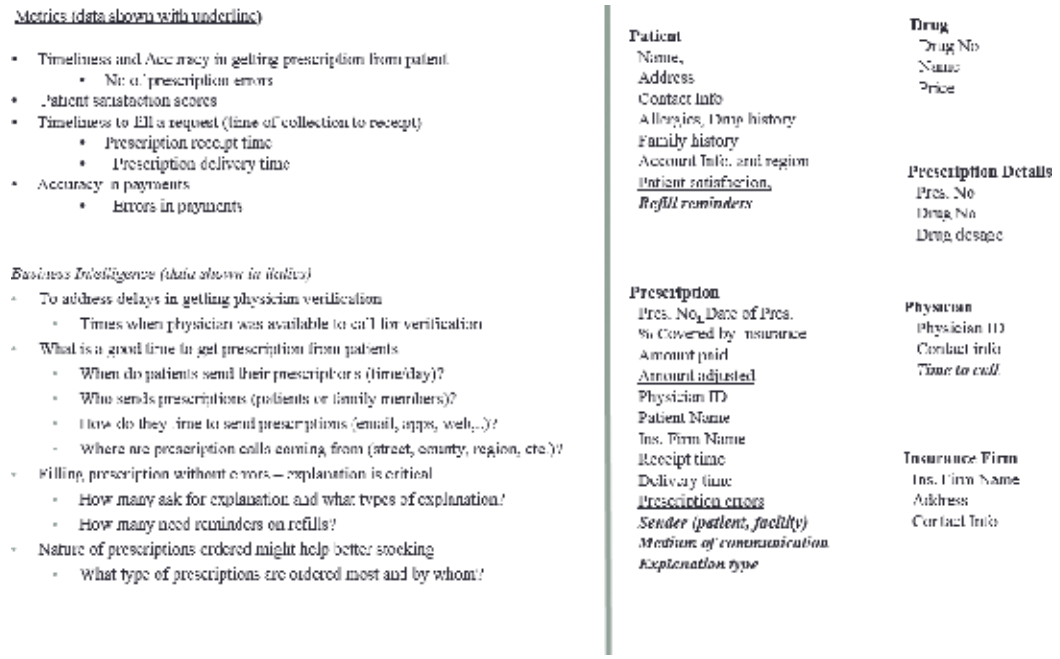

Figure 5. Data warehouse to support Prescription@Home services here.

want to provide prescriptions at their facilities. Some seniors can benefit from all services, while others may need only a few services (e.g. all but the payment option). In addition, a large pharmacy may use the new digital service to expand its reach into new markets, while another pharmacy may see it as deepening its service to its current patient market.

Step 7: Strategy

The service delivered to the individual patient or pharmacy is intended to support their competitive strategy—either cost reducing or value differentiating. Depending on the focus, one can position the service differently. Such flexibility in positioning a digital service to address differences in strategy is important to sustain competitiveness. In the example, some large pharmacies may view Prescription@Home as supporting differentiation, while others see it as supporting cost-reduction. Some individual seniors may see it as convenience (value-based differentiation), while others see it as reducing cost (e.g. gas expense) and saving time.

Step 8: Structure

The delivery of digital services to meet patient expectations rapidly will require a team of internal staff and external suppliers/partners with skills and experience that match the patient's or pharmacy's ability to adopt and implement these services. In addition, the newness of technology embedded in the digital service and the maturity of technology at the patient's home or at the pharmacy call for varying degrees of business skills and technical maturity on the part of the team delivering this service. In the Prescription@Home example, the service delivery team may combine internal pharmacy and data analytics experience with

external supplier/partner skills to collect payments and distribute prescriptions. The delivery team skills may also vary depending on the customer: pharmacy or a senior living at home.

Step 9: Risk management

The number of digital services using advanced digitization technologies, the significant gathering and use of sensitive customer data, and the use of new technology partners all contribute to risk, even if they all help support faster design and delivery of such services. These risks are classified as operational, technical, compliance, and strategic and can address patient or pharmacy risks. For Prescription@Home, the firm delivering the digital service may use established partners (e.g. PayPal or FedEx) to mitigate payment processing and distribution risks initially, use multiple layers of control to mitigate patient data risk, and use established technologies and larger pharmacies to deliver services in the early stage to mitigate operational and technical risk.

Step 10: Implementation and sustaining innovation

For Prescription@Home, the implementation strategy may use early adopters and less complex operations (e.g. refills) to build momentum for further implementation of other services. The implementation will not only address value propositions as promised to a patient or a pharmacy, but will also track expectation gaps in service design and delivery, leading to the identification of new opportunities for innovation. This becomes especially critical when digital services support multiple patient populations. Some of these gaps may also lead to identifying complementary services that can help seniors who still want to come to the pharmacy to pick up their prescription, but just want the convenience of ordering them from home.

In summary, we have discussed how the structured methodology proposed in this chapter is used to build agility in the way a digital service is designed (i.e. system architecture) and delivered for patients and pharmacies (i.e. business architecture). In this example, the service encounters are offered in sequence to complete the value proposition (collect and deliver a prescription at home). The next example illustrates how the digital services can be designed and delivered for service encounters that are relatively independent and yet offered as a mix to meet the needs of a particular customer segment.

3.2. Robot@Hospital

Within a hospital, a nurse needs to attend to many demands, such as dressing a patient's sores, administering medications, or preparing patients to be ready for transportation to labs for tests. These demands may limit the ability of a nurse to give personalized attention to a patient, and the challenge is one of empowering patients to seek assistance from something like a patient room robot. A personalized robot can tell a patient to wait for services when a nurse is busy, tell staff to wash their hands, provide educational material to a patient on treatment procedures, among others. Technologically speaking, a robot can make a "smart bed" talk to a nurse when a patient is trying to get up from the bed, remind the nurse about insulin when a diabetic patient is ready to consume food, and remind a nurse about a pain medication schedule that should be administered.

Such robotic services may not all exist today, but laboratories and companies are developing interactive robotic application and service platforms to address patient service needs [6–8]. The goal is to make robotic technology in whatever form (e.g. either as a "mobile robot in the image of a person" or simply an iPad with relevant apps) a platform to support the integration of communication and interaction among a number of caregivers and patients, even if what exists today is rather sparse [9]. We will illustrate the use of the digital leadership methodology discussed here by looking at how one might go about designing and delivering robotic services in a patient room.

3.2.1. Innovation

Many technologies are already being used in hospitals today, such as electronic badges for tracking care delivery staff, real time locator tags for tracking patient flow in the hospital, and distinct patient call buttons to request specific services (pain, bathroom support, etc.) [10]. They have become a way for patient-care delivery staff to communicate and deliver value to the patient. The discussion below provides the service system architecture used to design a patient room robot that is agile to address patient service needs. It is a combination of Steps 2–5.

3.2.2. Service system architecture

3.2.2.1. Services

We focus on four patient-care services: provide general non-clinical support, cater food, manage pain, and support patient lab visits. The primary customers for all these services are patients in a hospital room waiting for care or post-treatment during recovery and prior to discharge. The digitization of each patient service request, if handled by a nurse, can lead to too many alerts and contribute to stress (referred to as technostress [11]). While a robot can help reduce such stress, for the discussion here we will limit ourselves to value propositions that focus on patient support.

3.2.2.2. Processes/workflows

The first step in supporting each service encounter is to identify the processes/workflows used to operationalize this service. **Figure 6** identifies four service encounters and the associated processes/workflows that need execution. Note that EMR is a digital technology currently used to perform the processes in support of some of the service encounters.

3.2.2.3. Digitization

Figure 7 shows how the robot alters the processes/workflows. Here, the robot provides an integration of several of these workflows. For example, in support of lab transport, the robot monitors the electronic medical records, confirms with the lab, schedules an appointment, and communicates to all the staff. To build flexibility, the role of the robot is unbundled or subdivided into individual digital modules, so they can change if the technology or patient requirements change. For example, communicating with the lab staff is an individual module

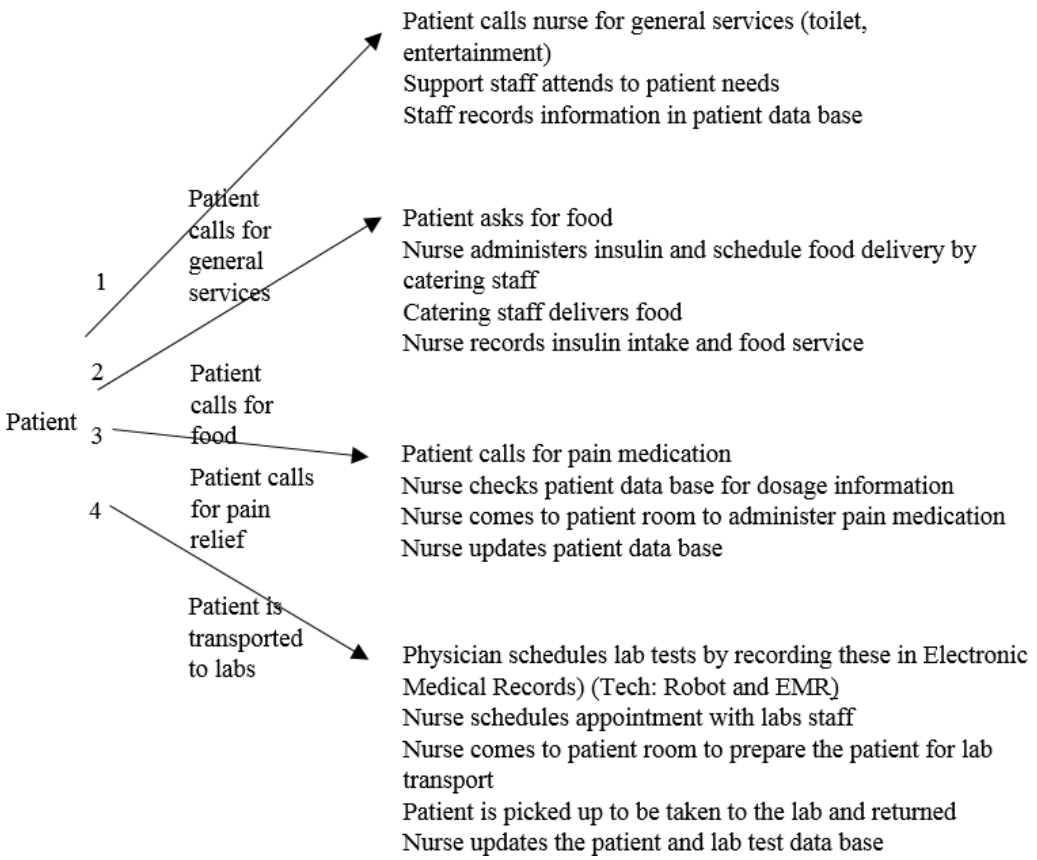

Figure 6. Patient services and process/work-flows.

and implemented as an email, a text alert, or even a phone message. Similarly, if an organization does not have transport staff and lab staff brings the transport to pick up the patient, then this module becomes unnecessary.

3.2.2.4. Data warehouse

The data for lab services include data related to diagnosis and tests extracted from electronic medical records, specific patient room transaction data (such as patient call data related to tests and lab tests data), staff contact to communicate information, calendar data to schedule tests, and so on. In addition to this operational data, the data needed to support performance evaluation includes time to fulfill a request related to the transportation of a patient to the lab, the response time of the nurse to a patient call request, the number of lab services performed, patient satisfaction, and responsiveness. Besides this performance data, one may collect other information that will help gain deeper insight into services requested by the patient (e.g. the type of tests performed and when they are performed, where they stayed in the hospital and when (before or after a major procedure), patient demographics, and the frequency of lab requests, etc.). **Figure 8** provides an overview of the service architecture to support one service (lab tests).

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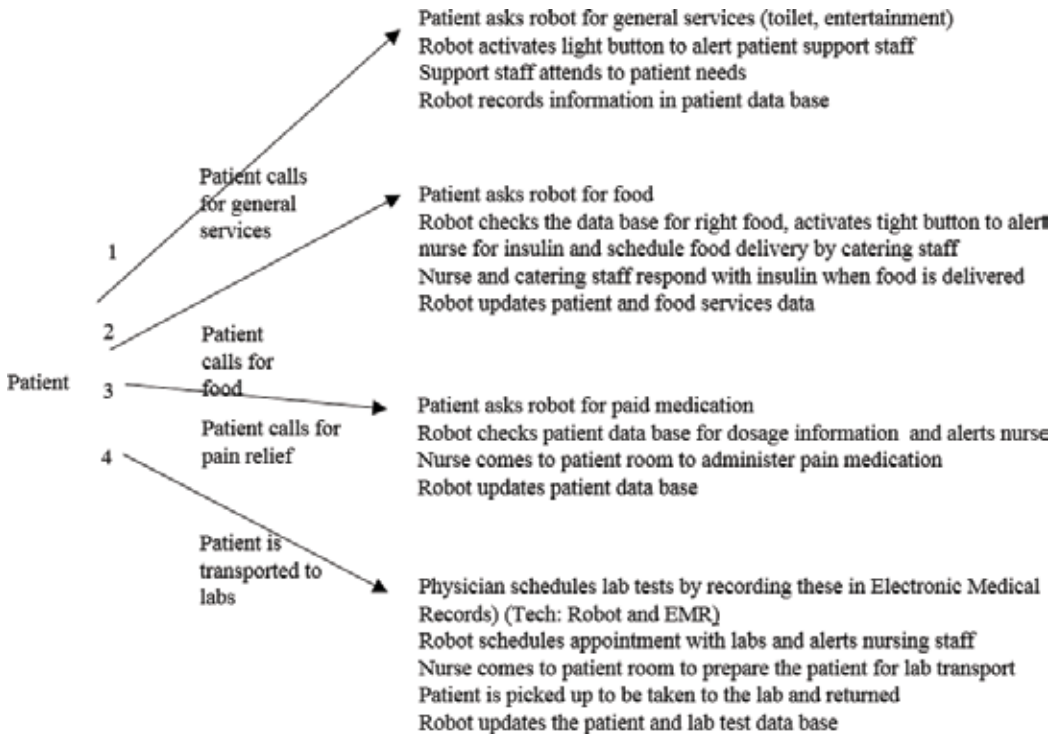

Figure 7. Digitization of processes/work-flows using patient room robot.

3.2.3. Business architecture

3.2.3.1. Positioning

The envisioned robotic services can help a hospital address different patient needs, such as providing these services to only certain rooms with critically ill patients and offering a select set of these services to skilled nursing facilities or patient homes post discharge. The flexibility of the service architecture can thus help a hospital look at its patient population and associated services and deliver them selectively to meet market needs.

3.2.3.2. Strategy

The robot will help a hospital's need for focused cost leadership. One of the unique characteristics of a digital business is the intermediate value generated by the data it creates. The data generated from the patient segments by a hospital can help it tailor its services effectively and alter room assignments and staff allocation and extend some of these services (e.g. diabetic support and lab support) post discharge. This can be useful for hospitals that want to use robotic services for value-based differentiation. In addition, the digital service provider and/or hospital can use the aggregated data to benchmark services that can reduce hospital costs, develop medical protocols for tests on patients with certain diagnoses, influence patient satisfaction at a hospital, and extend services to patients at home or at a nursing home. Some of these analyses can be a part of premium services for hospitals seeking a differentiation

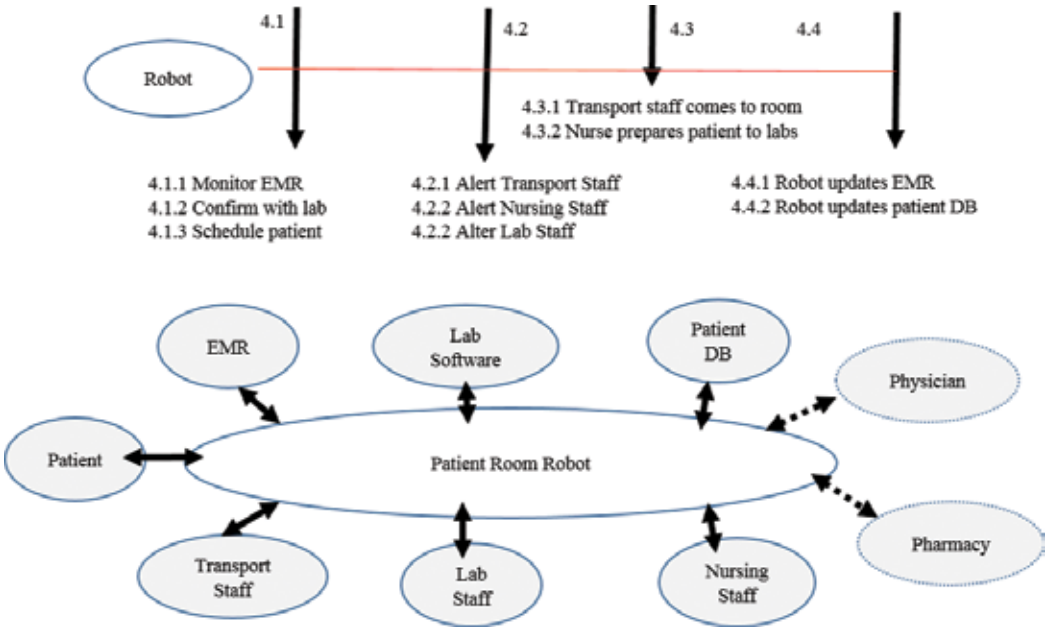

Figure 8. System architecture for service 4.

strategy or lead to the development of an entirely new market (e.g. nursing homes). In other words, the modularity in service design can help position the digital services to support either a cost leadership or a differentiation strategy.

3.2.3.3. Structure and partnerships

The patient room robot is an integrating device and needs access to communication protocols and data from a number of digital partners. For example, the robot needs a connection to a hospital's EMR and lab management, as well as staff scheduling systems (for scheduling transport staff). In addition, the robot has to connect to the nurse call systems that enable patient–nurse communication. By acting as an intermediary between the patient and the nurse, it can reduce the number of alerts using additional intelligence. Each technology vendor partnership has a differing impact on the success of implementation. In addition, the team involved in the design and delivery of the service has to be flexible to adapt to the culture and focus of the hospital, as well as the way the robot supports hospital strategy. In other words, the structure of the team involved in design and delivery, with various vendors/partners, has to be flexible as the positioning and strategy of the robot changes in responds to patient demands.

3.2.3.4. Risk mitigation

Agility to integrate digital services to meet changing hospital expectations on pricing, delivery, support, and so on, and work with partners (internal and at the customer site) to address technology and integration challenges all require an internal workforce that is adaptive and an organizational governance that is effective. Several issues surface when the robot supports

patient room operations. These include: Is there the right talent to design and deliver the services? Do the roles and responsibilities of the people involved reflect the changing market? Is there adequate security to address compliance needs? Is the technology sufficiently mature and risk free to develop the product and integrate it at the customer site? The operational risks (including talent-related challenges), technical risks (including both vendor and cyber security challenges), compliance risks (including governance and regulatory challenges), and strategic risk (including financial, reputational, and even partnership challenges [12, 13] have to be addressed using appropriate risk mitigation strategies.

3.2.3.5. Implementation

One way to mitigate some of these risks is to develop an implementation strategy that aligns with the speed with which a hospital wants to realize the value from a patient robot. Some of the implementation options here include: introducing the patient robot into a few rooms at first, integrating the robotic services to a few hospital technologies (e.g. EMR, lab management, and catering) to reduce technical risk, or offer services incrementally. In addition, the degree of stakeholder commitment to adopt robotic services may also dictate the order of implementation of these robotic services (lab tests, pain management, or dietary services).

Value propositions developed in support of patients will continue to change, and not all of them require the same type of services. For example, services needed for a cancer patient will be different from services needed for a patient who underwent a heart by-pass surgery. Technologies to detect bacteria in shoes worn by family members or staff entering a room may not be available today, but they could be useful in the future. Some patients may need a version of a patient room robot when they leave the hospital for select services (e.g. prescription reminders, follow-up physician appointments, diets, etc.). In the long run, the scope and scale of opportunities for service robots for patients will continue to increase. Patient rooms may exist not just in a hospital but also in other places such as nursing homes, individual homes, and so on. A patient may want certain services offered digitally, and some can be non-health related. Some of the services may be relevant even if a customer is not a patient by definition (e.g. people physically challenged).

In summary, both examples illustrate how an agile system and business architecture can help a hospital or pharmacy continually look for innovative opportunities to create value for its patients and use the digital leadership methodology to quickly design and deliver digital services that generate this value.

4. Conclusions

The pace of change has increased since the beginning of the twenty-first century, with the rapid introduction of advanced information technologies (e.g. Internet/Web, mobile devices, wireless communication, and Internet of Things (IoT), among others) that enabled businesses to bring customer purchasing decision-making into the business value chain. To track customer experiences and address their evolving purchasing behaviors, many new companies have entered the marketplace, with some dis-intermediating brick-and-mortar companies

and others acting as intermediaries of information aggregation and analysis. The net result of all these marketplace changes, in less than two decades, has made competing effectively quite complex.

Organizations in general are now forced to operate at two different speeds to address this complex market dynamic. The faster speed is to explore new opportunities and address threats posed by advanced digitization to their current business using innovative new products/services, and the regular speed is to continue to run the current business and adapt it to changes brought about from new products/service explorations to sustain growth. Digital leadership is an "enabling" leadership that supports continual exploration within an organization to create value for customers using advanced digitization. The digitization efforts start with a focus on creating value for customers ("customer centric") using a service lens (i.e. how does digitization lead to improved services for the customer?). These digital services are then quickly designed to help improve customer interaction, engagement, and experience, and brought into the market to create value. Such a digital leadership methodology needs a close partnership of both IT and business leaders, each driven by the customer's needs and expectations.

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Section 2

Management of Human Resources Systems

Chapter 7

The Role of Information Systems in Human Resource Management

Marlene Sofia Alves e Silva and
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Additional information is available at the end of the chapter

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Abstract

Over the last years, human resource management (HRM) has experienced significant transformations. The focus has passed from the administrative management tasks to becoming a strategic partner of the overall organization strategy, largely with the strong support of information technologies' evolution in this field of knowledge area. The extended use of information systems has a deep effect in the way HRM is managed nowadays. It boosted a major transformation of human resources (HR) processes and practices within organizations, namely on how they collect, store, use, and share information. Several HRM processes have become more efficient and the impact of this service level improvement allowed a greater involvement of HR in the business strategy. This new role in business strategy adds significant changes to HR function and to its professionals. Along this chapter, we discuss the effects of information systems in HRM, considering the existing literature on the topic, and describe the benefits and possible limitations of using them. We also provide an overview of some applications of technology in functional areas of HRM, within organizations.

Keywords: information systems, human resource management, HRIS, HR professionals

1. Introduction

Fast changing markets, industries, and services require organizational environments capable of constant adaptation with bright new ideas and reduced time-to-market. Under these

competitive reality, HRM has a more critical role than ever because new forms of business require new ways of involving people [1].

HR professionals must analyze social, economic, political-legal, and technological environment opportunities to redesign HRM processes and practices that are key success factors to the organization mission and objectives.

To respond to these challenges, HRM has been forced to adopt new logics and most HR managers must forget habits and ways of thinking and acting outdated. On the other hand, they should help organizations to define their strategies and build programs to develop their human capital [1].

In this context, information systems have increased the efficiency of HRM through more effective recruitment methods, organizational communication, employee involvement, and increased skills of HR managers [2]. From there, human resource management areas must relate human capital strategies to the most appropriate technological solutions. It means creating an eHR organization focused on interconnecting people with business strategy to achieve rapid adaptation to changing needs common to people and business. These same needs begin to make eHR necessary.

However, not all HR professionals work in strategic HRM. Many still find themselves pressured and seeing their time spent with day-to-day concerns. It is critical to get rid of the administrative burden or at least to mitigate it, to optimize your time and your contribution to the organization.

With this chapter, we intend to contribute to the definition of the role of HRIS in human resources management, as well as the role of HR professionals in this process.

2. Information systems in human resources management

In recent years, information technology has effects on almost every aspect of our society, as well on organizational processes, including HRM processes and practices [3]. From a position associated with administrative management, it has managed to become a strategic partner of organizations, largely because of the use of technologies.

"Continuous innovations in technology will fundamentally change the way HR work is accomplished" [4]. Information systems have a deep effect on HRM. It transformed human resources processes and practices mainly in terms of how organizations collect, store, use, and disseminate information.

The quality of HRM is a key success factor for organizations. The HR professional should analyze and consider the environment, social, economic, political-legal, and technological. To respond to these challenges, HRM has been forced to adopt new logics and most HR managers must forget habits and ways of thinking and acting outdated. On the other hand, they should help organizations to define their strategies and build programs to develop their human capital.

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In fact, the principal goals of HR in organizations are to attract, select, motivate, and retain talented employees in their roles, and "*technology has transformed the way HR processes are currently managed, essentially how organizations collect, store, use, and disseminate information about their HR"* [4].

Kovach et al. defines human resources information systems (HRIS) as a systematic procedure for collection, storing, maintaining, retrieving, and validating data needed by organizations about HR [5]. Tannenbaum defines it as a technology-based system used to acquire, store, manipulate, analyze, retrieve, and distribute pertinent information regarding HR in the organization [6].

HRIS shapes an integration between HRM and information technology [7]. HRIS is a management system designed specifically to provide managers with information to make HR decisions. Is a system that lets you keep track of all your employees and information about them. It is usually done in a database, or more often in a series of inter-related databases.

In this context, information systems have increased the efficiency of HRM through more effective recruitment methods, organizational communication, employee involvement, and increased skills of HR managers [2]. From there, human resource management areas must relate human capital strategies to the most appropriate technological solutions. It means creating an eHR organization focused on interconnecting people with business strategy to achieve rapid adaptation to changing needs common to people and business. These same needs begin to make eHR necessary.

2.1. Objectives

HRIS shapes an integration between HRM and information technology. Therefore, the basic objectives of HRIS are [7] (**Figure 1**):

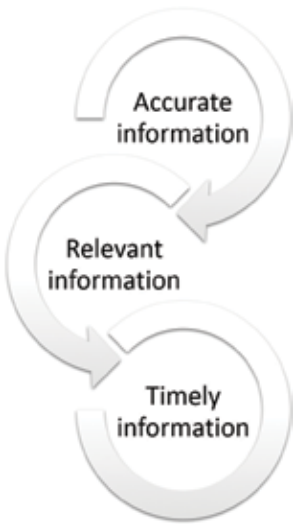

Figure 1. HRIS objectives.

- To provide accurate information about human resource and their functioning and relevant environmental factors.
- To provide relevant information.
- To provide timely information.

Organizations require information about their human resources and their functioning, but also require information from their external environment. Thereby, HRIS allows us to collect, store, manipulate, analyze, retrieved, and distribute information from internal and external environment.

HRIS in an organization should be developed in such a manner that the data stored in it can be used for several outputs. Because of these multiple uses of data, there is a need to develop a complete system of gathering, processing, and flowing of information [7] (**Figure 2**).

Chakraborty lists several examples of information that is collected from HR departments or from the surrounding environment and that makes part of HRIS, such as [8]:

Figure 2. Type of information needed in HRIS.

- Employee information (name, age, qualification, …);
- Type of employee recruited during the year;
- Training and development offered;
- Results of performance appraisal;
- Promotion, demotion, transfer, separation of employees;
- Compensation packages, both financial and nonfinancial, offered;
- Employee absenteeism and turnover;
- Maintenance, safety and health services;
- Availability of human resources from different sources;
- Training and development facilities available outside the organization;
- Expectations of human resources from the organization;
- Government policies affecting the employment conditions and labor laws;
- Trade union movement and its attitudes toward employer organizations;
- Benchmark of HRM practices.

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2.2. Components of HRIS

HRIS applications allow users to store and track all types of data that are related to HR [9]. In the research carried out by Dorel et al. is notorious that HRM was focused on collect and store personal data (records) of each employee, handle their salaries, benefits, vacations, etc. However, HR function has developed and became a very important function of management. Keeping this in mind, we can identify three major functional components of HRIS [5] (**Figure 3**).

Figure 3. Functional components of HRIS.

Input function allows us to enter personnel information into the HRIS. The maintenance function allows us to update and add new data into the database. To generate valuable outputs, HRIS needs to make the necessary calculations, and format the data in a way that it could be understood. Therefore, it is important to remember that the most important elements of HRIS is the information, rather the automation of the process or the hardware/software used [7].

In HRIS we can identify three dimensions of HRIS: operational, tactical, and strategic [10]:

- Operational human resource information system – provides data to support routine and repetitive human resource decisions (e.g. workforce, governmental regulations, …);
- Tactical human resource information system – provides data for support decisions related with allocation of resources (e.g. recruitment, job analysis, training and development decisions, compensations plans, …);
- Strategic human resource information system – provides data for strategic decisions in human resources plan.

2.3. Users

There are several users of a HRIS. So, who uses HRIS and how is it used? Essentially, we can define three groups of people: HR professionals, functional managers, and employees (**Figure 4**) [11].

Figure 4. User of HRIS.

In the HR professionals' case, HRIS helps them to fulfill the job functions, even the most elementary job tasks, like reporting and compliance, payroll and compensation analysis, benefits administration, applicant tracking, and skills inventory.

In the other hand, functional managers expect that HRIS provide data to achieve goals and objectives. They expect that the system provide information for performance appraisal and management, team and project management resume processing, recruitment and retention, training and skills testing, and management development [12].

Additionally, individual employees become end users of several HRIS applications, such as self-service, benefit options, career planning, or training and development. Boateng draws attention to the importance of web-based access and self-service portals that have simplified the use of the systems for the employees [7].

2.4. Costs and benefits

Information systems represent a major investment by the organizations. Thus, it is necessary to keep in mind the costs and benefits of implementing a HRIS (**Figure 5**).

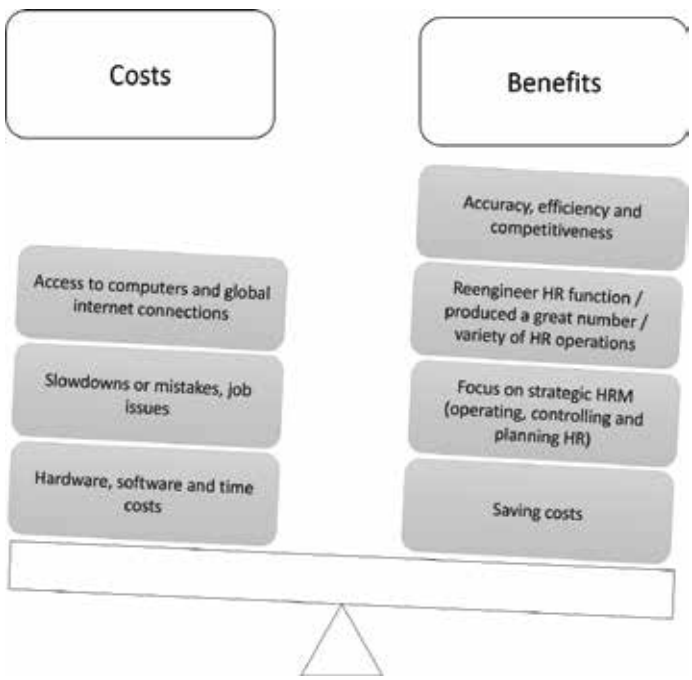

Figure 5. Costs and benefits of HRIS.

The common benefits of HRIS referred by different authors are:

- Improved accuracy [7, 13, 14];
- Provision of time and quick access to information [7, 10, 13, 14];

- Saving costs [7, 10, 13, 14];
- Operating, controlling and planning HR activities [7];
- Increase competitiveness by improving HR practices [9, 15, 16];
- Increased efficiency [10, 15, 17];
- Produce a great number and variety of HR operations [16];
- Shift the focus of HR to strategic HRM [9, 16];
- Make employees part of the HRIS [9, 15, 16];
- Re engineer HR function [16].

However, there are costs associated with a HRIS implementation:

- Employees need to have access to computers and global internet connections [7];
- Slowdowns or mistakes, errors [7, 18];
- Costly technology costs, time costs [7, 18];
- Job issues (change of tasks, need for training, change of posts, dismissal, …) [7, 9].

There are many software solutions offers, the choice it will be dependent on the decision of the user. Many types of computer-based training, internet access to the recruitment world, and the use of certain programs to assess employees in the hiring process are only available for those with technology-rich environments. The reality is that HRIS enable effectiveness and efficiency, and ensure competitiveness.

According to Hendrickson study, increased efficiency is a benefit of an HRIS [19]. Both time and cost efficiency can be addressed with the ability to do more transactions with fewer fixed resources. This can specifically be seen in areas such as payroll and benefits. In terms of accuracy, the HRIS helps in transactions. Additionally, the technology can be used to simplify processes [19].

3. The role of information systems in HRM

"Continuous innovations in technology is ganging the way HR work is accomplished" [4]. These technology developments made it possible to create a real-time information-based and interactive work environment. Personnel information systems have evolved from the automated employee record keeping into more complex reporting and decision systems [7].

In a traditional HRIS, practically we could only work administrative issues, like monitor absences, salary structures, training information, recruitment, media response, accessing to current information, medical information, and global administration.

However, we watched a break with the past and an increase in effectiveness. HRIS allows us to respond more quickly to changes and to needs of decision-making. HRIS allows budget

control, tracking and screening, skills matching, appraisals, feedback, manpower planning, succession planning, skills monitoring, training needs analysis, and global analysis [20].

The main issue is to define what are the real implications and the role of the information systems in HRM. HRIS can be applied in several areas, integrated into the HRIS system [12] (**Figure 6**).

Figure 6. Areas of application of HRIS.

According to the research of Kavanagh et al., HR professionals spend their time essentially in business process improvements, talent management processes, workforce metrics, HR strategy, workforce management and planning, and competency management [21]. We will now discuss some examples of the application of information systems in the functional areas of HRM [20].

3.1. Strategic HR management

Strategic HRM is characterized by the adoption of a dynamic vision of the resources it manages. It covers not only the planning and implementation of actions, but also the control of results, which must be related to the strategy of the organization [22]. In HRIS, we can find information at these levels:

- Environmental scanning: monitoring internal and external environments for detecting opportunities and threats that may influence organizational plans;
- Quality and productivity improvements: analysis and development to certify the development of HR quality and productivity.

3.2. Workforce planning and employment

HR planning of what the organization will need is of great importance to HR professionals, revealing different skills profiles, working schedules, enabling the organization to have the right people, in the right amount, at right time. It reflects the interests and perspectives of the organization as well as the aspirations of the candidates and collaborators [23]. The information that we can collect in this area from HRIS is, for example:

- Promotions, transfers, hiring, and termination rates: tracks data to analyze and make decisions about workforce planning and employment needs.
- Analysis and definition of work: allowing employees in geographically dispersed locations to work together.
- Recruitment and selection: ability to support processes by creating tools that are more agile and enable online work.

3.3. Human resource development

In addition to the need for work organization and decision-making, what will allow organizations to have increased levels of productivity will be the preparation of their staff and their motivation? In this sense, the development of HR will be a factor of competitiveness and even, in some cases, of survival. "*Organizational development is directly associated with the development of Human Resources*" [9, 23]. In these cases, the information that we can gather from HRIS is:

- Career development: analysis of careers, their evolution, development of career plans and the achievement of objectives outlined.
- Education, skills, and training programs: analysis and identification of competences, identification of training needs, access to training contents remotely.
- Evaluate employee performance: definition of performance goals, design of evaluation metrics, performance evaluation, and feedback of results.

3.4. Total rewards

Reward systems consist of all material and immaterial counterparts, which employees can receive, depending on the quality of their performance, the contribution to the development of the business and its identification with the values of the organization [9, 23]. HRIS allows us to identify the following information, regarding rewards:

- Salary information: salary processing, holiday management, absences and absences, automatic calculations of wage components.
- Retirement planning: identification of succession plans, pensions, streamlining of untying programs.
- Benefit administration: benefits attribution, attributed benefits analysis, cost-benefit analysis.
- Salary analysis: analysis of salary developments, salary comparisons.

3.5. Employee and labor relations

The role of HR professionals in the social relations system is considerable. They appear as a link between the organization, employees and trade unions and workers' committees [22]. HRIS can help us in different aspects of this area:

- Employee discipline records: access and management on disciplinary proceedings, disciplinary proceedings reports.
- Union and labor distribution: management of information on trade unions and workers' committees, work distribution, and analysis of work and labor relations indicators,
- Attitude, climate, culture, and commitment: possibility to automatically inquire the entire organization and perform the attitude, climate, culture and commitment analysis.

3.6. Risk management

Safety and working conditions improvement are areas with a profitability difficult to evaluate and considered as real investments for the company, being considered a specific domain of HRM. Thus, great consistency must be sought between the actions developed and the other areas of HRM [22]. HRIS can assist the risk management by analyzing the following points:

- Accident and illness: analysis of trend on accidents and illness; managing reports.
- Safety, insurance and workers' claims: agility and support to processes, records maintenance, monitoring of high-risk conditions and accidents.

4. The role of HR professionals in HRIS

Human resource management provides the guidance for an organization's workforce. "*The use of information technology (IT) in HRM is vital in order to meet organizational demands with well qualified employees and help support the organization"* [2].

Therefore, we can say that information systems have been a valuable tool for HR managers to facilitating HR processes and practices, as we have already seen. However, HR professionals have a special role in this path.

The Society for Human Resource Management [20] refers that HR professional should recognize that integrating an HRIS is a big project and a major change for the organization. Some employees (staff and even management) will resist changing and it is imperative that they are prepared to deal with the resistance.

HR professionals must support the change and facilitate the communication [20]. They need to:

- Recognize individuals may react negatively to change.
- Anticipate resistance and find ways to deal with it.
- Show commitment and a positive attitude toward the change.
- Involve people in the process.
- Ensure top management is visible and supportive.
- Remind that change is a process and successful change takes time.
- Reinforce change with incentives.
- Communicate with employees and management.

We simply cannot forget that it will take some time before success is apparent. HR professional needs to remember that HRM was limited to employee record keeping and was provided as a service to the organization [17]. The human resource function has undergone dramatic change. With global competitive success relying upon the application of knowledge, information and technology, HR professionals are now committed to engage more significant and strategic roles, improving efficiency. They become strategic business partners relying on the usage of HRIS in their job [17].

The future trends in HRIS can easily lead to confusion for organizations and HR professionals and it can cause great changes in the operation of HRM and an HRIS in organizations Kavanagh et al. Note the need to be attentive to the particularities of each context. However, they draw attention to the fact that organizations that are most successful are those who are able to leverage the technology and link it to their HR strategy [21]. In this case, HR professionals need to understand that:

- the technology of the future will be both collaborative and connected;
- there will increase the use of HR scorecards with workforce analytics;
- the automation process and the use of online analytical processing will be more used;
- will be possible to access to accurate real-time HR information due to advancements in communication tools;
- information security should be a top priority; and
- the worker of the future will be able to work anywhere, any time, and on any device [21, 24].

5. Conclusions

Increasingly, technology has a profound impact on HRM. As technology evolves, it will also force HRM to take on new contours in both its processes and its practices. HRIS emerged in response to the need for this change to be carried out in the most fruitful way possible, considering the improved accuracy, the quick access to information, the increased competitiveness and efficiency and the re engineer of the HR function.

There are still many questions about the true objectives of HRIS and the responses they allow to the real needs of HRM. It is true that there are still some limitations to its use and its results. However, its role in HRM allows us to respond more quickly to HRM changes and needs, for example, enabling to control budget, tracking and screening, skills matching, appraisals, feedback, manpower planning, succession planning, skills monitoring, training needs analysis and global analysis.

By focusing on using technology to continuously improve the quality of the work. Technology can improve the information available to HR, facilitating HR processes, and making them faster and more effective.

One of the biggest allies in HRM, HRIS is adopted to make organizations more accurate and effective. However, we face several challenges are faced. HR professionals need to prepare themselves for the future by gearing up for new roles or find themselves outsourced. HR professionals needs to integrate an HRIS as a big project and as a major change for the organization, assuming its role as business partner, as a data analyst, as an internal consultant, focused on the strategic issues of HRM, necessary for the development of people, business and organizations.

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Chapter 8

Decision-Making Problems in Sociotechnical Systems

Igor Petukhov and Luydmila Steshina

Additional information is available at the end of the chapter

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Abstract

The object of research is a human in complex sociotechnical systems (STS). A particular case of the sociotechnical system is the human-machine system (HMS). The subject of research is the professional activity of a person in the sociotechnical system, the structure of his professionally important qualities, the methods of assessing the professional suitability of a person, and the methods of training and training of operational personnel. The model of vocational aptitude and the process of decision-making in the class of hierarchical systems were developed based on the hierarchy analysis method. Intelligent processing of data was requested to be carried out by the use of decision support systems, which provides support to multicriteria decision in a complex system. The experimental research of vocational aptitude assessment for operators of transport-technological machines was carried out. The outputs of the decision support systems were obtained individual operator's portraits (IOP) and integrated estimation capabilities. As a result, it became possible to reduce the preparation cost of professionals and to raise the level of the operator's professional skills. In addition, based on the IOP, we can customize the HMC interface.

Keywords: man-machine systems, human-operator, professionally important qualities, decision-making

1. Introduction

Nowadays, it becomes evident that the future of our civilization to a great extent depends on the global community's capacity to mitigate technology-related hazards inherent to the contemporary technological level of manufacturing processes.

The objectives of technogenic safety and concerns for technology-related hazards become the issues of international importance that is proved by the specific activity of the UN Economic

Commission for Europe and by the Convention on the Transboundary Effects of Industrial Accidents signed by 72 countries.

Technological inferiority, obsolescence, and depreciation of technological equipment and its usage under potentially hazardous conditions, low qualified, and undertrained operational personnel—all these can stipulate high probability of technogenic accidents and industrial disasters practically in all the branches of production. At the same time, it is well-known that remediation of consequences even of smaller accidents costs 30 times more expensive than their prevention and preliminary mitigation of their risks.

Solution of some particular issues related to safety of separate subsystems of a technogenic object does not result in its sufficient reliability as a whole and does not meet the contemporary requirements to safety.

Thus, the modern society faces the need for a new methodological approach to ensuring comprehensive safety of a technogenic object and all its subsystems, which is the only ground for the desired effect in the scale of the whole industrial sector.

A contemporary technogenic object is a complex dynamic system being a combination of separate subsystems (that are different from each other by the elaboration level, energy type, organizational system, etc.) and connections between them.

According to this, the first objective of assuring reliability of a technogenic object is an analysis of its structure, revealing critical areas most prone to emergences and identifying the direction of the security effort.

The literature review shows that the modern concept of *reliability of technogenic objects* is based on the theory of sociotechnical systems (STS); where, *STS* refers to a complex operating system including a human-operator as its integral part, and the main objective is optimal distribution of functions between the operator and the device and their mutual complementation.

The analysis of accidence in the STS states that over 56% of accidents are caused by a human factor, and as for the STS of moving objects, their accidence index rises up to 70% including 80% of accidents caused by a human-operator (HO) working under tension, off-nominal conditions, or time pressure.

Consequently, as one of the most important STS subsystems HO in fact determines the quality of STS's functioning and restricts its performance, reliability, and effectiveness, and therefore, the problem of evaluation and assurance of HO reliability within STS is considered to be important and currently central.

An analysis of the HO's activity, evaluation of their reliability and a dynamic forecast of effectiveness of their vocational functions make it possible to assure a higher-level integration of a person with a technical or informational system, to implement a human-oriented design of newly developed STSs, and can predetermine the development of adaptive human-machine interfaces.

According to this, the first objective of assuring STS's reliability is an analysis of its structure, revealing critical areas most prone to emergences and identifying the direction of the security

effort, particularly within the distribution of functions between HO and a machine, the organization of HO's work and support of an operator's activity.

2. Issues of man: machine interaction

A significant number of research investigations are dedicated to the issue of man-machine interaction. Mostly, the emphasis is made on man-machine systems (MMS). The term *man-machine system* refers to a system that includes a human-operator, a machine, which they use for their work activity, and a working site environment. The operator's working site environment is a combination of physical, chemical, biological, and psychological factors that impact on the operator at their working site during their activity.

As for STS, we accept a wider definition of this term: systems of man-machine-environment-society-culture-nature interaction, **Figure 1**.

Therefore, in a broad sense of assuring comprehensive technogenic safety it is more appropriate to use the term *STS*, and from the point of view of assuring compatibility of a man and a technical system it is reasonable to use the concept of *man-machine system*.

HO refers to the personnel; *Machine* refers to technological equipment; *Work environment* refers to the space where they function; *Technology* refers to a combination of techniques used for modifying of a work object and including safety measures; *External environment* is everything beyond MMS that can affect the MMS's functioning and, in turn, may alter due to the MMS's functioning.

One of the system objects is a human-operator, and their involvement is determined by the following generally known factors:

- a person sets the purpose of functioning of both the control object and the operation system and controls them for attaining this purpose;

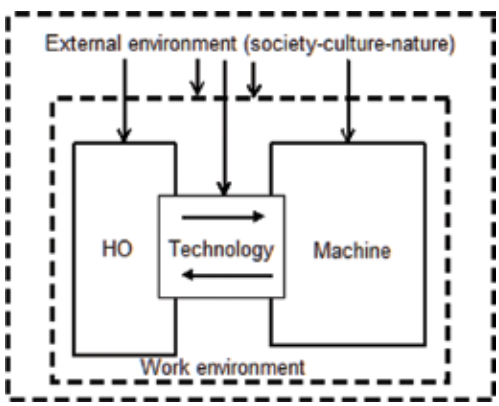

Figure 1. Scheme of sociotechnical systems.

- due to a number of reasons STS cannot be absolutely reliable, therefore the operator's involvement is necessary for control, diagnostics, search for and trouble shooting.
- due to imperfection of our knowledge about all the STS processes the external environment may produce the situations, which are called algorithmically unsolvable.

Assurance of human-operator efficiency is a sophisticated problem. From the systematic point of view, an operator is a complex, dynamic, stochastic, nonlinear, nonsteady, and self-organizing open system. In this connection, we face a challenge of revealing informative parameters that can ensure accurate and confident evaluation of the system activity as a whole. Besides, we should take into consideration the diversity of STSs implying the diversity of operational activities.

The main advantages of a man and a machine over each other are generally known and can be expressed as the following formulas:

- a man is capable to simultaneously perceive information both by separate analyzers and by their combination (sight, hearing, etc.), a man is capable to differentiate signals by their main and additional attributes; a man typically has a number of activity programs for consideration of attitudes and factors of the environment that can help fulfill operations under the conditions when it is difficult or impossible to predict the machine work;
- a machine assures high-quality programmed operations and functioning under the conditions that are impossible for a man.

It is obvious that within a firmly standardized technological process the abilities of technical systems prevail over the abilities of a man that results in developing automatic control systems. Under conditions of ambiguity and incomplete information, as well as in critical situations, the abilities of a man prevail over the abilities of technical systems.

In general, most researchers admit the dominating role of the anthropocentric approach to a man and technical systems that can be opposed to the machine-centered- or technocentric-approach.

The reasonability of the anthropocentric approach is determined by changes of both qualitative and quantitative parameters of the man and machine activities. Thus, particularly, work of the contemporary human-operator in STS is marked by the increase in the number of control objects and their parameters, in the capacity of symbolic information, in the speed and elaboration of control processes, which raise demands for operators' accuracy and response rate, their responsibility for the results of their own actions. In this context, we can observe the increase of the memory span and speed-of-response with associative mentality and brain structure interaction giving a cumulative effect in the development of human intelligence.

Severization of requirements to human-operator efficiency resulted in new forms and technologies of personnel training [1, 2], in particular, the technology of the virtual and introduced realities [3], the technology of biomechanical and cognitive support for the operator [4, 5].

The review of research literature shows that a typical causal chain of technogenic accidents is the following sequence of prerequisite events: an error of a person, equipment failure and/or an external adverse impact, emerging of a hazard (an energy or substance flow) in an unexpected

place and/or in a wrong time; absence or defects of the protective equipment intended for such cases and/or improper actions of people in such situation; expansion or impact of hazardous factors on unprotected equipment, people and/or environment; damage to human, material, or natural resources due to deterioration of their properties and/or integrity [6].

At the same time, accuracy of operator's actions depends on many factors [7]:

- tight time (frequency of errors in information processing is a logarithm function of the information rate);
- information overload (a number of errors increases by overload, particularly, when the number of information sources increases);
- qualification (operators with higher qualification make on average less errors);
- psychological characteristics of a person (for example, if a person is interested in the work they are doing, as a rule, they make less errors);
- sensory impoverishment (an increase in the frequency of errors during long-time monotonous work due to a low load of sensory receptors).

According to the statistical analysis, the probability of operator's errors in working with elaborated technical equipment may be up to 0.15, while in working with simple devices—from 0.01 to 0.05 [8].

As it was found out, principles of image formation of visual targets, a signal-to-noise ratio, and perceptive and functional complexity of images influence the effectiveness of object recognition [9, 10] and the effectiveness of operator' activities on the sensory level.

From the point of view of operator's actions, the process of decision-making is the most difficult issue, especially under conditions of imperfect information, critical situations, and tight time.

It is commonly believed that in critical situations an operator can respond using some standard procedures, or under ambiguous conditions using the procedures that include definition and development of action strategies. In such case, the probability of wrong decision-making under conditions of uncertainty is much higher [11].

The functional status of an operator makes a significant influence on proper decision-making, in particular, their stress level [12], and their emotional intelligence [13].

As it was found out, for the successful training and effective professional activity the operator should have professionally important qualities (PIQs) that are defined as physical, anatomic, physiological, psychic, and personal properties necessary for solution of their professional tasks. In this connection, numerous approaches to PIQ evaluation are developed, and they are based on testing and laboratory experiment methods and intended for simulation of an operator's activity.

At the same time, evaluation of the vocational aptitude is a sophisticated problem due to the incomplete and ambiguous information about the operator's vocational aptitude structure,

complexity of formalization of the operator's activity, numerous cross-connections between PIQs and criteria of their selection.

3. The model of decision-making on HO's efficiency

Currently, there are sufficient number of models representing HO's activity in the STS structure and their efficiency in the professional activity.

Speaking generally, it is possible to state that evaluation of the HO's vocational aptitude can be based both on the assessment of their PIQ level and on the analysis of their efficiency at different stages of the operational activity.

Such structure of knowledge about the process of vocational aptitude evaluation is related to the hierarchical structures that allow employing bulk information at the certain levels of the hierarchy.

For the purpose of representation and analysis of knowledge about the HO's professional activity in the STS structure, the process of interaction between the human-operator, the technical system, and the environment is represented as a semantic network, **Figure 2**.

As for the term of *act* within the operator's activity, we understand an act within the operator's activity as a completed sequence of individual nonrepeated operator's actions implementing a single control cycle.

According to this, further we consider the operator's activity as a cyclic implementation of such operator's acts.

Taking into account, the known division of the operator's activity into several typical stages, we can assume relevance of division of the operator's act into separate steps (Eq. (1)):

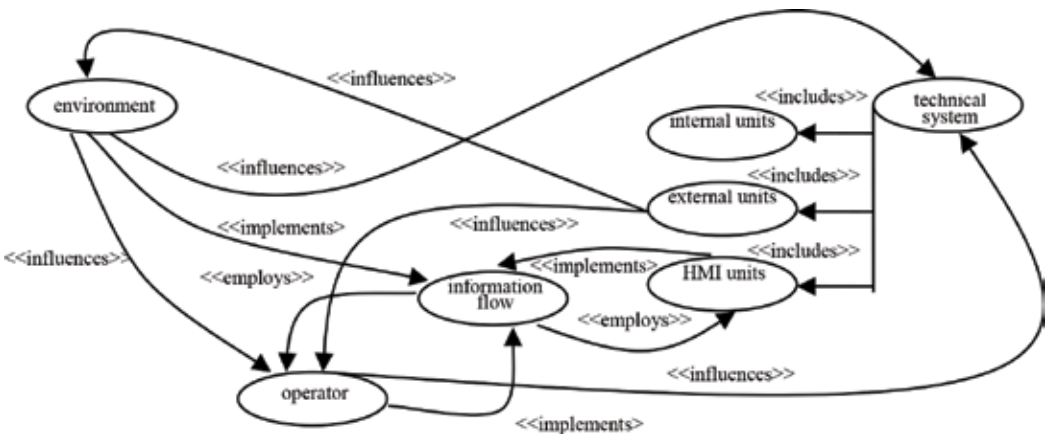

Figure 2. The analysis model of the interaction process within STS.

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$$S_t = \{S_{t_i}\}, i = 1, N \quad (1)$$

where St_i is the system element representing a single stage of the operator's activity (*system element* refers to a simplest atomic operation), i is the number of the operator's activity stages.

By means of a generalized structural analysis, the operator's activity is suggested to be divided into a set of hierarchical levels, each of them determines the modification of an operational control model [14, 15], **Figure 3**.

According to this system model, the operator's activity can be considered as sequential execution of the operator's activity stages: acceptance and perception of information, assessment and processing of information, decision-making, and implementation of the decision made.

In this model, the input data are the information from a sensory system about the control object status and the current state of the environment. At this stage of the operator's activity, the operator's actions are subject to the initial program control model.

After the input data are accepted and perceived, at the stage of information assessment and processing the data are transformed into the meaningful data. At this stage, it is possible to initiate a re-regulation process, in case if there is divergence between the accepted data and their admissible starting values specified by the program control model, and to replace the control model by interrupt control.

The control decision on modification of the control program should be made at the stage of decision-making when the situation model is constructed in dependence on the situation development.

Further, at the stage of the made decision implementation, the control impact on the system is formed on the base of the conceptual control model intended for defining the vector of the control impact for the purpose of the implementation of the further control program.

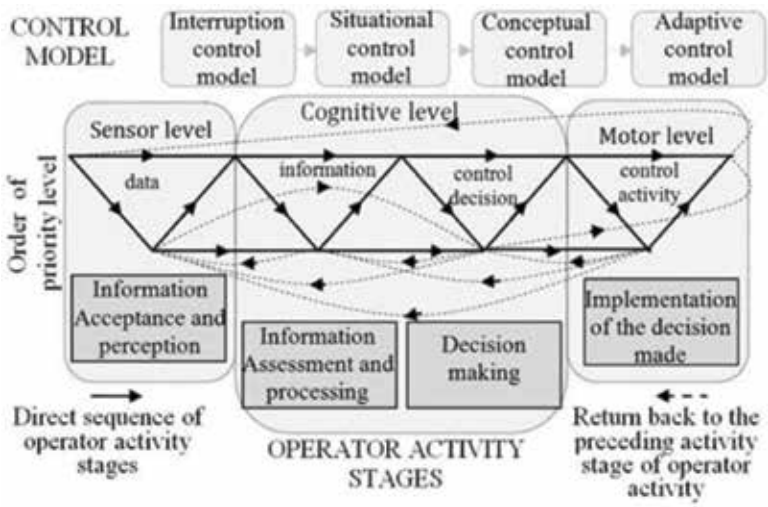

Figure 3. The system model of human-operator functions.

The outcome of this stage is the formation of the adaptive control model intended for defining the value of mismatching between the control impact made by the operator and the changes in the behavior of the control object.

The above described sequence of the actions is represented in the diagram by a solid line indicating the situation development. At the same time, it should be noted that a number of stages may be omitted when the full cycle of the operators' actions is implemented and repeated many times. Besides, it is possible to return to the previous stage of the operator's activity, or recursion. The mentioned situations are represented in the diagram by a dash line; the frequency of such situations, first of all, depends on the operator's experience and their effectiveness at the operator's activity stage. For example, if the control decision-making on the base of the available information is difficult, there is an alternative choice between decision-making under existing ambiguous conditions, additional assessment of the available information or returning to the stage of information acceptance and perception with the aim of data updating.

Obviously, the PIQ set for each certain case should be unique and depend on the specificity of professional work. Nevertheless, the diagram representing the interconnection between the operator's activity stages and the PIQs can be taken as an example for wide range of occupations related with control of moving objects, **Figure 4**.

Among these parameters the emphasis should be made on the following:

- the parameters describing the ability to sensory perception of information;
- the parameters describing the ability to the cognitive activity;
- the parameters describing the ability to the motor activity.

Among the parameters of sensory perception, the parameters describing the sight and hearing perception are the most valuable.

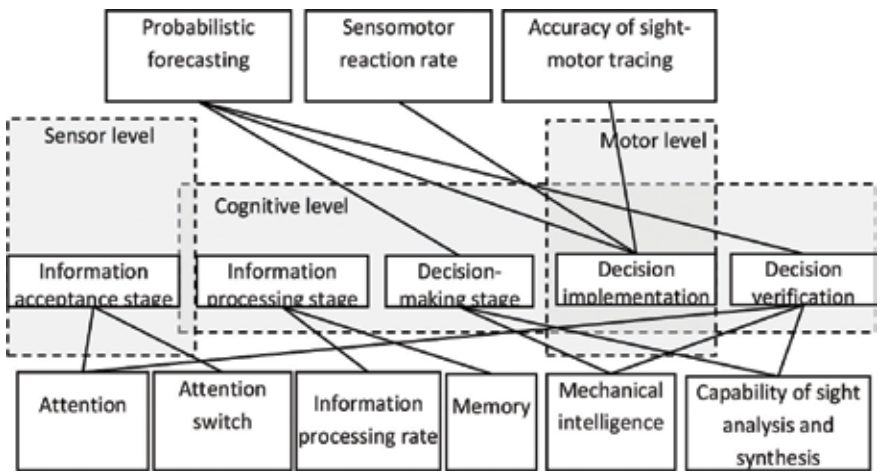

Figure 4. The diagram of interconnection between operator's activity stages and PIQs.

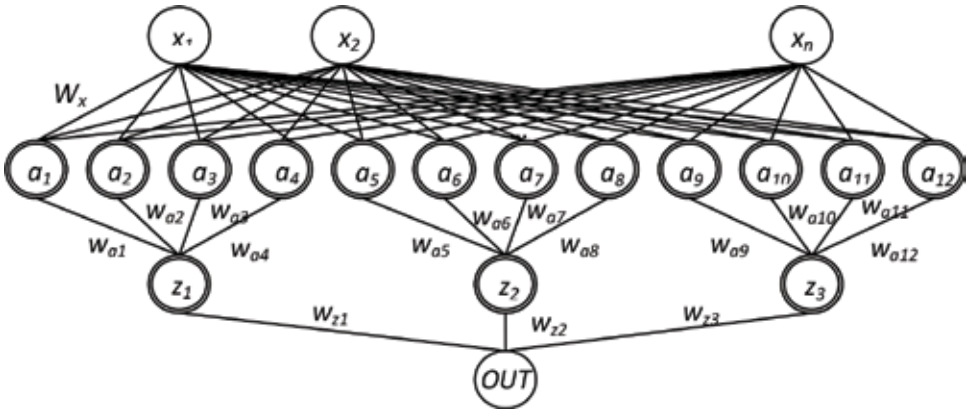

Figure 5. The hierarchical system of the logic inference for the STS operator's vocational aptitude level.

Among the parameters of the cognitive activity, the parameters describing the rate of information processing, memory, mechanical intelligence, and the ability to forecasting the situation development are the most important.

At the motor level, the parameters describing accuracy and the rate of motor program are the most significant.

The analysis of the system model and the pathways of the operator's actions makes it possible to reveal the most significant stages of the specific type of the operator's activity taking into account its peculiarities and to define a set of the operator's functions that determine the effectiveness of the operator's work in the greatest extent as well as to define the correspondence between the priority levels of operator's actions and the stages of the operator's activity.

In order to improve the confidence of vocational aptitude evaluation of the STS operator, the number of PIQs should tend to infinity. On the other side, it causes a combinatorial explosion and excessive complexity of computational algorithms.

According to this, we offer a methodological approach to evaluation of the integral index of vocational aptitude within the hierarchical system class on the base of the analytic hierarchy process; it includes the selection of 12 PIQs that are the most significant for the certain type of the operator's activity and their division into three groups: most important qualities (MIQ), important qualities (IQ), and less important qualities (LIQ), **Figure 5**.

Each group consists of its own set of four PIQs having weighting factors (Eq. (2)):

$$W = (w_1, \ldots, w_n) \tag{2}$$

The dependence of vocational aptitude value on the PIQs is modeled as follows (Eq. (3)):

$$OUT = f(P) = f(a_1, a_2, a_3, a_4, a_5, a_6, a_7, a_8, a_9, a_{10}, a_{11}, a_{12}) \tag{3}$$

on the basis of four knowledge bases that describe such dependences (Eq. (4)):

$$z_1 = f_2(a_1, a_2, a_3, a_4), z_2 = f_2(a_5, a_6, a_7, a_8), z_3 = f_2(a_9, a_{10}, a_{11}, a_{12}), z = f_3(z_1, z_2, z_3) \quad (4)$$

In other words, *OUT* is a tree root, the operator's vocational aptitude; z_1, …, z_3—nonterminal nodes, the second stage convolutions; a_1, …, a_{12}—nonterminal nodes, the first stage convolutions; x_1, …, x_n—terminal nodes, individual impact factors, and $W = [W_x = (w_{x_1}, \ldots, w_{x_n}), W_y = (w_{y_1}, \ldots, w_{y_n}), W_z = (w_{z_1}, w_{z_2}, w_{z_3},)]$—weighting factors.

For assessment of certain PIQs, we suggest employing an analytical laboratory experiment. According to it, a certain fragment of the professional activity is reproduced *in vitro*, while the rest elements are purposefully eliminated, it allows to some extent segmenting the certain stages of the operator's activity.

One of the analytical *in vitro* experiments is testing, or tests. According to the traditional terminology, *test* refers to a task used for verification of the development level of the operator's psychophysiological properties. This type of experiment is usually deployed for investigation of the impact of different conditions on certain elements of the activity.

In this case, we can formally describe the relationships between the PIQs and the assessment tests undertaken for assessing the PIQ development level as follows: $a_i = f(x_1, \ldots, x_n)$, where $(x_1, \ldots, x_n)$ are the results of the assessment tests.

The system output is an integral assessment of the vocational aptitude within the range from 0 to 100%.

In addition to it, we need assessments of the certain PIQ development level within the range from 0 to 100% marking the efficiency of the operator's functions at the different stages and constituting an individual PIQ portrait of a testee.

For this purpose, we offer the inference $A = \{a_1, \ldots, a_{12}\}$, where $\{a_1, \ldots, a_{12}\}$ are the set of certain PIQs constructing an individual psychophysiological portrait of a testee, **Figure 6**.

An individual psychophysiological portrait may be used both for operational personnel training and for adaptive adjustment of an informational and technical component of the ergatic system to the user's abilities taking into account their current functional state.

To accomplish this, the combination of individual psychophysiological portraits that provide the general vocation aptitude level "*not worse than normal*," was defined by using simulation methods.

From the point of view of assuring, the whole system reliability such conditions as "*the PIQ level is not worse than bad*" and "*the PIQ level is not worse than normal*" are chosen as marginal ones.

Under the condition $\mathrm{PIQ}_{\mathrm{ij}}^{\mathrm{testee}} < \mathrm{PIQ}_{\mathrm{ij}}^{\mathrm{norm.}} \mathrm{PIQ}_{\mathrm{ij}}^{\mathrm{test.}} < \mathrm{PIQ}_{\mathrm{ij}}^{\mathrm{norm.}} a_{ij}^{testee} < a_{ij}^{\mathrm{norm.}}$, the controlling action is formed in accordance with the set quality functional. Such controlling action is intended for operational personnel training that is for the development of the certain PIQs ensuring improvement of the general level of the operator's vocational aptitude (Eq. (5)):

$$\Delta a_{ij} = a_{ij}^{norm} - a_{ij}^{testee}, \quad (5)$$

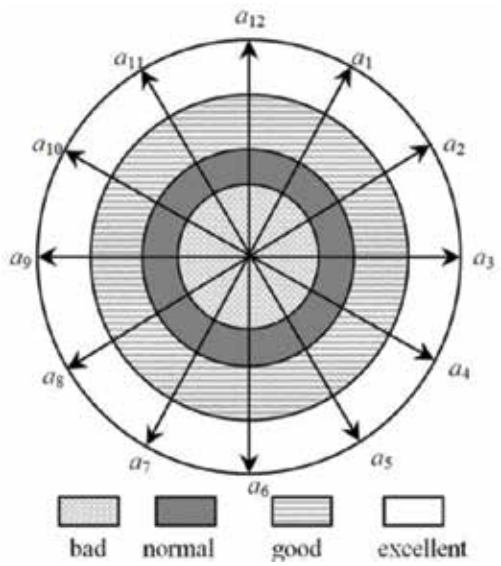

Figure 6. The individual PIQ portrait of the operator.

where $a_{ij}^{testee.}$ is the PIQ development level, a_{ij}^{norm} is the PIQ level "*the PIQ level is not worse than normal*."

So, the quality functional for practicing the certain PIQ of the greatest importance can be presented as the following (Eq. (6)):

$$J1 = \max_{ij \in k} f\left(w_{ij}, c_{ij}, \varphi\left(a_{ij}{}^{testee}, a_{ij}^{norm}\right)\right), \tag{6}$$

where w_i is a weight coefficient of the PIQ significance in the general structure of the vocational aptitude, c_i is a weight coefficient of the PIQ development difficulty that divides the PIQs into developing, conventionally developing, and nondeveloping ones, $\varphi\left(a_{ij}{}^{testee.}, a_{ij}^{norm}\right)$ is a function describing possibilities of the PIQ development in compliance with the initial level law.

The quality functional for practicing the PIQ combination may be presented as follows (Eq. (7)):

$$J2 = \sum_{ij \in k} f\left(w_{ij}, c_{ij}, \varphi\left(a_{ij}{}^{testee.}, a_{ij}^{norm}\right)\right), \tag{7}$$

At the same time, according to the initial level law, $\varphi\left(a_{ij}{}^{testee}, a_{ij}^{norm}\right)$ represents a nonlinear dependence of the possible change of the current a_{ij}^{testee} value on its relative level and may be expressed in the exponent form (Eq. (8)):

$$\varphi\left(a_{ij}^{testee}, a_{ij}^{norm}\right) = \exp\left(a_{ij}^{norm}\right) - \exp\left(a_{ij}^{testee}\right), \tag{8}$$

Practical evaluation of the operator's activity using of the hierarchical system of the logical inference for the STS operator's vocational aptitude level is offered to perform on the base of analyzing the PIQs' development level that have been defined by the test outcomes.

According to this, we face the challenge of developing a decision-making support system, which should connect local assessments from tests with the PIQ assessment and the evaluation of the operator's vocational aptitude in general.

Due to the difficulty of formal expression and structuring of the STS operator's activity both at the certain stages of the operator's activity and in general, it is proposed to use the fuzzy set theory for the operator's vocational aptitude evaluation.

The analysis of possible approaches to handle the problem of evaluation of the operator's activity shows that the use of so-called soft computing is one of the promising approaches to such tasks.

For modeling the operator's vocational aptitude, the mathematic model on the base of the fuzzy logic and the system of fuzzy inference have been developed, **Figure 7**.

In accordance with the proposed inference scheme, we can accept that on the first stage of evaluation the input variable x_i is the values of the assessment test (AT) outcomes (T_i).

We can accept the variation range of the input variable x_i as the universe of discourse. Space partition of the input variables was performed on the base of certain minimal and maximal values of the input variables—the AT values: $x_i \epsilon \left[x_i^{(min)}, x_i^{(max)}\right]$, where $x_i^{(min)}$ is the minimal

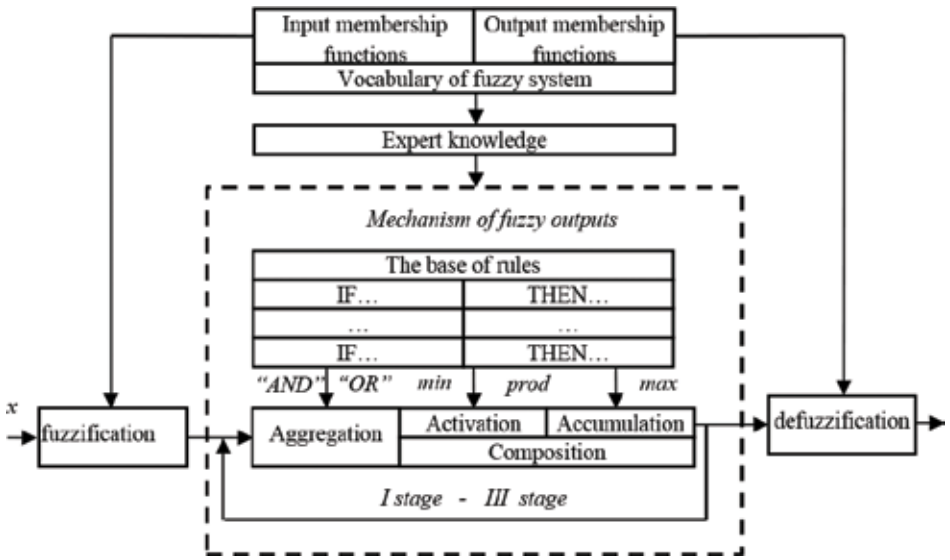

Figure 7. Structure of the fuzzy inference system.

value of the input parameter; $x_i^{(max)}$ is the maximal value of the input parameter. The membership function was preset for each part. According to the fuzzy logic theory, we can accept the existence of the crisp set X that is the universe of discourse.

In accordance with the hierarchical inference scheme, we can accept the existence of multiple pairs corresponding to the certain PIQs, (Eq. (9)):

$$T_i = \left\{ \left(x_i, \mu_{T_i}(x_i) \right); x_i \in X \right\} i = 1, \ldots, n, \tag{9}$$

where x_i is the input variable - the outcome of the T_i test, μ_{T_i} is the membership function.

The values of a linguistic variable are presented as a range of five fuzzy variables "very bad," "bad," "normal," "good," and "excellent."

As all the input parameters, $X = (x_1, \ldots, x_j, \ldots, x_n)$ make a different influence on the ultimate outcome, we used input ranking with weight factors.

The formation of a rule base for the certain operator's activity is performed by using special methods of expert assessment for each case. It allows transferring the general vocational aptitude model to the specific spheres of the operator's work. The whole process can be expressed as (Eq. (10)):

$$\begin{aligned} R_1 &: IF\ (x_1.IS.L_{11}).AND.(x_2.IS.L_{12}).AND.\ldots..AND.(x_n.IS.L_{1n}),\ THEN\ a = B_1 \\ R_i &: IF\ (x_1.IS.L_{i1}).AND.(x_2.IS.L_{i2}).AND.\ldots..AND.(x_n.IS.L_{in}),\ THEN\ a = B_i \\ R_m &: IF\ (x_1.IS.L_{m1}).AND.(x_2.IS.L_{m2}).AND.\ldots..AND.(x_n.IS.L_{mn}),\ THEN\ a = B_m \end{aligned} \tag{10}$$

where x_k is the input variables; a is the output variable; L_{ik} is the specified fuzzy sets with membership functions.

The inference scheme has been chosen taking into account that the Sugeno algorithm restricts the linearity between the input and output data, while the Mamdani mechanism allows using nonlinear membership functions. Besides, it is known that the Mamdani inference mechanism is more appropriate for expert systems due to transparency of the Mamdani fuzzy models. It is believed that the Mamdani inference mechanisms are more appropriate for applied problems, where the possibility of content interpretation is more important than simulation fidelity.

In this connection, it is proposed to present the inference on the base of the Mamdani mechanism using a mini-max composition of fuzzy sets.

As the scheme of the hierarchical fuzzy inference implies the operations with intermediate variables, it was considered to use two methods of their organization: with the intermediate procedure of defuzzification and fuzzification for the intermediate variables and without this procedure.

As according to the requirements to the decision-making support system, it is necessary to perform assessment of the PIQs; then at the first hierarchical level, we accept the scheme including two procedures: (i) the procedure of the output of inference result from the intermediate knowledge base as a fuzzy set without defuzzification and fuzzification of the intermediate

variables and the transfer of the found membership degrees to the fussy inference mechanism of the next hierarchical level, and (ii) the procedure of defuzzification of the results with the aim to construct an individual professional portrait of a testee and their PIQs.

This can assure equivalency of fuzzy sets before and after the procedures of defuzzification and fuzzification of the intermediate variables transferred to the next hierarchical level.

On the other side, this allows obtaining crisp values in the output of the first hierarchical level for construction of an individual professional portrait of a testee and their PIQs.

At the second stage, PIQ_i is used as a linguistic variable, it is preset by a range of five elements, and the fuzzy variables are preset as follows (Eq. (11)):

$$PIQ_i = \left\{ \left(a_i, \mu_{PIQ_i}(a_i) \right); a_i \in A \right\} i = 1, \ldots, 12, \tag{11}$$

where a_i is the input variable—the PIQ (PIQ_i) values, $\mu_{PIQ_i}(a_i)$ is the input value degree of membership in this fuzzy set.

The input for the third stage of evaluation is the result of the second stage output. The fuzzy sets in this case are (Eq. (12)):

$$GPIQ_i = \left\{ \left(z_i, \mu_{GPIQ_i}(z_i) \right); z_i \in Z \right\} i = 1, 2, 3, \tag{12}$$

where z_i is the input variable—the Grouped PIQ ($GPIQ_i$) values, $\mu_{GPIQ_i}(z_i)$ is the input value degree of membership in this fuzzy set.

Defuzzification makes it possible to transform the obtained fuzzy set into a crisp value by means of the known methods.

The formation of rule bases for the certain operator's activity is performed by using special methods of expert assessment for each case. It allows transferring the general model to the specific spheres of the operator's work.

4. Results

The developed evaluation system was applied for experimental research into evaluation of the vocational aptitude of the transport-technological machine operators performed in the group of 100 testees at the Interregional Forestry Resource Center (Yoshkar-Ola, Russia).

First of all, the main operator functions were singled out, **Figure 8**.

Then, according to the developed methodology, using qualification criteria, the experts identified PIQs, divided them into groups, and represented their correlation with a set of the developed and known ATs (psychophysiological tests), **Figure 9**.

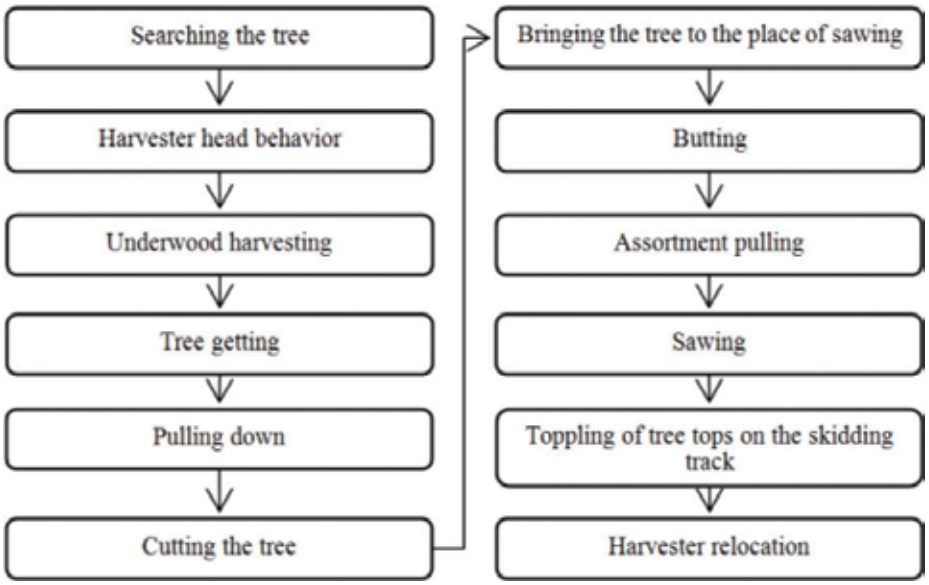

Figure 8. Correlation structure of PIQs and ATs.

Weight coefficient		PIQ	Persistence of vision	Visual perception time	Accelerating object response time	Visual analyzer lability	Ability to correct actions	Response time to the object moving towards the	Predictability	Visual analysis ability assessment	Excitement and suppression correlation	Landolt ring test	Mixed lines test	Eysenck Personality Questionnaire	Sensomotor reaction time	Nervous system strength	Nervous system instability	Fatigue tolerance during visual-motor tracking
PIQs of special importance																		
0,95	PIQ 1	Accuracy of visual-motor tracking					0,85	0,9			0,7				0,6			
0,9	PIQ 2	Speed of central processing, nervous system lability	0,7	0,8		0,9											0,8	
0,9	PIQ 3	Probabilistic forecasting					0,75	0,8	0,9									
0,85	PIQ 4	Concentration, refocusing	0,6	0,7						0,8					0,6			
Important PIQs																		
0,6	PIQ 5	Emotional stability												0,9				
0,7	PIQ 6	Emotional balance									0,9							
0,6	PIQ 7	Object identification accuracy		0,6	0,9		0,7			0,7								
0,55	PIQ 8	Attention span										0,9			0,7	0,9		
PIQs of little importance																		
0,5	PIQ 9	Attention allocation											0,9					
0,45	PIQ 10	Accuracy of visual analysis	0,6	0,7							0,8					0,6		
0,55	PIQ 11	Efficacy and fatigability																0,85
0,5	PIQ 12	Adaptive capacity					0,9										0,8	

Figure 9. Correlation structure of PIQs and ATs.

The research into the vocational aptitude included the cycles of data base compiling and the development of a rule base of the informational support system for decision-making, the procedures of assessment testing and the procedure of the analysis and evaluation of the vocational aptitude. The input of the transport-technological machine operator model comprised of individual AT assessment grades of each testee obtained at the stage of the psychophysiological tests. The vocational aptitude value of each testee expressed in percents and

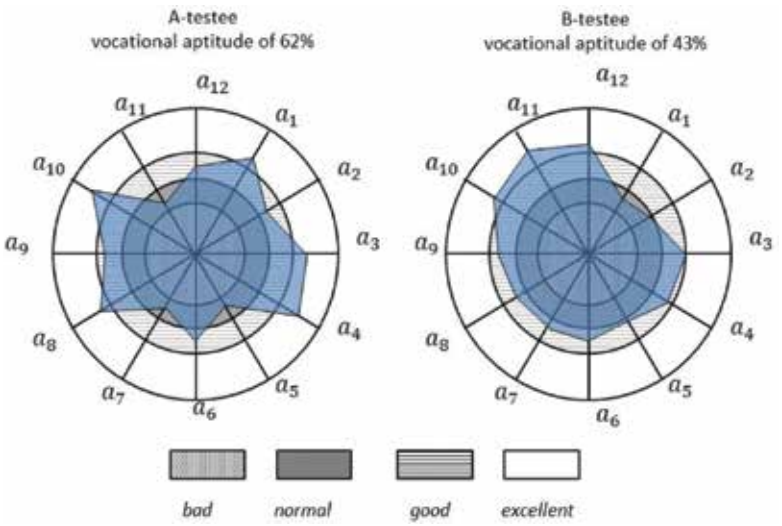

Figure 10. Individual portraits.

the individual professional portrait were obtained at the evaluation system output after defuzzification.

So, for example, for the quality of PIQ_1, such tests as AT_5, AT_6, AT_9, and AT_{13} are responsible. That is, the best result ("excellent") at the output of these tests: *If* (x_5 is "excellent") and (x_6 is "excellent") and (x_9 is "excellent") and (x_{13} is "excellent"), then (a_1 is "excellent").

The constructed individual portrait provides an opportunity to make a conclusion about the PIQ development level; it may be used both for training the operational personnel and for adaptive adjustment of informational and technical components of ergatic control systems to the user's abilities taking into account their current functional state, **Figure 10**.

The experiments showed the effectiveness of the developed methods for evaluation of the vocational aptitude within the occupational selection for operators of transport-technological machines. It was found out that application of the decision-making support system for enrollment into student groups specializing in operation of transport-technological machines helped reduce the dropout of students during the professional training by 1.5–2 times; it proves the effectiveness of the developed decision-making support system.

5. Conclusion

Thus, the concept of decision-making for evaluation of the human factor influence on the STS is presented; this concept is based on the analysis of the action effectiveness at each stage of the operator's activity and the priority levels of the operator's actions considering the known requirements to the PIQ content.

It is obvious that each type of the operator's activity corresponds to its own specific PIQ set, which determines the performance quality of professional functions.

In order to define a necessary set of PIQs, it is required to make a profound analysis of the professional activity, as each type of the operator's activity has its own peculiarities conditioned by the technology (work types and the work process elements, different work modes, shifts, different intensity of work, different levels of automation within the production process, etc.).

According to the proposed experiment model, special tests or test sets can be selected for each stage of the operator's activity, and they help to characterize the corresponding capabilities of a testee.

Application of different tests provides an opportunity to effectively simulate most types of the operator's activity in different environments of a human-operator, when different factors of the ambient environment affecting them, and to obtain quantitative and qualitative characteristics of their working capacity.

The special feature of the proposed model is application of the fuzzy analysis already at the stage of testing and application of the outcomes of one AT for evaluation of a number of PIQs. The proposed model, in general terms, represents the functional dependence of the operator's vocational aptitude index on the PIQ development level, while these PIQs are defined by the outcomes of testing on the base of fuzzy methods.

The feature of novelty of the developed model of the vocational aptitude consists in the integral evaluation of the vocational aptitude in a hierarchical system class; it makes it possible to take into consideration the system of interconnections between the PIQs and the AT outcomes, to improve the completeness and accuracy of the made decisions, to form quality functional for the training of operational personnel.

The main advantage of the developed evaluation system and the evaluation model is the possibility of the focused training of the certain operator's functions and the development of the certain PIQs that can improve the vocational aptitude indicators. This allows to intensify the training process of the operational personnel and reducing resource and time expenditures for their training.

Thus, it was established that the developed system of the vocational aptitude evaluation can be applied for evaluation of the human factor within research into STSs including elaborated technogenic objects.

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Chapter 9

Information and Information Technologies in Conflict Management

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Additional information is available at the end of the chapter

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Abstract

This paper analyzes information and modern information technologies as applied in different organizational environment and considers the content and peculiarities of conflict management process based on implementation of communicative scenarios. Currently, the need for escalated organizational transformations has become imminent, taking into account the intensifying development of the differentiated information society, which requires properly interactive and transparent policy-making. Correct understanding of information and effective implementation of information technologies is a rational attempt to harmonize the modern organizational environment reducing the level of conflict and improving efficiency indexes.

Keywords: information technologies, conflict management, IT innovations, strategy, communication

1. Introduction

Evidently, policy-making process in contemporary organizations takes place in conditions of uncertainty, flux, unpredictability and variation. It means that the analysis of policy design and implementation requires clear understanding of a multi-agent system affected by various internal and external communications. The policy-making approach and the underlying policy process need instruments that help to control potential risks preventing their turning into destructive dangers for organization environment. In that case, conflict management plays a significant role in decision-making process and cannot be ignored for deeper understanding of efficient strategy formulation in modern organizations.

Many books, thesis papers and articles have already dealt with negative points of conflicts at a workplace. Surprisingly enough, that is not the end of it. Having conflicts at a workplace appears to bring benefits as well. Morozov in his article dealing with conflicts at a workplace [1] classified the gain of them into seven main categories. And let us dwell a little bit on them. The first one is that conflicts help people adapt and integrate into the organization better. The second one is that they relieve the inner tension and in the long run make the working environment more balanced. The third one shows that conflicts indicate a changing balance of power within the organization. The fourth is that conflict brings to the surface deeply hidden objections, dissatisfaction and mistakes. The fifth is that a conflict may provoke a solution that would not happen otherwise. This kind of solution may be very dramatic and unusual, not to say unexpected. The sixth is that conflicts stimulate organizational processes. And finally, the seventh one clearly shows that after facing a conflict, the group actually becomes more efficient as a nation at war does. People sort of stand together to solve the problem and it certainly promotes cooperation and team spirit. Needless to say, it only works in case the conflicts are successfully settled and not suppressed.

Organization environment may be considered from various scientific viewpoints, for example, sociological, economic, political, psychological, cognitive, semiotic, etc. However, the processes of globalization, high industrialization, scientific and technical advance (which caused significant transformation of modern civilizations in twentieth and twenty-first centuries) led to the appearance of new aspects in understanding of management process. In the near future, modern enterprises will primarily need informational and communication development; therefore, actors are required to work more efficiently in order to transform the current habitual non-transparent administration methods. Despite the formal structural development of modern organizations, the need for escalated transformations has become imminent, taking into account the intensifying development of the differentiated information society, which requires proper interactive and transparent policies implemented wherever. Strategic models in administrative process are rationalized attempts to understand how it is possible to avoid common disruptions, accelerate the development of the entire variety of the organization structure, and, most importantly, come to social, economic and political modernization. In the current organization environment, the study of conflict management as an intellectual product is intended to analyze the significance of various factors of the behavior of subjects for the purpose of creating universal patterns of reproduction and positive transformation of organization realm based on the implementation of communication and information technologies.

Currently, dramatic information flow has affected almost all spheres of life. It is attended by the development of new communicative structures and processes, profound changes in the social communicative environment and communicative nature of organizational reality, and reconsideration of the role of information technologies in global development. This prompts the need for a new paradigm and methodology of studying information and communication as an autonomous objects of study that perform specific functions in conflict management process. Transformation of the socio-cultural, political and economic reality during the last 20–30 years has significantly shifted our understanding of the effectiveness of the managerial process. These changes are mostly described using the methodology of post-industrialism with the help of such terms as: technological revolution, network society, information

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economy, globalization, characterized by growing instability and the disintegration of social systems, unpredictability and the extreme complexity of economic processes, social identity problems, confusion and the exceptional diversity of cultural currents.

In these conditions, the key component of an effective conflict management process is communication ability or communication success. By "communicative efficiency" in conflict management, we will understand the function of minimizing transaction costs, considered here in a broader sense, as the costs of ensuring unimpeded communications in the process of social and economic exchanges, as it was presented by Kurochkin [2].

The proposed approach to the conceptualization of the concept of communicative efficiency and, therefore, drawing four types of information technologies is based on the following methodological assumptions: (1) Communicative conflict management efficiency consists of minimizing uncertainty at all levels of the organization management, offering clear "rules of the game" for all counter parties and closely controlling their execution. (2) Communicative efficiency directly depends on the coordination potential of the organizational core, as well as the ability of the preventive conflict resolution. (3) The main way to enhance the coordination potential of the corporation is by introducing the development and implementation of institutionalized practices that clarify the social and economic interactions of actors, as well as ensuring fairness of interactions and, as a consequence, preventing and eliminating conflicts. The basic theoretical foundations of this approach are the concept of communicative action and the theory of agreements in institutional economics.

The concept of communicative action, developed by Habermas [3], proceeds from a new interpretation of the very act of communication: not as an indirect transfer of information from subject A to subject B, but as an equitable discursive dialog, during which both sides should strive to achieve a rational consensus. An important addition to the theory of communicative action in evaluating the effectiveness of conflict management process is the idea of the plurality in value orders structuring communication of people, which found the most complete reflection in the works of French neo-institutionalists, representatives of the theory of agreements: Theveno, Boltyanski, Favorot, Kyapello etc. [4].

Based on works of such researchers in the field of communication and conflict studies as Burton, Karpenko and others, we will carry out the analysis of specific features of the conflict and reveal how rejection of information influences its development. Methods of conflict studies are mostly based on the theory of activity. According to it, the activity of the subject (a) is motivated by certain needs and interests and (b) is aimed at some items (things, money, knowledge, status, etc.) that he needs. But in the process of this activity, the subject is forced to enter into relations with other people. As a result, he himself unwillingly (or wishing) is in conflict with other actors.

2. Conflict analysis: causes, background, escalation and peculiarities

If we investigate the following assumption in more detail, we should suppose that, first of all, there is no doubt that conflict management process depends on a number of value-related, epistemological, organizational and social elements as a sequential exchange of information

and opinions that connects all groups of individuals in a dynamic system in space and time which requires comprehensive analysis. In addition to this, the process of creating favorable opportunities for information exchange between actors in the organization is based on the implementation of certain modeled processes and programs.

Roethlisberger, one of the founders of the "human relations" school, once remarked [5] that an organization is not only a means to fulfill economic goals but also it is an organization of people, in which they strive to achieve their dreams and aspirations. This definitely highlights the fact that in a situation where there is a strong urge to achieve personal goals, there is competition and that means the lack of resources, and that, in its turn, leads to contradictions.

Lewis Coser pronounces the following [6] "The decision-makers are engaged in maintaining and, if possible, strengthening the organizational structures through and in which they exercise power and influence. Whatever conflicts occur within these structures, will appear to them to be dysfunctional. Firmly wedded to the existing order by interest and sentiment, the decision-maker tends to view departures from this order as the result of psychological malfunctioning, and to explain conflict behavior as the consequence of such psychological factors. He will therefore be more likely to concern himself with 'tensions' or with 'stresses' and 'strains' than with those aspects of conflict behavior that might indicate pressures for changing basic institutional arrangements. Also, decision-makers are more likely to consider the dysfunctions of conflict for the total structure, without giving attention to the functions of conflict for particular groups or strata within it".

Tjosvold rightly states [7] that "just working, managing and living in any organization automatically means being in conflict". The problem of conflict management in social and political organizations has been covered in many different works by various authors. They all treat an organization as a complex body, that includes not only individuals, with all their moral sets of values, statuses and interests, but also different social institutions, whose goal is to take the best place in organizational structure, to change the existing order and the relationship order in this organization. Although the individual aspects of political communications have been the subject matter of many studies, there is still a definite lack of topical conceptual proposals that would make it possible to analyze all the aspects of the investigated phenomenon, its specifics and trends in the current conditions. In the case of communication interactions with the naturally inherent elements and characteristics of social communication, we may refer to human factors that distort the perception of communicated messages. Negentropy or negative entropy refers to the case when, in spite of all of the distortions and missing information, an incomplete/distorted message is understood by the receiver due to his discerning ability. All the above mentioned also leads to all kinds of tension, that in its turn evolves into conflicts.

Investigating theoretical framework of organizational communicative scenarios, the Dutch researchers Bordewijk and Kaam [7] derived a four-term logical matrix of models of alternative kinds of information flow. The first model is called the broadcasting (allocution) model: it is typical non-reversible communication, propagation of information from one person (center) to many others at the same time. The second model is the dialog model of direct communication of individuals without a center and intermediaries. This model makes it possible to choose the time, place and subject of information exchange. The third model is the consulting

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model, where an individual at the periphery of a communication sends selective requests for information to a large data-storage center. The fourth model is the registration model, which is the opposite of the previous model. In this model, the center asks for and receives information from a peripheral source, processes the data that is received and forms a uniform narrative that is transmitted to the individual. Moreover, the center has more control over information traffic than the individual at the periphery of the communication network. However, we have to admit that the presented models make it possible to view the formal process of using information in communication process rather as some trade and practical activity than consider potential patterns of conflict resolution.

For the reason that, while dealing with conflict any person is bound to make a decision (including an ethical one) more reflectory than reflexively, one has to take into consideration the fact that there are obstacles such as social and individual typical reactions in the way of researching and professional interference into social conflicts. These reactions clearly display the level of consciousness and the extent of consciousness in reflexive thinking of an individual. Let us take a moment to present the most important ones.

Conflict phobia is a fear of any conflict at all. Some people believe that all conflicts are equally dangerous, and the person who demonstrates a conflict-oriented type of behavior should be isolated from human society. These kind of people tend to overload the situation with their own speculations and they end up making the problem roughly the size of an elephant in doing this.

People who tend to perceive conflicts inadequately. They are also in the habit of seeing a conflict where there is none at all, but unlike the previous category, they are not afraid of conflicts. They start to actively fight for what they consider right, but that actually has no relation to what is really happening. These sort of people are predisposed to turn any conflict into a situation of either victory or defeat.

People are inclined to ignore the conflict altogether. They seem to be totally unaware of it even being the very eye of it. By sort of wearing, specially devised blinkers, they do not realize that minor unimportant conflicts will sooner or later grow into unruly overwhelming processes featuring definitely destructive quality.

Shainov has a very interesting idea of comparing work-related conflicts to a fire [8]. They both possess two very similar features: first, it is easier to prevent one then to deal with one when it is already in process; second, the later one starts to fight it, the harder it is to put an end to it. For example, if the problem originated as a confrontation of two individuals and was not resolved, it could eventually lead to the whole organization splitting into two war parties. To form conflict resolution ability, one is supposed to overcome two opposing complexes of defensive conflict behavior: conflict avoiding and conflict pursuing.

If conflict avoiding predominates, then this type of person is most afraid to “lose his/her face” and hence the person is scared of facing any contradictions and the discussions that may follow. For example, the manager would rather avoid either interfering into a difficult situation or discussing essential problems as he would rather “weather the storm” hoping it would “blow off” eventually. Part of conflict scare is also communication that lacks feedback and a personal point of view and this sort of communication could be best described as unsure and vague.

If pursuing a conflict prevails, then all the contradictions, whether being imaginary or real, provoke ego-centric reaction and striving to aggressively defend one's own ego from imaginary and real threats. In case any real working problems arise, a manager with a conflict pursuing complex can easily start blaming other people, could use threats and would rather manipulate other people's a sense of guilt. While discussing the situation, the manager would perceive any disagreement or a rush word as a threat to his/her own status, he/she then would use cruel irony and sarcasm, and so with his/her own reactions would ease the dynamic tension in the conflict, and eventually shift from discussing the problem itself to personal opposition.

Conflict resolution ability is an alternative to these two extremes in ego-centric behavior and is expressed through a set of motivational, cognitive, emotional, will-power, behavioral and communicative characteristics: either perceiving a wide range of conflict manifestations: emotions, images, words, actions "both in yourself and other people" as soon and as clear as possible, without either intensified taking all the necessary measures to promote non-escalation; or assertive communication that is aimed at explaining and expressing one's own point of view, clearing all the discrepancies and holding discussions; judging one's own personal potential in conflict resolution clearly and readiness to turn to third parties for help, if necessary.

Organizational conflict is defined in modern literature is not just any conflict of interests that happens within the organization but also the one that is caused by breaking rules of behavior or sets of values, that happens due to contradictions of formal organizational standards and the real behavior of the people within that group that is aimed at fulfilling the interests of the parties involved on the basis of opposition. These types of conflicts are tightly connected with the organization itself and its working conditions.

The most widely spread reason of conflicts is inequality because of the position in imperatively coordinated associations in which some people manage and rule, while the others have to submit and follow the commands and orders. Conflicts are defined by people's consciousness, contradiction in personal and public values, difference in expectations, practical intentions and actions and misunderstanding each other's actions; conflicts are also caused by all sorts of misapprehensions, logical mistakes and a wide range of semantic difficulties in conducting communication, either lack or distortion of information. Incompatibility in the claims of the parties involved, while having to deal with restricted means, could be called a universal source of conflicts. A conflict is a clash and confrontation of individuals and groups that is characterized by inflicting mutual damage that is aimed at protecting one's real and/or imaginary interests.

Conflict at a workplace as Antsupov and Shipilov remarked [9] has four basic functions: first, it balances personal, group and company interests. Sometimes it strengthens the bonds between employees as they unite against one common problem or one common opponent; second, they indicate that something is wrong within the staff; third, they promote innovations and creativity, as conflicts help the company to develop economically, socially and spiritually; fourth, they change the climate within the organization, encouraging trust, respect and authority.

All the participants in these types of conflict could be roughly divided into three groups that include: (1) a boss and an employee, (2) two employees and (3) groups. The first is actually the mostly wide spread, constituting about 53% of the total number of organizational conflicts. As

for the second type, it has a very peculiar distinction. Employees tend to have more disagreements if they are quite close at a career ladder. The farther they are at a job hierarchy, the less likely they are to come into conflict.

Work-related conflicts are also gender oriented more than it could be evident at a glance. Women tend to have more conflicts over personal matters at work, such as choosing vacation time or customizing a workspace, whereas men are more inclined to disagree over work matters, such as dividing the workload. There are other peculiarities that mark organizational conflicts. For example, competitiveness that is inherent to most jobs can become a very bad stimulant, while resolving conflicts at a work place. Also, some conflicts at a work place are not actually job-related but are essentially personal ones that are just masked. This makes them harder to pinpoint and resolve.

Organizational conflicts actually present a big problem. It may prove to be more serious than it seems at a glance. Studies have shown that the factor that has more effect on job efficiency is the person's mood and it in its turn is mostly affected by relations with other people. It turns out, that healthy working environment is the key to a company's prosperity as a whole. Dorofeev estimated that up to 20% of the working time management spends solving conflicts at a workplace [10].

3. Conflict triggering issues

Viewing conflict resolution from a practical standpoint, it looks viable to break all the reasons that cause conflicts into five main categories. Understanding this will definitely help the mediator to promptly find a way to resolve the conflict most efficiently. Lincoln in [11], defined the following attributes: structural factors that exist intrinsically, despite our wishes and capabilities and those could not be changed within a conflict: (1) values, (2) relations (directives, stereotypes), (3) behavioral reactions, (4) information-related incentives, that is, the information that kindled the conflict. The way particularly, these factors influence the conflict and what exact role they play in it constitutes the essence of the present analysis. In various socio-humanitarian discourses, a conflict issue is essential and integral. Society is mostly treated not as a static and stable condition but as an ever-going process, infinite flow of events that consists of not some stable conditions but rather endless conflicts and tension.

The conflict issue is one that could be described as a key question in social perception and it requires appropriate knowledge with a wide range of applicable resources that would enable to reasonably interpret the logic that predominates social processes and can produce relevant apparatus for immediate correction and managing these processes. It is clear that the role and importance of information in social conflict dynamics is essentially a troubled area that becomes the center of a discussion, concerning defining the limits and forms of socially acceptable conception that has long become more than just academical. Eco once opened his mouth to say that [12] "in the immediate future the entirety of our society is bound to split into or maybe it has already done so- two groups: those who only watch TV and thus get ready-made images and conceptions about the world affairs without any right to critically

select the information they get; and those who look at the computer screen, this group is capable of selecting and processing information. So starts the division of cultures that has already existed since the Middle Ages: those who were able to read manuscripts and so could critically assess religious, philosophical and scientific issues; and those who were brought up in churches via images that were previously chosen and processed for them."

Finally, it is of extreme importance to comprehend how the area of conflict expands due to the impact of informational influence concerning the issue of information safety and carrying out state policy in communication management area. We believe that the theoretical approaches to conflict studies that already exist require serious supplements and improvement.

Conflict is not just a simple phenomenon possessing particular traits that indicate some extent of deviation from a regular series of events that defines human behavior. As an attributive property of society, conflict has as its ultimate foundation and source not certain feelings and emotions that distort human relations but rather the relations themselves (and in terms of a systemic approach it means its social structure), in whose institutional foundations its subjects hold more or less meaningful positions.

Ashirov [13] stated that any organization develops only in case it works on the improvement of the already existing relations within the company. One of the key aspects of it is preventing and resolving any conflicts that may arise. If conflict resolution is focused on the conflict itself and not on the underlying issues that brought it, then there could be a shift of values, in case of which parties pay more attention to winning the conflict, than to resolving the issue. In case of a conflict in a workplace, one of the factors that make the situation even worse, is the fact that people involved in the conflict see themselves as a part of the group, thus removing from taking any personal responsibility and instead following the lead. One of the key strategies in resolving conflicts at a workplace is realizing that even opposing parties share some interests and aspirations and in this area lays the solution. All the participants have to understand that the solution would not mean just victory for one party and total defeat for the other one.

As a starting point for one aspect in the consideration of the special nature that defines any conflict, we have chosen the toolkit developed by Luhmann. This choice is explained by the fact that his communication theory combined many elements with different approaches to the understanding of conflict. As was noted by Cooley [11], the study of the information system in society is still one of the best ways of understanding social and value changes.

In developing the theory of self-referential systems, Luhmann made the following statement: a system is something that can distinguish itself from the outside environment and render this borderline. Society constantly makes a distinction between itself and the outside environment; it is this distinction that provides the society with the right to be called a system. According to this notion, he considers communications and not people and their actions the as the elements of the social system.

In this way, society as a system consists of various distinctions (communications) than in due course lead to other distinctions. Power, truth, money (property), law, religion, art and love constitute communicative codes. As Luhmann clearly shows, communication essentially means distinction between information, messages and understanding. It is impossible

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to communicate without all these three elements being united. This approach provides a different perspective to understanding the secrets of conflict. This is not just a tribute to another, this time "communicative" trend in fashion, which considers communication as one of the fundamental properties of sociality. Hence as our starting point we take a famous remark by Gilyarevskii [14] that information is the actual meaning that a person attributes to this particular data according to the rules of its presentation that is inherent to this particular person. Luhmann goes on to support a very similar conception that political communication is not just a multi-level system of information circulating around but above all, it is the meaningful context of a political process. We should also keep in mind that communication has its indispensable components, which are communicative relations (delivering the meaning) and communicative acts (delivering information via technology).

Luhmann coordinate system, which in the communicative categories fixes the role of conflict in social evolution, makes it possible to explain a basic approach using a unified theoretical foundation: the causes of conflict lie in the area of any interaction, thus reflecting distinguishing features if this particular interaction, in which case the degree of interdependence and mutual obligations is higher than of "common values" or "social contract".

The key conclusion speaking about studying conflicts is the notion that by utilizing the conflict potential and society's tolerance to conflicts (or declaring it in a different way, due to refusal to externalize all conflicts as it was typical for segmentary societies) social systems require instability, otherwise they will fossilize, while through strengthening of the potential of conflicts and tolerance to conflicts in society" [15] accumulation and acceleration of social evolution occurs.

According to Luhmann in Ref. [16], potential conflict is an attribute feature and a natural state of all social systems. The degree of actualization in the conflict potential may vary and basically depends on the degree of differentiation within the system and the stage of its evolution. The conflict itself, in its turn, is a source of the communicative evolution in the society. Conflicts in legislative societies are neither suppressed nor avoided; each citizen is provided with an appropriate form of communication in order to evade its violent resolution.

This analysis allows Luhmann to allocate several criteria to the communicative features of a conflict: (1) a conflict is an attribution of independence to the contradiction in communication; (2) a conflict only takes place in a situation when anticipation of communication is present, while the opposing party, on the other hand, transmits total denial of communication [14]. Thus, conflict is a consequence of inadequate ("negative") communicative responses to challenges and deviations from these challenges; (3) a conflict is clearly separated from the contradictions which are either suggested or watched. Conflict is not actually an interruption or termination of communication but is in fact its continuation in some particular form. Conflicts lend themselves to the continuation in communication and maintain its openness, including the use of denial. Logically, unfolding the complex and multi-valued definition of a conflict, Luhmann draws our attention to its parasitic nature and forms its conceptual core, that a conflict is a negative form of interaction. A conflict as a negative form of interaction is a set of forced actions that definitely possess an affirmative-negative character. Negative interaction which is characterized by parties acting at cross purposes is observed when one of the parties seeks to neutralize the counteracting subject or a group of subjects.

Later, this original definition is supplemented and developed using the following suppositions: first, conflicts do not only put the potential of socio-political deviations to the test but also lead to behavioral integration within the participants; second, noting the "disturbing influence" of conflicts on the social system, Luhmann articulates their special properties, such as the easiness with which it all comes out of control; third, suppression of conflicts by using violence, that is, "extremely burdensome suppression that leads to suppressing conflicts, is a vital characteristic of early societies". With increasing social complexity, development of political domination and the emergence of legitimate force to suppress illegitimate violence, which is able to affirm its own type of communication, it becomes "possible to achieve a greater number of conflicts and greater peace options at the same time", while simultaneously increasing the deviation in various communication proposals and removing the burden of possible conflicts that arise from this deviation; fourth, as a fundamental social fact, Luhmann describes the possibility of allowing conflicts while de-emphasizing them through social regulation or third-party influence; fifth, while the complexity of social systems increases, it is concurrently accompanied by differentiation in the causes and topics of conflicts, which are increasingly searching for new issues. All the while, although the structural mechanism of conflict initiation does not present a "solvable problem", the system is able to bear conflicts since differentiation of their causes helps one to identify deep structural foundations in society that lead to outbreaks of new conflicts.

The seriousness of the problems touched upon by Luhmann lies in the fact that the present analysis gives one reasonable grounds to construe that if actors, while having no communication between themselves, make predictable decisions within the rigid framework of rules in the game of their own design, they do not actually need social interactions. Accordingly, the problem of social order is not so much a problem of political power as rather a problem of socialization [17].

Zaitzev in [18] remarked that one can clearly see the correlation between the group's maturity and efficiency and the types of conflicts that prevail there. Highly developed companies with strong group identity are characterized by having professional conflicts that on the other hand mostly suffer from personal conflicts. He also stated, that Russian business culture, unlike the typical American and European ones which were defined by Hofstede in 1980, possesses six unique features that define it. They are strong ideology, definiteness, highly developed hierarchy, collective mind overtaking individual one, sociality (social stability and protection) and own views concerning the future.

In today's information society, the information transmission process is mediated by the mass media, as direct interaction between the sender and the addressee is virtually impossible. Luhmann considers in [19] that something must be new and deviating to become one of important assumptions that determine whether some object becomes information. Moreover, this selection principle is essentially the conflict itself. The system faces a choice whether to continue creating new meanings, continue communication or cease to exist at all. The social system can successfully function only through communication. So the negative assessment is not just an evaluation of the entire world but of a specific system. The communicative system can continue to show its ability to communicate only on the basis of ongoing

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communication. However, communication may still be misinterpreted or may be rejected altogether. Does this mean surrender? According to Luhmann, no, as there is still a powerful mechanism that ensures the continued existence of society even in case of misunderstanding and rejection. Society provides a self-control mechanism in which the process of communication refers to itself and engages in communication about its own difficulties, reorganizing itself through conflict.

Burton, who believes that [20] "communication is a characteristic of any relationship. In human relations, communication streams typically include messages and established interactions. Communication takes place even in the absence of messages and interaction" established the dependence in the use of communication in relationships of either cooperation or conflict on the content and understanding of its content, uses the concept of "effective communication", understanding it as the following: intentional transmission of information; obtaining and interpreting information in the exact way which it was intended during transmission; and including information into the forming and changing of values, interests and goals.

The effectiveness of communication depends on: whether the information is intentional or unintentional; the transfer purpose: accurate or misleading information; and the accuracy in the interpretation of information.

Each and every of the above-mentioned characteristics depends on the type of communication (verbal or visual, direct or indirect) and the circumstances that accompany it (its transmission being conveyed either in the conditions of fear or security, awareness or prejudices).

Burton concludes that there is a close correlation between conflict and ineffective communication. He correctly believes that: first, information does not always harmonize relations in behavioral systems, because people resort to communication both in conflict occurrences and peaceful relationships; second, there may arise communication antipathies, in case the flow of any other messages and interactions is blocked, that in its due course affects the behavior and opinions of people; third, conflict stems from inefficient communication; fourth, the first step in the study of conflict and its resolution is the establishment of effective communication; fifth, conflict resolution must include the need for controlled communication (raising its level to transform relationships of competition and rivalry into the search for common values); sixth, the process of conflict resolution primarily consists of confirming that information has been obtained exactly. It seems worthwhile to consider a general model that describes the way political communication takes place. The formula of this model is to answer the following questions: Who communicates? What is being communicated? Which channel is used? Who is it communicated to? What is the final result?

The general model of communication in that case looks like this: the communicator (the author of the message); the message (information); communication channel (message transfer means); the recipient (the message addressee); and the impact achieved (communication efficiency). Thus, to resolve social conflicts, society requires a constant increase in the number of information channels and their capacity, as "words and labels that we use define and create our social world" [20]. In this sense, social information should be treated as the key concept in the analyzing conflicts.

The information that is false, distorted, excessive or untimely is closely connected with the wrong understanding and interpretation of the facts and events that are present at the conflict. Information could be clearly perceived or distorted depending on the fact whether it was perceived as "friendly" or "alien"; according to Shainov in [8], people tend to trust and admit the information that came from friendly hands and misinterpret and omit the information originating from suspicious sources. The parties involved into a conflict, always come to it with a ready conception of what is right or wrong about the events concerned. They never bother to consider the possibility that they could be wrong and should double-check. Their expectations are always negative and never include letting the opposing party have its say. They establish their own behavior accordingly, never doubting that the other party shares the same views. The next step involves setting into motion the mechanism that should confirm the hypothesis stated, that in its turn ignores the information that does not follow the pattern, thus confirming the "evil design" that was already attributed to the opposing party, which solely aims at hurting the interests of the contender. That brings us to the notion that actually the information itself is most widely spread reason for conflicts breaking out. It essentially is the "most sensitive" indicator of the conflict escalation. In any given conflict it becomes the first factor that shapes hostility and mistrust. It happens at the very beginning, at the stage when behavioral change occurs, the information instantly starts to be adjusted, distorted and withheld. So, what particular information leads to a conflict fueling? It is the sort of information that is perfectly acceptable for one party and is totally unacceptable for the other.

Rozanova points out in [21] an evident some somewhat underplayed idea, that as many conflicts occur while the person is seriously unhappy, this hinders his ability to think clearly thus making the situation even worse for both parties.

The Russian expert in conflict resolution Karpenko [22] summarizing the studies of Lincoln, structured the most common information-related problems that contribute to creating a conflict. He stated them as the following: incomplete and inaccurate facts, including issues related to the concept of why the problem originated in the first place and the history of the conflict; irrelevant facts/sets of facts; unwanted disclosure of information that could offend the values of one of the parties, violate privacy and leave unpleasant memories; underestimation of facts and their implications; suspicion of the deliberate information concealment; involuntary misinformation; experts, witnesses, sources of information or data being unreliable, including controversial results of appraisals and issues concerning new unproven technologies, as well as inaccurate translations and media reports; rumors; arbitrary interpretation of language.

Another interesting case in point was that mentioned by Shainov in [8]. He remarked that more women than men actually admit having conflicts at work. He attributed it to the fact that women tend to be more emotional and sometimes over-dramatize. A series of surveys that attracted the author's attention indicated that younger people tend to be more involved into conflicts. It could be more than just getting older makes one wiser. Shainov remarked that this fact could be specific for our country where the older generation that was brought up and educated during the USSR era was encouraged to comply with the system and strongly commanded not to challenge it.

Making attempts to examine the above-mentioned problems, it became possible to develop a more or less adequate and efficient theoretical solution formulating the criteria for the applicability

of information in the development of strategic models, which is represented as follows: (1) Coherence is the ability of actors in the organizational environment to use internal communication lines between hierarchical structures, institutions and sectors with success when preparing and making key decisions; (2) Competence is the level of rational evaluation and understanding of the meaning of information; (3) Loyalty is the ability of actors in the information environment to form an idea about the greatest acceptability of their proper activities in comparison with other players and about modification of information in the social context by transaction of values and mindsets; (4) Efficiency is an instrumental evaluation indicator of the efficiency of decisions that are made on the basis of information and the implementation of results in the organizational environment. This functional environment is exactly where it becomes possible to reformulate the issue of information relevance in the context of analyzing strategies of conflict management.

4. Crucial strategies in conflict prevention and resolution: Information technologies

When we consider the means by which information affects efforts to overcome organizational conflicts, we must use such techniques as the extrapolation of trends, prediction of changes, control by weak signals, selection of central strategic positions and the grading of strategic tasks. It is thus evident that the role of information in strategies of conflict resolution is confined to the maximum focus on opportunities, not on tasks. In the context of organizational environment, it is appropriate to pay particular attention to ideal projective structures. It has already been noted that one of the essential tasks of strategic modeling is to obtain and propagate timely factual information, both within the network and from the external part of the organizational environment. Without this information, the integral process of administration can be treated merely as a subjective opinion. In terms of management, information processes need ordering via the formation of a special corporate culture based on procedures for the treatment of information, that is, information acquisition, intelligent information processing and the use of information to carry out an entire corporate strategy. Thus, organization will avoid previous mistakes or repeated invention of long-tested methods of administration.

Along with the importance of understanding the differences in the axiological aspects of participants in communicative processes as one of the causes of the emergence of conflicts, it is necessary to recognize that the main catalyst for organizational tension is the unsatisfactory information exchange. In that sense, we will examine mediation as the key technology for conflict resolution and implementation of IT programs as the essential technologies harmonizing communicative processes based on the most productive use of information.

While considering scenarios of conflict management, one should focus on analysis of IT programs for computerized automation of communication processes as it was presented by Maltseva [23]. By adopting information technologies, information is retrieved from its abstract storage area, processed and returned in a new form; as a result, entire administrative discourses can be gradually modified minimizing emergence of organizational conflicts. This allows to consider several types of information technologies that are thought to be efficient when applied to reduce advanced development risks in communicative field.

All in all, technologies which are normally implemented in contemporary organizations can be divided into programs intended to search for and make efficient decisions; resource management service programs; programs to arrange internal structural operations of institutions and encourage cross information exchange among different internal bodies and their relationships with economic, research and engineering partners; specialized software for on-line use, Big Data, etc.

Examining the field of conflict resolution based on management of information, we will draw our attention to four types of technologies supporting formation of effective communicative scenarios and preventing organizational conflicts. The first type of programs, those that make up the structure of the strategic information model, is interpreted as a decision-support system (DSS). DSS programs provide a set of theme-based blocks that are composed individually for each organization. Each particular block is an area for potential decision-making. These programs are efficiently integrated in various organizations and have a standard set of blocks: local intra-organization area (HR decisions, financial analytics, restructuring of subdivisions, anti-crisis arrangements, etc.), key large-scale projects and the marketing and representational area of the activities of organization. All the blocks utilize different methods, whose range depends on the processing complexity of the program and, therefore, the direct cost of its development. Let us consider the specifics of the basic methods used in DSS programs. First of all, these include search tools. DSS programs must be developed in such a way as to contain as detailed information as possible to support the formal part of decision-making. In this context, we include a branch database of legislative decrees and the system of test cases, scientific and theoretical support of decision-making, access to permanently updated global news blocks, etc. Second, a significant role is played by mathematical forecasting of various processes, as well as methods for scenario or simulation modeling; this makes it possible to reject a huge number of variants that are not adequate for particular cases without excessive test costs. Finally, the most innovative and efficient measure is to use interactive consulting techniques in decision-making; this makes it possible to obtain advice by a broad range of highly skilled specialists within the shortest time, including scientists, political strategists, economists, lawyers, etc. from around the world. The list of these specialists is formed for every new DSS program in advance. The sphere of decision-making bears the maximum conflict potential, so simplifying the analysis of information in the formulation of policies significantly reduces the frequency of conflicts.

The second type of program that forms information model matrix is intended for resource accounting and distribution. These are referred to as resource management systems (RMSs); they have been in use for more than 20 years in the structural business units of most transnational corporations, especially in power engineering. RMS programs can enable institutions to control resources on a continuous basis. The list of these resources is entered in the program as required by a customer. In the case of implementation in organizations, we consider it topical to make certain additions to standard RMSs, along with the mathematical evaluation of financial resources that are expended and received. Firstly, this is human-resource accounting via the formation of a database of the employees of organization with detailed personal records, including expertise, achievements, range of functions, work results, etc. This saves much time in strategic task grading, as well as in choosing a candidate who will

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be responsible for implementing particular decisions. Secondly, the area of administration requires accounting for private corporate investments in state projects, which will make it possible over time to identify trends and reliable lines for cooperation. Thirdly, modern information technologies make it possible to use powerful tools for the budgeting of innovative technologies; as a result, it becomes possible to work out a plan of the expected input of resources and continue to plan by modeling possible areas of their use. These areas will be proposed to administrative bodies in the form of charts and diagrams by the RSS program itself, which carries out complex accounting of the resource potential of organization, as well as the fields for and efficiency of its application. These programs maximally disregard the extent to which the human factor interferes in the financial and resource sectors, which reduces the level of conflict in the organization.

The third type of information programs encourages development of integrative exchanges among the substructures of organization. We will conventionally call this type of program an information-sharing system (ISS). It is based on the creation of enormous data servers that are connected to a single system. Each server is a combination of dominants (information blocks) ordered according to size, which can be of strategic significance for partners. An ISS platform may contain variable databases that are open for exchange, analysis of adopted laws and transmission of their gradual materialization as if it were on-line (i.e., in continued update mode) on different subjects for the purpose of objective evaluation of reality and sharing experiences, as well as means of observation and control over the activities of partners in particular joint arrangements (e.g., when a project is overseen by several departments and the work of each largely determines the efficiency of the others). Moreover, it is not infrequent that bodies and departments find it difficult to find information about each other's operations; even documentary acts are sometimes documented only on paper, which makes the organizational process unstable and slows decision-making procedures. It is thus quite obvious that specialized ISS programs can make humans activities considerably more structured and move it from individual to system-based action. It contributes to the harmonization of the climate in the team, the elimination of duplicate operations and as a result reduces the level of conflict global processes [24].

The fourth type of program platforms is intended to ensure the up-to-date information for organization. Essentially, this context serves to consider traditional virtual programs (as intended for use on data servers or standard web resources which allow individuals to be involved in the decision-making process receiving timely detailed information on-line). These programs are at the heart of a huge number of concepts based on the primary role of information in processes. Being installed on a personal computer they allow the user to continuously monitor any information in the environment that he or she is interested in. As an example, these include programs that are intended to provide transparent consideration and adoption of laws (a Law Analysis System or LAS); the programs that are intended to promptly deliver information on changes in the value of stocks of corporations and to make forecasts based on measuring variations in their value (Stock Holder System or SHS), base for legal entities, etc. Such programs increase the effectiveness of the decision-making process (especially in the rapidly changing environment), which facilitates the organizational process and reduces the conflict potential within the organization.

5. Conclusions

For a variety of reasons Russia turned a blind eye to the area of conflicts that happen in organizations for many years. Not until 1989 had the Russian legislation included an article concerning conflict resolution at a workplace. Since that time conflict resolution became an essential issue that touched upon many areas of science. The analyzed peculiarities of information and information technologies in conflict management clearly prove that the main problems of organizational development have to do rather with excessive information treated in a very perfunctory manner, which determines the subjective perception of communication in general. Finally, the most global property of intelligent innovations unfolds in the communicative field of administration, where information resources are produced that require further storage, reformatting and transmission to contiguous environments in expectation of feedback. As a result of this pattern, the analysis of the range of innovative information technologies as well as the search for efficient communicative scenarios becomes an inevitable part of management process. The adoption of the indicated technologies in conflict preventing and resolution is intended to harmonize processes by combining its ethical aspect with efficiency rating increase. It is therefore quite obvious that the timely implementation of innovative information and technological models harmonizes administration process by endowing it with consistency and rationality, optimizing the decision-making process, coordinating operations of non-overlapping sectors in organizations, optimizing the use of the resource base and developing interactive tools wanted for. That brings us to the conclusion that in order to successfully eliminate the informational ingredient of the conflict, one should get to the source of information and thoroughly check the reliability and sufficiency of the information. Analysis of the communicative conceptual optics of considering the specifics of conflict shows that its causes to lie in the area of information exchange, in which each of the communication partners seems meaningful for the other and is affected by the other. Conflict, as a resource of communicative evolution of the society, exists only when rejection of information is communicated in response to an expectation. Conflict occurs as a result of negative communicative responses to challenges. Conflict is the result of ineffective communication; the first step in resolving conflict is to establish effective controlled communication.

Analysis of the information problems that contribute to conflict initiation and affect information perception in a conflict shows that conflict is perceived as a type of situation that concerns an individual only personally. We reached the conclusion that the information about a particular conflict often describes existing stereotypes of public consciousness rather than reality. Understanding of this fact allows to create efficient strategic models and, as a result, to harmonize information management process.

In the light of the dynamism and complexity of modern communications, their great dependence on knowledge and the verified commercialization of informational innovations for economic growth, the strengthening of the general influence of innovations on all branches of human life, the organizational structure should be changed toward greater horizontally oriented networks, flexibility and adaptability. Ideally, information management is a multifunctional decision-making system that determines the strategy, forms the normative basis

for the regulation of innovation activities, ensuring a continuous process of foresight, policy development, implementation, monitoring and evaluation. The multi-functionality of the decision-making system corresponds to the modern model of the formation of efficient organizational systems on a network basis with clear patterns of conflict management and conflict resolution.

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Chapter 10

Management of Program Projects in Conditions of Unstable Development Teams

Igor Nikolayevich Skopin

Additional information is available at the end of the chapter

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Abstract

Project management issues of teams with outsourced developers are discussed. Peculiarity of these teams is the difficulty of recruitment and, as a consequence, the instability of staff. We propose a special approach to overcome the issues in these circumstances. It is based on the use of a special role in the project team, called the personnel coordinator, who allows risk mitigating of project failure. The main result of the proposed work is the technique of tuning Highsmith's Adaptive Software Development approach to the conditions of projects developed by the unstable team. Another important result is the definition of the functions of the personnel coordinator, which he/she must fulfill in the project.

Keywords: management of software projects, personnel coordinator, the life cycle of software development, hard and agile methodology, adaptive methodology

1. Introduction

The organization of software projects management has long been the subject of research, the goals of which are to increase the efficiency of collective work and to support the quality of the developed products. Today, this area has developed as an independent discipline, offering various methods of managing software projects (commonly called methodologies), which have proved themselves in the practice of designing software systems. Among them are two classes of methodologies: rigid, also called heavy, or even monumental, and agile (accelerated, lightweight). The first prescribe to rely on the collection of the most complete set of requirements and their careful analysis, resulting in the construction of a seriated often call waterfall or an iterative development of the project (most of such methodologies can be found in [1]).

The latter abandon detailed a priori development planning and focus on the priority implementation of the vital needs of users (see, e.g., [2]).

Studies of problems of project management always pay attention to methods of organizing teamwork. As an illustration, it is appropriate to point out the bestseller written by F. Brooks [3], which shows that the problems associated with the division of labor in the project team and identified in the 1970s of twentieth century remain relevant today. Some specialists, noting that human resources (HR) are the main factor determining the success of project development, offer methods of accounting for it when choosing a methodology [4, 5]. At the same time, there are practically no recommendations on how to act as a manager when he/she does not have the opportunity to work with an established team with sufficient qualifications for the project. The peculiarity of this situation is the instability of the development team and the need for ad hoc design solutions. It is typical for start-up companies trying to organize their business for the implementation of a promising idea, but do not have the resources to form a full-fledged team that can act within the framework of solid methodological support, for example, in the style of the MSF (Microsoft Solution Framework) approach [6]. It is tempting to use the rules for organization of works like MSF, but the problem with most of these methods is that they are applicable only if the projects are executed by working groups of specialists who are not only qualified but also well organized in interacting with each other. This is not only a problem of the staff deficit, because of which it is necessary to employ outside persons. It often turns out to be impossible to ensure a constant workload of employees with the necessary qualifications, to provide them with comfortable working conditions and stability of wages. All this increases the risk of instability of the team.

In accordance with the Capability Maturity Model for Software (SW-CMM) standard, which is supported in numerous approaches to improving the software development processes that go back to the Paulk, Curtis, Chrissis, and Weber ideas (see [7]), instability of the command is usually considered as a characteristic of the initial level of the organization's maturity. The standard assumes that if an organization pretends to grow in maturity, it should strive to move to the following levels: repeatable, defined, managed, and optimizing by continually improving the design discipline. The standard holds that moving up the ladder of maturity makes the organization resistant to instability by developing not only the target products of the project but also documents reflecting the accepted discipline. In other words, the project team should gradually get rid of the influence of the human factor, which in its essence leads to a rigid development strategy, which all project developers are required to take.

We should note that when the instability of the team is objective, the maturity condition for SW-CMM is not achievable. However, this does not mean the impossibility of successful activity. The most notable example is outsourcing. If a manager gives the development task for an external executor as a closed proposal, if she/he composed this proposal exactly accurately and unequivocally, then the risk from outsourcing reduces to an acceptable level, and certain advantages be achieved. Nevertheless, the failures of unstable teams are possible and frequent, in many respects, they occur by the lack of suitable methodological support. In the proposed chapter, we discuss some fundamental aspects of the rational organization of the production process of unstable teams, the account of which allows the project manager to build a reliable methodology for the project activity.

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The proposed material based on observations and analysis of the experience of several unstable teams, who managed to build their activities so that a better part of the projects developed was successful. The most significant contribution to this analysis made the information on the remote team that managed to determine the rules of work with external executors of project assignments during the development of a series of projects. A distinctive feature of this team is the great attention that it pays to training employees [8].

Today, communication tools allow organizing teams of performers working remotely. It has become quite common for them to be executed projects by outside performers, using e-mail, chat rooms, and teleconferences. This leads to teams with employees who may not even know each other. In most cases, remote commands are unstable. It is necessary to provide for special rules of interaction for them. We discovered this aspect of instability by observing the activities of the abovementioned successful teams. It largely influenced the approach of the project management, presented in the following sections.

2. Features of the project team

Unstable teams of project developers can be built in different ways, but always the project executors in such a team are divided into three groups:

1. *Key developers*—a stable part of the team. Its members have their own interest in the effective development of the project and obtaining meaningful results. They do not need external stimulation. Key developers are often the initiators of the project. These are employees, whose exit from the team is highly undesirable for the success of the project.
2. *Constantly working developers*—performers who occupy roles in the project, allowing substitution without significant damage to the project. Their distinguishing feature is that, not being key developers, they are available for constant interaction.
3. *Optional developers involved*—performers who are used to fulfill individual tasks, but not on an ongoing basis. The requirements for qualifications, discipline, and other qualities of this employees involved can be different. With the uniqueness of the qualification of the developer involved , in case of his dismissal, the risk of non-fulfillment of the project task increases. The need for such employees defines the team as unstable.

With constantly working developers, management problems do not usually arise—their reliability level is known. However, if there is a need to assume the optional developer involved, then the manager has to decide to whom and on what conditions it is possible to propose a task for the solution. The main reasons for this situation are as follows:

- Inadequacy of the capabilities of key and constantly working developers for the implementation of the project in an acceptable time.

- There is a lack of qualification of the employees of the first two groups for the implementation of the project, and as a result, it is necessary to search on the side of either the executors of the tasks or for consultations, possibly for training.
- Simultaneous execution of several projects, because of which key and constantly working developers concentrate only on the most important projects.
- There is no need to hire employees for full working hours.
- The need to recruit new constantly working developers, which can be met through well-established optional developers involved when they performed tasks.

The style of work of the project manager of the unstable team assumes a permanent search of outside employees involved to perform autonomous tasks. It is necessary to distinguish tasks that involve obtaining the results needed for the development of the project environment and such tasks, the implementation of which should contribute to the success (in all senses) of project development. The latter may be loosely associated with the project, and decisions about their announcement made, for example, for checking the employee. In any case, the autonomous task should be precise and contain an awareness of when, for what, and how the results obtained would be used in the project. In accordance with the answers to these questions, the project manager should formulate regulations of work both for the performance of autonomous tasks and for products received from third-party developers. It should be noted that the autonomous task must be precise formulated. It should contain pointing of when, for what, and how the results obtained are used in the improvement of project activities. When the formulation of the task assumes repeatable using of its fulfillment results, in addition to the usual work acceptance, a special analysis is required *before* and *after* its setting and execution. The first is planning reusing, and the second is the decision of adaptation the result to the project environment evolution.

Instability of the team most often leads to the fact that it is necessary to allocate resources to adapt the skills of employees to the requirements of the project. Primarily, this concerns constantly working developers who have proved themselves in the performance of assignments as potentially effective participants of the project. Do not neglect the need for training and optional developers involved. Even in cases when they have the skills and experience necessary for the project, the autonomy of their work does not promote the growth of their status to constantly working developer and even more so to a key developer. Activities aimed at, on the one hand, the study of the feature of the project being developed, and on the other hand, the acquisition of common skills and experience, needed to support the process of stabilizing the team. These activities must necessarily be provided for when the project developers seek to become a mature and stable team. At the same time, one cannot ignore that training, as a rule, is very expensive and therefore may not be profitable in the current project situation.

3. Mini-cycles of iterations and the life cycle of project development

Typical for any reasonable methodology, a cycle of project development with an iteratively repetitive sequence of overlapping stages of work, we present as follows (see **Figure 1**). Here and later, we use the notation of the life cycle diagrams proposed in [9]. In this notation, vertical

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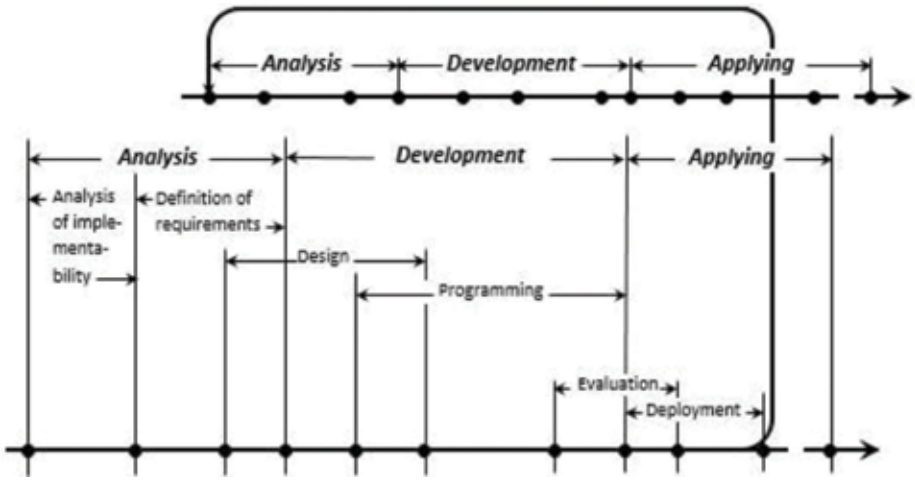

Figure 1. Life cycle of project iterative development.

columns provided with captions show the project phases. The inequality of columns height shows the possibility of overlapping phases: the joint performance of works on a common area of neighboring phases. The bold horizontal arrows present the lifetime of the project iterations. Breaks of arrows indicate that the use of the iteration results continues beyond the development cycle. Crossing the boundaries of phases with lifetime lines are control points and milestones of the project. The colored circles mark them. We display the lifetime of the first iteration with more details than of the second one since their structures are the same. The arrow from the end of the deployment phase of the first iteration leads to the next iteration, possibly with overlapping them. The images of iterations with a shift relative to each other reflect the character of the project development as an ongoing process, during which new tools offered to the user take into account the experience of applying the results of the already passed iterations.

For definiteness, we use the following general breakdown of the process of developing software systems into phases that corresponds to the generally accepted structure of projects (we will use this decomposition later in the discussion of the proposed methodology in Section 5):

1. *Analysis of implementability*—identification of tasks, the implementation of which is relevant for solving user problems that determine the project objectives.
2. *Definition of requirements*, or *development specification*—the development of agreements on what and how should be done in the project.
3. *Design*—definition of the architecture of the system being developed, its decomposition, that is, affirmation of the component structure.
4. *Programming*—creation of software components identified during the previous phase and their verification in terms of meeting the requirements.
5. *Evaluation*—checking the significance of the results obtained both from the point of view of the user's need and for the prospects of the project's development.
6. *Deployment*—transfer of a software product for distribution and use.

This standard life cycle schema for the iterative development process is not entirely suitable for cases where optional developers involved perform some autonomous tasks. Each such task requires the organization of a special process, which we call a mini-cycle, nested in the main iteration of the project to complete the task. The mini-cycle is associated with the splitting of the main process into two branches, performed simultaneously: the continuation of the project and the identification of the task. Splitting can occur at any point in the life cycle of a project when key employees are aware of the need to solve an autonomous task and formulate it for an optional developer involved.

In a mini-cycle (see diagram in **Figure 2**), key developers identify the task for outsourcing, and optional developers involved carry it out. It is clear that for the correct statement of the task, its analysis is necessary, and at the end of the mini-cycle, key developers should make a decision about future using of obtaining results. The latter includes a decision about when the splitting should end, that is, the definition of the latest point in the lifetime line of the iteration, when the results obtained remain useful for the project. The diagram indicates this point as ***F***.

Consider the performance of splitting and mini-cycle details as follows:

- The appearance of splitting occurs at point ***A*** of the lifetime line of the iteration. This is the moment when the key developers realize the need to perform a certain task.
- The mini-cycle begins with an analysis of the identified need at point ***B*** of the lifetime line. Because of the analysis, the task is set for autonomous implementation, and its executor is determined. The team can appoint a developer from any of the groups identified above as the executor. It guides by the staffing situation of the project and other considerations in

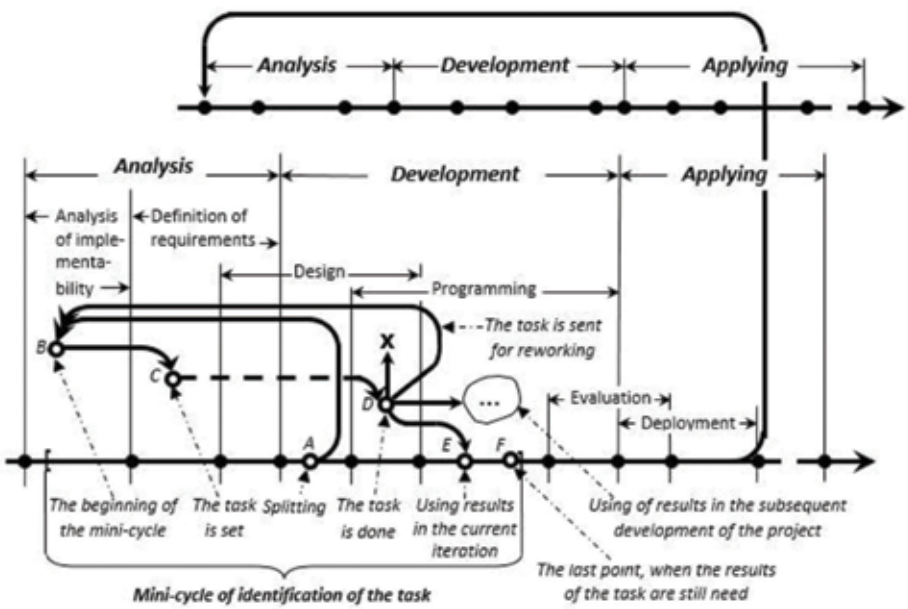

Figure 2. Splitting of the life cycle.

this appointment. In particular, the team can choose an optional developer involved. We are now discussing this case.

- Analysis and statement of the task end at some point in the lifetime line, designated as ***C***. This is the moment when the optional developer involved started working. His activity, shown by a dashed line, ends at the decision point ***D***.
- Analysis of the results obtained in the point ***D*** reduces to the verification of products with the task and, if it is accepted, the results may be included in the project. This activity may lead to the following options.
    - The required results do not match the expected from the optional developer's involved work. The diagram indicates this as **X**. Key developers in this situation must make a decision regarding the executor of the assignment. In particular, is it worth continuing cooperation with this optional developer involved.
    - The work done needs to be improved. The diagram indicates this as the arrow leading to point ***B***. Key developers in this situation must repeat analysis to set updated task and, possibly, to provide assistance to the performer.
    - The results obtained can be used in the further development of the project beyond the current iteration. The diagram indicates this as cloud with "…" text. This situation requires a special evaluation of the developer's activity, on the one hand, and on the other hand, work on drawing up specifications for the product to use. At the same time, key developers should determine whether the interaction with the optional developer involved was productive and comfortable and give recommendations on how to continue cooperation in the future.
    - The results obtained satisfy the requirements, which are necessary for their use in the current iteration both in quality and in terms of execution time. The activity of key developers is the same as in the previous case.

From the suggested discussion of the mini-cycle of implementation of the task by the optional developer involved follows that the analytical work ceases to be a separate stage in the project development life cycle. It becomes a constantly performed production function of the project, the content of which at the beginning of the cycle is the formulation of tasks. When the task is completed, the content of this function (at the evaluation stage) is to prove the feasibility and appropriateness of using the results of the task in the project.

4. Personnel coordinator

The roles of executors of the project for the developed methodology remain the same as in the traditional schemes. The concretization of roles depends on the methodological scheme adopted by key developers. The same applies to the problem of compatibility of roles. The only change is the distribution of roles between performers, which should include third-party developers. Consequently, it is necessary to solve the task of staffing the project, considering it as a special *production function* that is constantly implemented during the development of the

project. It is associated with the special role of the *personnel coordinator*. Usual methodologies do not consider this role specifically, because believe that the project manager is engaged in the team formation at the initial stages of the work.

The role of the personnel coordinator is not reduced to the functions of a human resources officer—a personnel department employee, usual for the traditional style of doing business in the organization in Russia. It does not come down to the work of a more habitual HR manager (Human Recourses Manager). The main difference of the new role is that it assumes the real project work (predominantly design) of the personnel coordinator, while the human resources officer deals only with technical issues of hiring and firing, and the HR manager in addition to them—training of personnel with soft skills and organization of necessary enterprise developers' attraction. The personnel coordinator performs only the last function of the HR manager, although with a slightly different content. We must emphasize that the HR manager plays the role of the administrative structure of the enterprise, which, although it affects the project activity, but indirectly, creates conditions for the work of the project teams by allocating resources to them. If we talk about unstable teams, for the most part, they are almost independent of any kind of administrative superstructure. Most often, such teams only rent premises and pay for the use of infrastructure on contractual terms. They do not form an administrative structure with a special personnel department as a rule.

The new functions of the personnel coordinator are as follows:

- Receiving and processing a task that the team offers to constantly working developer or optional developer involved.
- If a project team tasks an assignment to a constantly working developer, the interaction of the personnel coordinator with the development team in the course of the assignment is subjected to the methodological scheme adopted for the project.
- Formulation the task for an optional developer involved as a proposal, independent of the project.
- Finding a candidate for the position of an optional developers involved (using all the usual methods and sources of information on potential candidates).
- Monitoring the activities of the optional developer involved associated with the task.
- Evaluation of the activities of the optional developer involved in terms of the desirability of further cooperation with him/her.

Depending on the scope of the assignment task (scope of work planned, time constraints, etc.), the personnel coordinator becomes either a project manager formed for an autonomous task or a responsible implementer of the task. Autonomy of a task is limited to planned control activities that are consistent with the main project.

The role of a personnel coordinator can be assigned to a manager or a dedicated employee, but more efficiently when it is distributed among key developers. The advantages associated with such a distribution are a wider coverage of candidates, which means that it is possible to attract employees on a competitive basis.

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5. Basic provisions of the methodology

As already noted, one of the problems of an unstable team is the lack of a suitable project development methodology. However, the forceful implementation of the methodology is unacceptable for solving the problem, since any of them presupposes the consent of the developers and mindfulness, which is impeded by instability. Therefore, in an unstable team, the methodological scheme of the project activity, as a rule, develops spontaneously and with violation of many generally accepted canons, but taking into account the human factor. This is what Cockburn calls for in his noteworthy work [4].

If we exclude from consideration methodological aspects related to interaction with the project customer, who often define them for the unstable team, then taking into account the specifics of the project activities of the team, we can recommend Highsmith's approach ASD (Adaptive Software Development) [10]. ASD is not a methodology in the strict sense of the word, but a kind of a template. Following principles of this template, the developers can choose a methodology, adapting it to the project and to the characteristics of the team. The approach focuses on teams in which training and cooperation as fundamentally important working conditions are considered. Highsmith calls for a flexible attitude toward planning: "in an environment that requires adaptability, planning is a paradox" and believes that deviations from the plan lead to objectively determined decisions. Consequently, developers should consider them not as errors or wrong attitude of performers to work, but natural, "correct" and needing to study circumstances that are the true causes of problems. Project management should aim at providing communication, as developers themselves are able to find answers to emerging issues.

From the just presented review of the ASD concepts, it is clear that they correspond to situations usual for unstable teams. The concrete definition of the methodology for project management for them that meets the principles of ASD can be any; however, the operational steps that involve a methodology for project management activities should be coordinated with the basic scheme of the adaptive development that is the reason of all methodologies that adopt the concepts of ASD (see **Figure 3**).

As one can see from **Figure 3**, in the developing project, there are three overlapping phases that are distinguished: *consideration* → *cooperation* → *learning*. They cover the entire development of the project, divided into stages, represented by rectangular blocks. The evaluation works allocate to the stages, the content of which is associated with the quality result reviews and with the processes of their obtaining. The results of the competitive works (blocks L1, L2, and L3) are evaluated to determine decision making. If satisfactory results are not obtained, and if new tasks are to be performed, a return to adaptive cycle planning occurs, the next iteration of which takes into account the process quality assessment. This cycle plays a dual role as follows:

- Adaptation to the emerging conditions of project management on the basis of the experience gained.
- Learning (in different senses) in order to improve the process and its results.

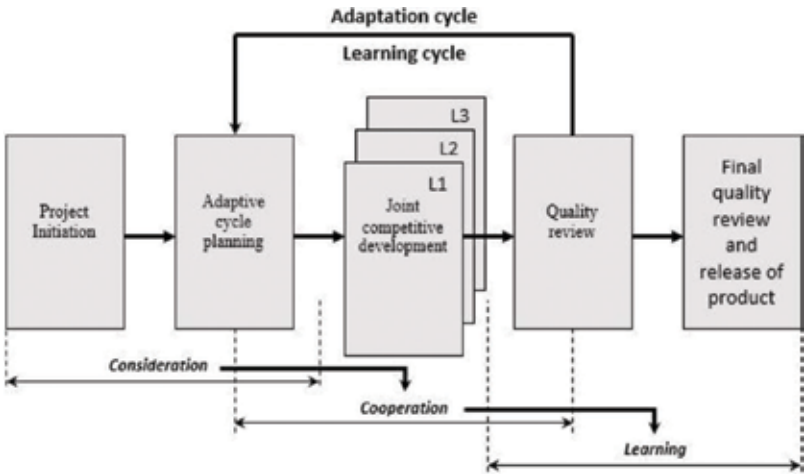

Figure 3. The development cycle of the ASD project.

Adoption of the ASD scheme for an unstable team, as a rule, does not cause difficulties even without a special discussion. As for concretization of the methodology adopted for the team, this requires the unanimous approval of key employees. The consent of the project participant with the adopted methodology of the project activity is a prerequisite for determining she/he as a key developer. The consent of the all key developers with certain methodology is a good chance of successful adopting it for the team. Realizing this, we give only a sketch of the concretization of the methodology that corresponds the ASD scheme with the usual phases of the life cycle of the project development. In this coordination, we take into account the need of splitting and organizing mini-cycles of assignments by optional developers involved, as well as the work of the personnel coordinator.

The subsequent sketch uses the concepts presented in the discussion of the life cycle of the project and the organization of mini-cycles for outsource performing tasks.

Consideration phase:

- *Initiation of the project*. This is the formation of a development task. The task is based on an external order or from the realization of the need to implement the development.

  It corresponds to the analysis stage and the beginning of the definition of requirements. The stage is associated with the initial definition of tasks that one can formalize as offers for autonomous execution.

  The personnel coordinator evaluates the resources available and necessary for the implementation of the project.

- *Adaptive cycle planning*. This is a preparation of architectural solution. For the first iteration, when an architectural decision has not yet been made, information is collected for its development. For subsequent iterations, questions are resolved for the integration of new

components into the existing architecture, as well as the modernization of architecture. An important part of adaptive planning is the definition or adjustment of the quality criterion of architectural solutions.

The staffing task of the stage is the appointment of the performer to whom the team assigns the following work: the search for a ready similar component or a statement of the need to develop a new module. Priority in providing work to executors is given to key and constantly working developers. For assignments, which is decided to offer to constantly working developers and optional developers involved, a *curator* from among key developers is determined. The role of the curator is compatible with the role of the personnel coordinator. The execution of external assignments is in the responsibility of the curator.

Cooperation phase:

- *Joint competitive development of opportunities*. This is the completion of the architectural design phase and the execution of the programming phase. The stage involves the following works:
  - developing solutions for each of the tasks, if the need for this is recognized;
  - identification and implementation of works on the adaptation of selected and developed solutions to the requirements of the system.

  The execution of works by key developers is not specifically regulated. The curator of external works consults (in different forms) their performers (option developers involved) and reports to the personnel coordinator. She/he also identifies situations when the implementation of the task requires the mastering of special educational material. In this case, one of the key developers organizes the necessary classes for interested performers (e.g., in the form of teleconferences).
- *Primary quality estimation*. This is the completion of the execution of external work and discussion of the solutions obtained (overlapping works with the next phase). If one cannot choose the solutions suitable for the development of the system being developed, then a mini-cycle of learning is organized or a transition to the iteration of the adaptation cycle is done. In the discussion, the performer (key or a constantly working developer) and the curator participate. The results of the discussion are forwarded to the personnel coordinator for analysis.

  The stage corresponds to an evaluation, as a life cycle stage in that part of it that is associated with a local estimate of external results by a curator and a personnel coordinator.

Learning phase:

- *Quality review*. This is an assessment of the work carried out and the decision to continue or complete the project. The purpose of the review is to decide whether the release is ready or need to organize a transition to the iteration of the adaptation cycle.

Communications of this stage do not differ from the discussion at the stage of primary quality assessment with the only difference that all key developers are involved in them.

The stage corresponds to the completion of the "Evaluation" phase of the life cycle, during which a conclusion is made about the attestation of the results obtained, that is, about the expediency of the transition to the offer for release.

- *Final quality review and release transfer to the customer*. The content of the activity of the stage consists of determining the level of success of the work in general and the organization of activities that ensure:
  - integration of the results obtained as products for users;
  - evaluation of product quality from the point of view of users;
  - organization of works on support and maintenance (new design tasks).

  Communication of learning phase is a discussion of the success of the implementation of all three phases of the project with the aim of adjusting the future activities of the team and evaluation criteria, taking into account the experience gained, as well as interaction with users and with the customer, regulated by them.

6. Illustration of the proposed approach

In this section, we provide information about the company NetGon, whose activities served as the basis for the formation of the proposed approach to the organization of management of software projects in the conditions of personnel instability. This company specializes in the development of web applications and support tools. Information for the company's work directions, as well as on implemented projects can be found on the company's website http://netgon.ru/.

NetGon emerged as a typical IT start-up. Its creator had the idea to implement a system that could support the rapid development of small applications based on pre-prepared frameworks, templates, and technological toolkit. He managed to find a group of three like-minded people who became key developers of the gradually formed team. Currently, the company employs 15 constantly working developers and approximately 30 optional developers involved. Key developers keep a record of specialists involved in one-off works. Creator NetGon is the manager of the company.

The methodology of project activities in the company evolved spontaneously and based on the experience of previous work. This is usually for beginners. The team realized the need for an appropriate methodology when there was a feeling of a loss of control. In response to this, the team introduces the rules for working with the repository of the basic components. Then, it began to use the *evaluation cards of the employees* involved. These cards maintain information about the strengths and weaknesses of employees, their competence, prospects, and so on. Key developers consider and use the permanently updated database of such cards as a tool to mitigate the staff instability of the team. Optional developers involved, who performed one-time tasks well, receive the status of constantly working developers, and the status of those who did not quite cope with the tasks is reduced perhaps to the level of an undesirable candidate.

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At the same time, key employees analyzed different project management methodologies and their tools. As a result, key developers identified the approach of the ASD, which turned out to be conceptually close to the style of work of the company. The provisions of this approach, associated with the development of their own methodology for project implementation, attitude to errors, and the requirement of adaptability to rapidly changing working conditions have become the basis for improving the implementation processes of both custom and initiative projects.

On this basis, the company distributes the work among the developers, monitors the performance of tasks fulfillment, controls the quality of work results, and builds relationships between employees. Very attractive especially for hired employees are the so-called training sessions, on which the developers share their experience in implementing projects, inform the participants of impressions about the materials they read, and so on. These regular and episodic classes use remote communication tools.

As noted earlier, with respect to optional developers involved, the listed activities are the content of the production function that determines the role of the personnel coordinator. This role is shared between key employees who are assigned to track optional developers who are involved in work related to the tasks assigned to them. Designated employees, not optional developers, are responsible for the task execution process. They represent this process for the team.

These and many other organizational and technical measures allowed the company to improve its efficiency significantly. For instance, if in the initial period of the company's work the time spent on creating the project was from a week to a month, then after the adaptation of the ASD approach, it stabilized for most projects within a week. Initially, the company consisted only of key and optional developers. The group of constantly working developers was gradually formed. It grew by increasing the number of optional developers involved and identifying among them the most reliable and interested employees. This group stabilized when the company began to organize training sessions.

It is worth noting that the NetGon team has a need to disseminate the accumulated knowledge and experience gained in real projects. This is a direct consequence of the orientation toward the ASD approach to the organization of project activities, which involves the learning of employees. As a result, the company offers for the market a number of special products, the content of which is directed to training on web-programming techniques. Today, it is too early to talk about the real demand for these products. Nevertheless, the initiative itself deserves attention.

7. Methods of increasing maturity and reliability of an unstable team

The illustration just presented demonstrates the development of the maturity of the company, which sought to achieve stability through the using of a suitable methodology and organizational

solutions. The analysis of this experience makes it possible to present the method of overcoming instability problems that was obtained as result of the company development. It is based on using some indicators important for effective evaluation of the company:

- Percentage of unsuccessful projects.
- The share of complex projects in the company's works.
- The stability indicator of a group of constantly working developers.
- Conformity of constantly working developers to the qualification requirements of the execute and perspective projects.
- Growth or decrease in the requirement to use optional developers involved.

We do not consider here indicators related to the economic evaluation of the company: profit, profitability, costs, and so on. For the choice of methods of strategic planning and evaluation of the solutions to be adopted, we recommend the reader to refer to the special literature (see, e.g., [11]). At the same time, we emphasize the importance of using economic indicators for monitoring the state of processes in the company and in the case of unstable teams.

How selected indicators are measured depends on the characteristics of the company and its projects. However, to increase the company's maturity and, in particular, to overcome the problems associated with instability, it is necessary for key employees to agree on how to use the adopted indicators to evaluate the company's performance.

Ignoring these problems leads to the degradation of the company and, ultimately, its destruction. Most of the programming teams whose activities we observed sooner or later were forced to go through the process of reorganizing the spontaneous processes and reach the maturity level, which in the CMM classification is called repeatable. Unfortunately, some of them lost their independence and in fact became an external unit of the large companies, forgetting about their initial plans and intentions. In this respect, NetGon is one of the few good exceptions.

For NetGon company, the first indicator changed significantly. If during the first year of the company's existence, there were about 30% of unsuccessful projects on average, by the end of the year, the percentage of such projects stabilized at 10%. The second indicator has grown. The share of projects that last more than 2 months has increased to 30%, whereas before the reorganization of the development processes, the company could not afford more than two such projects (one of them is an initiative project). The third non-quantitative indicator is very important for assessing the quality of the company. It can be estimated by the number of stop-working employees from a group of constantly working developers, but taking into account their importance for the company's activities. There were no such employees in NetGon. To determine the fourth indicator, key employees should take into account not only the current needs but also the development strategy adopted for the company. Using this information, they assess the need for the development of the company's personnel and, thus, establish

qualitative and quantitative parameters for the process of attracting additional employees. This information serves as a guide for the fifth indicator: deviation from the specified parameters is undesirable. Today, in NetGon, the only task of attracting external developers is to test them as candidates for the constantly working developers. This is considered as an element of the company's personnel policy.

We pay considerable attention to the discussion of maturity indicators, because the use of them by key developers allows *to identify and understand the problems of the team that, in particular, hamper the involvement of the good developers*. In its essence, this is the first step toward increasing the maturity and reliability of an unstable team.

The second step toward increasing the company's maturity is *to identify the risks that arise from unsatisfactory indicators and to collect proposals for mitigating them*.

The work of the team with the optional developers involved is always associated with certain risks for the project. First of all, these are unjustified expectations of performing the tasks with due quality and in a timely manner. *Mitigating of this risk is usually attained with entering into contracts with third-party developers* and, if agreements are reached and formalized legally correctly, this can guarantee against financial losses.

Unfortunately, the contract cannot provide for threats related to inaccurately or incompletely formulated requirements for the program project and, possibly, to the tasks proposed for outsourcing. In such cases, the company has a natural need for a suitable methodology for the project activity. *The introduction of such a methodology is one of the important methods for increasing the company's maturity*.

Adequate project methodology only contributes to mitigating risks, but does not exclude them. Interacting with constantly working and optional developers, the project manager can and should apply other *well-known techniques for risks mitigation.*[1]

Permanent contact with employees and prompt correction of decisions are one of the conditions of the risk mitigation policy. When solving tasks of optional developers involved, the opportunities for the contacts with them are significantly limited. Therefore, *the tasks proposed for outsourcing should be set so that the expected results are useful, regardless of the possible changes in the projects that are being implemented*.

The teams that we were able to observe often made mistakes due to the failure to fulfill this condition. Some of them had to abandon the use of the optional developers involved. And this can be considered as a radical method for solving instability problems. However, those of them that correctly evaluated failed were able to determine what tasks can and cannot be outsourced. As a result, they got quite good opportunities for effective using of outsourcing. For example, NetGon today trusts up to 60% of project works for the optional developers involved and, accordingly, reduce the costs of development. Thus, *the thoughtful selection*

[1]This topic is beyond the scope of this chapter; for its study, we recommend the publication of [12] on the MITER resource (https://www.mitre.org/) and other sources to which it refers.

of tasks for the optional developers involved mitigates the risks of inefficient use of outsourcing by unstable teams.

This statement is necessary, but not a sufficient condition for the success of using outsourcing. If the team does not care about managing the implementation of external tasks, the effectiveness of third-party developers can significantly decrease. That is why we single out a special production function for the project, whose purpose is to monitor the performance of external works. This function is related to the role of the *personnel coordinator, whose definition we consider as the base of the proposed approach to increasing the maturity and reliability of the unstable team*.

The role of the personnel coordinator can be distributed between key or constantly working developers, but for each optional developer involved or for a group of such developers who are jointly performing a task, there should be a single supervisory coordinator. The area of responsibility of the coordinator includes communications with optional developers involved and the management of outsourced tasks. It represents to the team both the results and the progress of the tasks. If necessary, the coordinator organizes staff training for both optional developers involved and, possibly, other employees.

The successful development of any company depends not only on the maturity of the projects development processes but also on the attractiveness to potential developers. An important component of success is the formation of an inviting reputation: caring for employees, creating comfortable working conditions, providing opportunities for professional development, career prospects, and so on. This is very important for a company that, in conditions of instability, seeks to increase its maturity. Although the issues of reputation enhancement are beyond the scope of this chapter, we note that the ASD methodology, which we discussed earlier, is very productive in conditions of instability. *Three phases of the project: considering, cooperative, and learning, which involve all developers, create conditions for the active joining external employees with the team members*.

8. Conclusion

In this chapter, we presented methodological proposals for organizing the activities of programming teams that attract external performers for carrying out projects. A list of typical works for which such outsourcing can be useful is described as follows:

- Implementing a new or adapting an existing toolkit with precisely defined functions required for the execution of a project.
- Development of library facilities that meet the fixed conditions for their use.
- Optimization of the developed components, and/or adaptation to special equipment.
- Consulting services of various kinds: clarification of user requirements, analysis of the target market for the project products, recommendations on the instruments used, and so on.
- Audit of project and organizational activities of the project team.

Teams that are forced to use outsourcing, we conditionally call as unstable, to emphasize obvious for them staff variability. The successful experience of external outsourcing by teams that consciously focus on the main directions of the project and pass on to others what is not fundamental deserves attention. Observations and analysis of the experience of several such teams allowed us to identify general principles, the adherence to which we can recommend in similar situations.

The approach to the specification of the methodology in order to achieve compliance with its accepted conceptual scheme is presented in the alignment of the classical stages of the life cycle with the scheme of adaptive development of the ASD project. One can consider it without relation with the particularity of unstable teams. When adapting any methodology to specific conditions, it is necessary to solve a similar problem. It is especially important to raise this problem if the methodology of teamwork is spontaneous, and the team needs to systematize the processes of projects development and use a methodology that corresponds to the working conditions of the team. At the same time, we should not absolutize the proposed constructions. The concretization of the methodology depends on so many factors, and therefore it would be naive to believe that it is possible to give "universal" recipes for solving this problem. The only thing that we can here recommend is the awareness of the choice of organizational forms of project activities based on the study and critical analysis of existing approaches.

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Chapter 11

A Hybrid Model for Optimizing the Municipal Public Budget

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Abstract

Participatory management establishes a dynamic of democratization of the public administration, since it associates planning and widespread participation, through political definitions and adjustments and changes. Its purpose is to discuss and define the population, in a democratic way, the distribution of investment resources. Major challenges put pressure on governments at the federal, state, and municipal levels, requiring them to be more creative and effective ways of achieving results, from the employment of increasingly scarce resources and an increasingly demanding and participatory population. Considering that the process of managing public resources is defined in the budget, it is necessary that it contains all the elements that facilitate and allow a correct application of these, among the universe of interests presented by the population through the participatory management process. Moreover, we propose a model for the management of optimization of the Public Budget, whose objective is to provide the administrator with the instruments necessary to optimize the application of available public resources. The methodology in the analysis of the feasibility, and the application of a multicriteria structured model and mathematical programming applied to the public budget, having as a case study a macro view of the budget for Municipal City Halls.

Keywords: public budgeting, mathematical programming, multicriteria, linear programming, municipal city, M-Macbeth

1. Introduction

Participatory management establishes a dynamic of democratization of the public administration, since it associates planning and popular participation, through political definitions and adjustments and adjustments in the process, when necessary. Its purpose is to discuss and define the population, in a democratic way, the distribution of investment resources. Exactly because it is the result of the discussion and the decisions of the society, the works or investments prioritized, in general, involve the most complex problems of the communities. They are works that require more detailed projects and careful executions. Significant challenges put pressure on governments at the federal, state, and municipal levels, requiring them to be more creative and effective ways of achieving results, from the employment of increasingly scarce resources and an increasingly demanding and participatory population.

Considering that the process of managing public resources is defined in the budget, it is necessary that it contains all the elements that facilitate and allow the correct application of these, among the universe of interests presented by the population through the participatory management process.

Within this context, we present a methodology for modeling the problem that seeks in science based on multicriteria and linear programming the optimal solution for its proposition for the Public Budget, whose objective is to provide the public administrator with the necessary tools to optimize the application of the available public resources, considering the environment in which it is inserted. To determine the optimal way of applying the funds authorized by the Legislative Power, in order to maintain the administrative machinery, enforce the laws and still meet the desires of the population with increasingly scarce financial resources. Our proposal is to apply these technologies to public finances, whose objective is to model the public budget in order to maximize the available resources, taking into account the government programs and the current legislation.

In the Section 2, presents Budget Guidelines Law. Moreover, Section 3, is given Hybrid Model for Optimization. More details of the Multicriteria Modeling provided is Section 4. On the other hand, in Section 5 provides more information on the applied methodologies. Furthermore, in Section 6 the computational results obtained using. Finally, Section 6 presents conclusions and future works.

2. The budget guidelines law

In the Budget Guidelines Law (BGL), expenditure is classified through several criteria, the most important of which are functions, programs, nature of expenditure and elements, which leads to a more complex and more difficult codification, different interpretations for some of its components. The Law requires that some principles be observed in the execution of the budget, especially flexibility, that is, adaptation to new or unforeseeable situations. This flexibility necessary for public managers is extremely limited due to the restrictions imposed by

the current legislation. In this sense, public administrators have great difficulty in defining the application of financial resources, by the legal limitation and by the population's demand for the services that they considered to be priorities.

Moreover, the system has laws that restrict, and on the other, increasingly demanding citizens who always demand more quality public services, lies the difficulty of determining the solution to find the best way to distribute resources. This article focuses on government programs that define how public administration seeks solutions to social problems. Each government program is linked to activities, to which are associated resources among which the financial necessary to carry out the actions that underlie the programs in question. For any expenditure that is desired, it is necessary to pre-exist the corresponding budget allocation. We seek to define budget allocations for each government program to optimize the available resource and meet the population's wishes. Budget allocations are distributed among the various Government Programs. Each Government program has an importance for the Public Administration in office, and must be defined to distribute the budget allocations for the activities related to it, and then the expenses necessary for the implementation of the Program can be made.

3. Hybrid model for optimization

The proposed model is composed of two steps: initially to construct the objective function from the multicriteria analysis [1–3]. Next, the construction and solution of a linear programming model based on the objective function constructed in the first phase and the legal, minimum and maximum constraints defined for each variable to be calculated, called budget allocations.

3.1. Model in linear programming

The aim is to maximize the actions to be carried out through budget allocations, considering the degree of importance of these actions (Government Programs). Budget allocations are defined as variables x_i.

The best distribution of the budget will be the one that better attends to the actions of the Government Programs, considering the importance defined by the widespread participation coordinated by the administration in question. The optimization criterion is then the sum of the budget allocations of each activity weighted by the degree of importance of the Government Program to which it is linked. We can stand for the objective function in Eq. (1),

$$\max \sum_{i=1}^{n} k_i x_i \tag{1}$$

x_i = Budget allocation of the activity related to the Government Program i;

k_i = Degree of importance of the Government Program i;

n = Number of government program activities in the budget.

The evaluation of the pertinent legislation Budget Guidelines Law (BGL), and Fiscal Responsibility Law (FRL) allowed to find some legal restrictions, which we present below. The definitions given are merely illustrative for the assembly of the model; In their application, should follow what is recommended in the specific literature.

3.2. Restrictions

I. Expenditures may only be made up to the limit of the budget credits and additional credits, and following the disbursement schedule of the Unit, duly approved in Eq. (2),

$$\text{Restriction } \mathbf{1}\text{: } \sum_{i=1}^{n} x_i = \text{RCTot} \tag{2}$$

n = Number of government program activities in the budget;

RCTot = Total revenue previously defined by the finance team, according to the pertinent legislation;

II. According to Eq. (3) for the FRL, personnel expenses are the sum of the expenses of the Federation entity with the assets; The expenses for inactive and pensioners; Fixed and variable salaries and benefits; The subsidies, retirement benefits; Reforms and pensions; The added ones of any nature; The gratuities, overtime and personal advantages; Social charges; The contributions collected by to private pension entities. The FRL limits spending on public sector personnel to 60% of net revenue for states and municipalities. In the municipal sphere, the 60% limit will be distributed among the Legislative Branch: 6% (including the Municipal Court of Audit) and Executive Branch: 54%.

$$\text{Restriction 2: } \sum_{i=p_1}^{p_n} x_i \leq 0.495^{*} \text{RCL} \tag{3}$$

$p_1 \ldots p_n$ = activities of Government Programs in the budget related to personnel;

RCL = Net revenue.

III and IV. According to Eq. (4) and Eq. (5) for the Federal Constitution, the municipality must distribute to education, not less than 25% of its tax collection and transfers. Of these 25%, 60% should be earmarked for primary school funding and the remaining 40% for other levels of education. In addition, 60% of the resources should be earmarked exclusively for the payment of teachers' salaries, with a view to enhancing the teaching profession and improving the quality of teaching.

$$\text{Restriction 3: } \sum_{i=e_1}^{e_n} x_i \geq 0.25 \times \text{RCE} \tag{4}$$

$$\text{Restriction 4: } \sum_{i=fund_1}^{fund_n} x_i \geq 0.25 \times 0.60 \times \text{RCFund} \tag{5}$$

e_1, …, $e_{n=}$ activities of Government Programs in the education budget;

$fund_1$,…$fund_n$ = activities of Government Programs included in the budget for primary education;

RCE = income for education, defined in the Budget Guidelines Law (BGL);

RCFund = revenue for calculation of fundamental education, defined in the BGL.

V. Expenditure on health: the linking percentage is 15% of its tax revenue and constitutional transfers in Eq. (6). This rate must be reached within 5 years from the entry into force of the Amendment. In their first year, percentages below 15% for health financing should be increased gradually by the 5th year after their approval, reducing that gap by at least 1/5 per year. For modeling purposes, we are considering only the percentage of binding of 15%, understanding that the Administration in question is with this percentage stabilized.

$$\text{Restriction 5: } \sum_{i=s_1}^{s_n} x_i \geq 0.15 * \text{RCS} \tag{6}$$

$s_1 \ldots s_n$ = government Program activities in the health budget;

RCS = For calculation of Health, defined in the BGL.

VI. The budget distributed to the City Council should be at most equal to 5% of tax revenue in Eq. (7).

$$\text{Restriction 6: } \sum_{i=c_1}^{c_n} x_i \leq 0.05 * \text{RCT} \tag{7}$$

$c_1 \ldots c_n$ = number of activities of Government Programs gave in the budget relative to City Hall;

RCT = Tax revenue, as defined in the BGL.

VII. In Eq. (8) to current expenditure cannot be financed by capital expenditure; That is, the value of current expenses must be less than or equal to the value of current revenues. Current spending is the cost of supporting public services; Without any return to equity of equal value. Capital expenditures are expenses where there is the reward for the direct entrance of a kind, of corresponding value, in the patrimony; that is, investments, financial investments, and capital transfers.

$$\text{Restriction 7: } \sum_{i=dc_1}^{dc_n} x_i \leq \text{RC} \tag{8}$$

$dc_1 \ldots dc_n$ = current expenses supported in the BGL;

RC = Current revenues (revenues directly from the Public Administration that are directly or indirectly consumed in expenses with the maintenance of public services previously created - do not include capital funds).

VIII. Finally, in Eq. (9) all Government Programs to which the budget allocations (model variables) are linked have a certain political importance for Administration (index k of the model); and, so, they must be positive, different from zero, greater of a value u and smaller of a value d, both decided by the Administration; or in the range:

$$u_i \leq x_i \leq d_i \forall x_i \tag{9}$$

4. Multicriteria modeling

The degrees of importance of government programs should be defined based on the multicriteria methodology, defined as k in the model, will define the maximum value of the objective function and will be a decisive factor in the definition of controlled variables of the model. The information required for the model to be provided [4]:

- The revenues, included in our model, that restrict the value of the controlled variables;
- The relation of the activities of the Government Programs that will define the size of the vector of controlled variables. Government Programs will be treated as constants in the model;
- The classification of the activities of the Government Programs, through Participatory Management, duly reviewed by the Principal Manager. This classification will be the input to calculate the degree of importance of each Government Program.

In addition, each government program is divided into activities and each of these activities should be classified into two levels: initially classifies the activity by fundamental values such as Health, Education, Environment, etc. Moreover, specifies each fundamental value, called here sub-criteria, creating a two-level classification. The value tree will be built with as many fundamental values as believed necessary by management, including the participation of society (fundamental value A, B, C, D, etc. …). Each fundamental value will have as many sub criteria as are defined by management and society (sub criteria I, II, III, etc. …). The proposed modeling considers that the software Measuring Attractiveness by a Categorical Based Evaluation Technique (M-MACBETH): method elaborated by [5, 6]) is applied to define the degrees of importance, from the tree of Values built. The attractiveness indexes of these fundamental values among themselves and the sub-criteria should be giving by consensus within a participatory management program of the actors.

Furthermore, a matrix of fundamental values (A, B, C, …) is created and the attractiveness of them is compared to each other, generating the index f of each of these values by the M-MACBETH method. The index f is the result of comparability of the first level of the value tree. Each fundamental value will have sub-criteria linked to it, which should also be compared to each other. A new value matrix is constructed for each fundamental value, comparing the attractiveness of its sub criteria, generating the index s of each sub-criterion by the M-MACBETH method (second level index of comparability).

The degree of importance k, related to the government activity to which the budget allocation x is bound, will be the product of the index set up for its fundamental value (first level) by the index set up for its sub-criterion (second level): $k = f \times s$.

4.1. Range of variation of f_i

The actors decide which fundamental value has the greatest and the least importance, they then receive grades 100 and 10, respectively. These levels of attractiveness, because they are defined as major and minor, by the actors must receive the maximum and minimum values, and therefore cannot assume intermediate values; Consequently, there is no variation interval.

4.2. Range of variation of s

For each fundamental value the actors' levels of attractiveness were defined by their sub criteria. As in the valuation of f, in each case there is an item of greater and another of lesser importance. These items receive degrees 100 and 10, respectively. These attractiveness levels, since they are defined as major and minor by the actors, must receive the maximum and minimum values, and therefore cannot assume intermediate values; Consequently, there is no range of variation.

Furthermore, each parcel f and s that composes index k can assume a range of values, without, however, changing the level of attractiveness that is calculated by M-MACBETH. We call this range of "Interval" values. The M-MACBETH presents the ranges of variation that the f and s indexes generated by it can assume, guaranteeing the valuation of the levels of attractiveness defined by the actors.

A range of variation for the index k, defined from the solution of the problem in linear programming, considered objective function and constraints. Let's call this interval "Interval θ ".

Moreover, each step of our proposal generates a set of values in which the degrees of importance of government activities (k) may be inserted: the intervals β and θ. The intersection of these sets stands for the interval at which, in fact, our objective function indexes k may vary, the "Interval γ".

4.3. Variable time

The construction phase of the model supports the analysis of the time horizons of the proposed modeling. The budget part is a public instrument defined for the fiscal year (fiscal year - 12 months). Your legal restrictions must be respected at the end of each exercise. This hybrid model proposes a method for the construction of the budget piece for a given fiscal year, which guarantees compliance with the legislation, and other restrictions imposed. It can also be used in budget supplementation, during the exercise, to verify compliance with legislation; Since, once the restrictions have been respected throughout the year, we will be guaranteeing compliance with these restrictions at the end of the exercise. But in this case, we must evaluate the results in time every round of the model.

4.4. Duality analysis

The primal of the proposed model has as goal function the sum of budget allocations that are weighted by the degree of importance of the Government Program to each of them associated, degrees these, defined from multicriteria analysis by popular participation. Its restrictions are the legal ones regarding the revenue and the minimum and maximum limits defined by the public administration for each activity. These values of revenue and maximum and minimum limits are constant values in our proposal, defined at the time of the elaboration of the primal model. They change the distribution of the budget: if, for example, Total Revenue is changed, the values of the budget allocations will change. If the minimum or maximum amount to be applied in the school lunch activity is changed, this will have a greater or lesser impact than a variation in Total Revenue.

Consider:

z = number of restrictions on budget allocations;

w = number of legal restrictions;

r_j = values defined as restrictive revenue from the applications of budget allocations;

p_j = values determined as lower/upper limits of the budget allocations for the activities of the Government Programs;

y_j = degree of effect about values defined by the public administration as lower/upper limits and revenues in the budget distribution.

On the other hand, restrictive revenues (r_j) are those present in the constraints of the primal as legal impositions. Some constraints of the primal are formed by equations that impose to the budget allocations x_i minimum limit, others impose maximum limit. These minimum or maximum values determined by administration at the time of constructing the primal are p_j.

By "degree of impact" we mean the relative importance that these lower (upper) limits on the main problem have in defining budget allocations. That is, y_j measures the relative impact of that arbitrariness of the lower value (or higher) and of the revenue in the budget distribution. We can present in Eq. (10) the duality of the proposed model in the form:

$$\text{Dual objective function: Min} \sum_{j=1}^{w} r_j y_j + \sum_{j=w+1}^{z} p_j y_j \tag{10}$$

The values "p_j" and "r_j" are "arbitrated" in the primal, that is, they are constant values defined at the time of the elaboration of the primal model. Once altered they affect, in some way, the solution of the primal, that is, the distribution of the budget.

The purpose of the dual is to MINIMIZE the impacts of the "arbitrated" upper (upper) limits and legal restrictions on revenues in budget distribution.

The greater the degree of effect y, the greater the impact of the arbitrated limits, or the revenue, on the distribution. That is, a change to a greater or lesser extent in the coefficient going with

the y in the objective function of the dual will have a greater or lesser impact, respectively, in the distribution of budget allocations.

Each constraint of the dual will be formed by an inequality where a k will be present in its second term, which will stand for them by in Eq. (11):

$$\sum_{j=1}^{m} q_{x_n} y_j \geq k_n; 1 \leq n \leq v \tag{11}$$

at where:

m = number of constraints of the budget distribution;

v = number of variables budget allocations;

q = is the coefficient of x in the nth budget constraint.

5. Case study: Fortaleza city hall

We used as a case study the budget data for the 2013 fiscal year of the City Hall of Fortaleza, approved by the Municipal Council and published in the official gazette.

The City Hall of Fortaleza 2013 Budget is composed of several tables. Among them, we show the Government Programs and the General Summary of Revenue as being of most relevance for the development of this work. We look for the government programs defined as goals to be achieved in 2013 by the City Hall of Fortaleza, and their respective activities; And, from there, we apply the definition proposed in the model. The targets will be achieved through the application of the budget allocations defined for each of the activities planned for the government programs.

5.1. Application of the model

Initially, we start from the Government Programs table of the 2013 City Hall of Fortaleza budget and classify activities as fundamental values. We call the areas of general interest in society: Education, Infrastructure, Environment, Administration, Health, Economic Development and Social Assistance. For each fundamental value, we define classification sub criteria as presented in **Table 1**.

The areas and their sub criteria were defined based on interviews with several specialists in the areas of planning, education, health, administration, infrastructure, etc. … The proposed method consists in classifying each budget activity as the fundamental value, that is, if that activity refers to Education, Infrastructure, Environment, Administration, Health, Economic Development or Social Assistance; And the sub-criterion presented in the table above. We apply M-MACBETH to compare the attractiveness of fundamental values and their sub criteria and then define the "degree of importance" of each activity group. We understand by activity group the set of budgetary activities that have as fundamental value and sub-criterion the same classification. The definition of the attractiveness indices predicted in the

Fundamental value	Classification subcriteria				
Management	Staff	Safety	Patrimony	Administration policies	Control
Social assistance	Habilitation	Social assistance programs	Laser	Citizenship	Policies social assistance
Economic development	Training	Economic development programs	Policies	Tourism	Culture
Education	Feeding	Fundamental	Infant	Adults	Education policies
Infrastructure	Road	Collective transportation	Lighting	Traffic	Policies infra
Environment	Oversight	Urbanization	Preservation	Privacy Policy	—
Health	Hospital	Basic attention	Medication	Surveillance	Health policies

Table 1. Fundamental values and their sub criteria.

M-MACBETH method was carried out based on research with some actors from different social levels, selected at random. We defined as "consensus" between the actors the arithmetic mean of their answers in each comparison, calculated from the one-to-one correspondence of the attractiveness, on a scale of 2 to 6 proposed in the model (from 2—Much less important to 6—much more important).

We understand that the choice of actors and the definition of consensus among them should be the object of specific research within a participatory management project. Our aim in this case study was to stand for an interest of a randomly defined community, without scientific research on the representativeness of the community since this research transcends the object of our research. On the other hand, to apply the M-MACBETH software, inserting the result "of this consensus" in steps:

5.2. Definition of the attractively index among the fundamental values

We present in **Table 2** - Summary of the M-MACBETH Indices, column "f - Index" the result of the comparison of the attractiveness of the fundamental values (Health, Education, Social Assistance, Environment, Economic Development, Infrastructure and Administration) - MACBETH. On the other hand, Health was identified as the most important fundamental value and Management was of the least importance. In the table of values of M-MACBETH we defined with 10 points the lowest value of attractiveness for calculating the individual indexes.

5.3. Definition of the attractiveness index among the subcriteria of the fundamental values

We present in **Table 2** - Summary of the M-MACBETH Indices, column "S - Index" the result of the comparison of the attractiveness of the subcriteria of each fundamental value, using

Fundamental value	f_i			Subcriteria	s_i			k_i		
	Index	Maximun	Minimum		Index	Maximun	Minimum	Index	Maximun	Minimum
Health	100	100	100	Hospital	1	100	100	1	1	1
	—			Medication	0.8125	84.99	77.51	0.8125	0.8499	0.7751
				Basic attention	0.4375	45.62	40.01	0.4375	0.4562	0.4001
				Surveillance	0.25	26.87	10.01	0.25	0.2687	0.1001
				Health policies	0.1	10	10	0.1	0.1	0.1
Education	81.59	83.63	79.55	Child education	0.8159	100	100	0.6657	0.8363	0.7955
	—			Feeding	0.4328	54.99	45.23	0.3531	0.4599	0.3598
				Elementary education	0.3051	45.2	35.44	0.2489	0.378	0.2819
				Education adult	0.1455	21.73	10.01	0.1187	0.1817	0.0796
				Education policies	0.0816	10	10	0.0666	0.0836	0.0796
Assistência social	63.18	64.2	55.01	Housing	0.6318	100	100	0.3992	0.642	0.5501
	—			Social assistance programs	0.4093	68.69	53.06	0.2586	0.441	0.2919
				Recreation	0.3352	64.77	41.31	0.2118	0.4158	0.2272
				Citizenship	0.2609	45.21	37.4	0.1649	0.2902	0.2057
				Assist. social policies	0.0632	10	10	0.0399	0.0642	0.055
Environment	55	57.04	46.83	Urbanization	0.55	100	100	0.3025	0.5704	0.4683
	—			Preservation	0.451	86.49	73.01	0.2481	0.4933	0.3419
				Oversight	0.4015	81.99	64.01	0.2208	0.4677	0.2998
				Privacy policy	0.055	10	10	0.0303	0.057	0.0468

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Fundamental value	f_i			Subcriteria	s_i			k_i		
	Index	Maximun	Minimum		Index	Maximun	Minimum	Index	Maximun	Minimum
Economic development	46.02	54.99	45.8	Training	0.4602	100	100	0.2118	0.5499	0.458
	—			Culture	0.3774	86.49	73.01	0.1737	0.4756	0.3344
				Tourism	0.3359	81.99	70.76	0.1546	0.4509	0.3241
				Economic development programs	0.191	45.99	37.01	0.0879	0.2529	0.1695
				Economic development policies	0.046	10	10	0.0212	0.055	0.0458
Infrastructure	38.64	45.79	36.6	Roads	0.3864	100	100	0.1493	0.4579	0.366
	—			Lighting	0.3232	91.79	67.29	0.1249	0.4203	0.2463
				Collective transportation	0.26	83.63	59.11	0.1005	0.3829	0.2163
				Traffic	0.1967	67.27	46.83	0.076	0.308	0.1714
				Policies infrastructure	0.0386	10	10	0.0149	0.0458	0.0366
Administration	10	10	10	Administrative control	0.1	100	100	0.01	0.1	0.1
	—			Staff	0.0788	84.09	76.18	0.0079	0.0841	0.0762
				Safety	0.0524	57.59	47.11	0.0052	0.0576	0.0471
				Patrimony	0.0269	31.14	10.01	0.0027	0.0311	0.01
				Policies administration	0.01	10	10	0.001	0.01	0.01

Table 2. Summary of M-MACBETH indicies (applied to city hall of Fortaleza/2013).

the method M-MACBETH. According to the proposed model, the degree of importance k for the government activity whose budget allocation x is bound will be the product of the index established for its fundamental value by the index established for its sub-criterion: $k = f \times s$. **Table 2** presents in the column "k - Index" the product of the columns "f - Index" and "s - Index" for each established subcriteria.

The objective function applied to the case study can be seen in the https://www.dropbox.com/s/ga4flhp61291ro4/Restrictions%20and%20degrees%20of%20attractiveness.pdf?dl=0 through the horizontal reading of the table, by the sum of the product of the fifth column (relation of the k's) by the corresponding x.

5.4. Restrictions

Each budget activity may be present in more than one constraint. This model applied to the City Hall of Fortaleza in 2013 can be seen in tabular form in the https://www.dropbox.com/s/ga4flhp61291ro4/Restrictions%20and%20degrees%20of%20attractiveness.pdf?dl=0. The columns 1 and 2 present the budget allocations of government activity x; Columns 3 to 9 show whether the activity is present in restrictions 1 to 7, respectively; And columns 10 and 11 refer to the specific constraints of each activity (minimum and maximum values, if any).

The table reading can be done horizontally, where you can see each model variable, that is, the budget allocation of each activity and the vertical form of columns 3 to 9, the sum of the rows in each column is the composition of A restriction. Columns 10 and 11 shows whether there is a specific constraint, that is, whether there is a restriction on the maximum or minimum value, respectively, for the budget allocation of that activity. The revenues that make up the second term of the restriction can be found in the "General Summary of Revenue" table, in the fiscal year 2013 of the City Hall of Fortaleza, approved by the City Council and published in the official Gazette.

The first lines of the model, that is, the objective function and the first constraints (those imposed by the specific legislation) are formed by many variables. The other constraints of the primal problem are specific to each government activity, and therefore are made up of only one variable.

We applied LINDO/PC, release 6.1 for analysis and solution of the model in linear programming applied to the City Hall of Fortaleza. The software generated the result of the application of the model for budget optimization/City Hall of Fortaleza - 2013, presenting an array of 578 rows and 285 columns.

6. Computational results analysis

The graphs presented in the following figures were constructed based on the computational results generated by the implementation of the proposed model applied to the City Hall of Fortaleza, exercise 2013. In the abscissa, we find the budget allocations x (where i ranges from 1 to 285, number of variables of our Primal problem). In the ordinate, we have the values

the values of k. These figures graphically show the sensitivity of the computational results. **Figures 1** and **2** shows, respectively, the ranges. The curves in pink present the maximum value and in yellow the minimum value that k can assume.

Following the model, we must construct the intersection curve of these two graphs. **Figure 3** shows the interval, intersection of the curves shown in the earlier graphs. The curve in pink shows the maximum value and the yellow line the minimum value that k can assume.

We can see that the variation spectrum of k is small, since the curves almost coincide. There is a small gap in which each k can vary without changing the budget distribution.

If we have two methodologies in the proposed model that generate two intervals (e) for variation of k, we must analyze which of the two methodologies contributes to the definition of the maximum limit and the minimum limit of the solution. The pink color curves presented in the graphs (**Figures 2** and **3**) that present the maximum values for k in the intervals (intersection) and (M-MACBETH), respectively, were superposed and are shown in **Figure 4**:

The dotted line in green stands for the maximum values of the M-MACBETH curve and the continuous in pink represents the maximum values of the intersection curve. It is the comparison of the two, in which the curve of the intersection of the maximum value of k coincides with that of M-MACBETH. We can see, then, that the definition of k by the actors (multicriteria method) imposes an upper limit of the values of the budget distribution. Let us therefore evaluate the main contribution of the lower limit. **Figures 5** and **6**, below, show the comparison of the minimum boundary curves of the intervals.

Except for a few points, the curve of the intersection of the minimum value of k coincides with that of LINDO. We conclude that legal and specific constraints (linear programming) impose the lower limit of the values of the budget distribution.

In the case of the City Hall of Fortaleza, participatory management (definition of k) by the actors (community) limits the budget distribution by assigning the maximum values of the

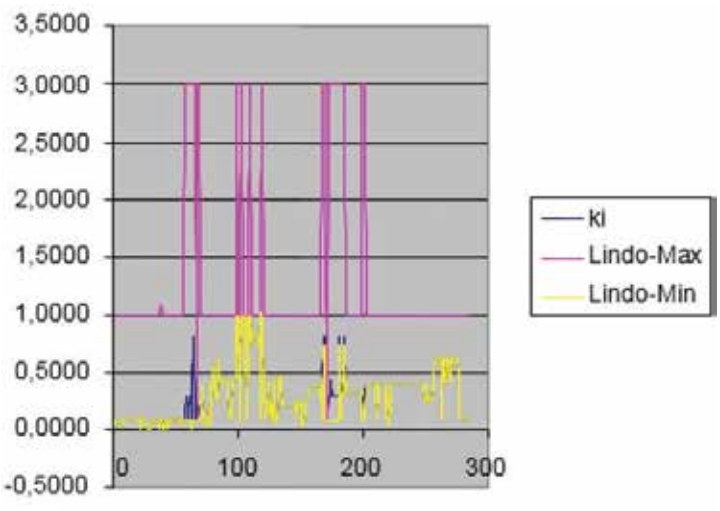

Figure 1. Variation of k - LINDO.

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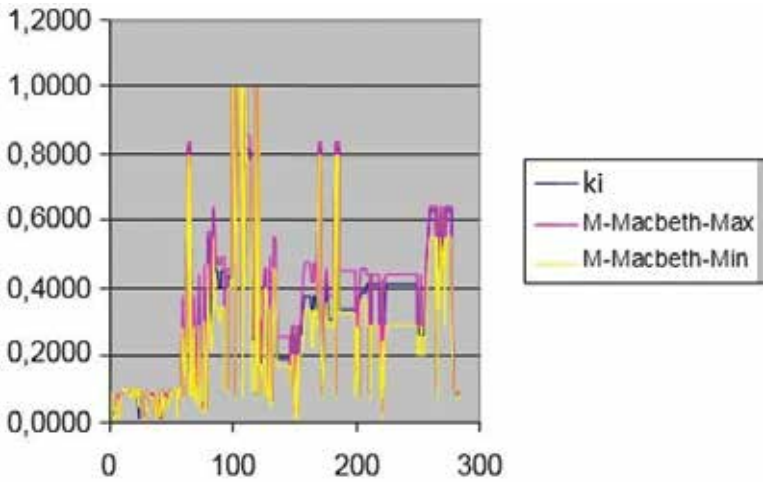

Figure 2. Variation of k-M-MACBETH.

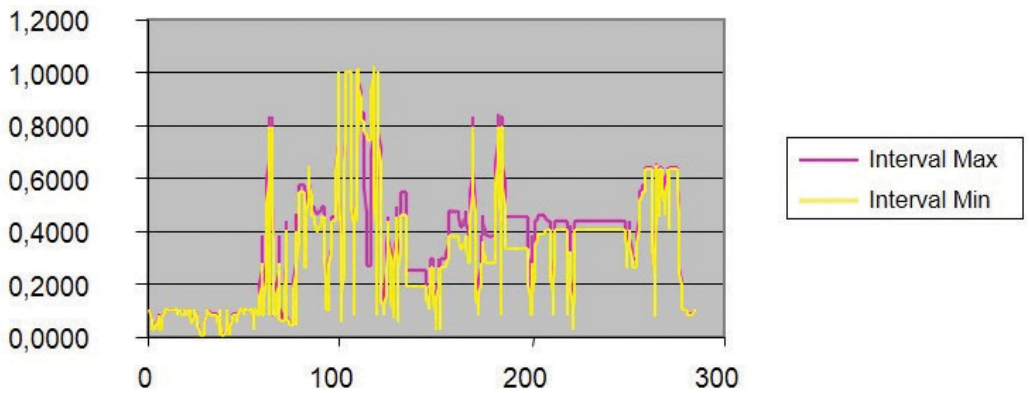

Figure 3. Interval (intersection LINDO and M-MACBETH).

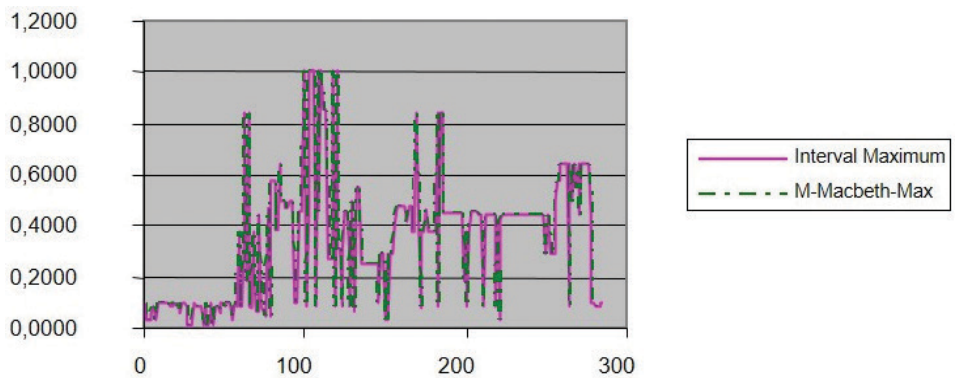

Figure 4. Comparison of M-MACBETH and intersection - maximum.

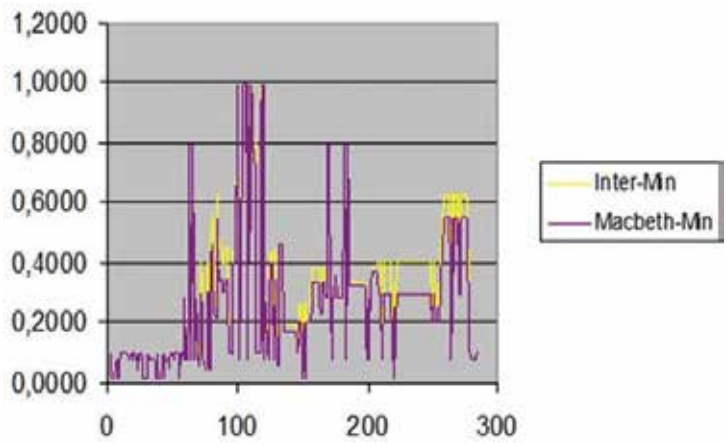

Figure 5. Minimum curves: intervals β and γ.

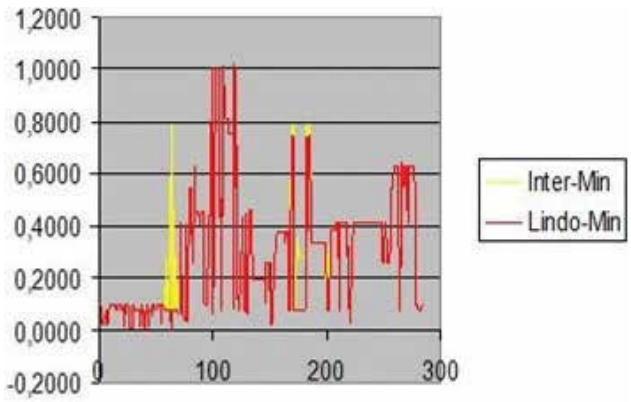

Figure 6. Minimum curves - intervals θ and γ.

priority grades of the budget activities. It is the legal and specific restrictions of each activity that impose the minimum amounts of amounts of the budget activities. Both seek a balance of budget distribution, reconciling the will of the population and laws.

7. Conclusion and future works

The present proposal defines a process of modeling in linear programming for the Municipal Public Budget, whose aim is to offer the administrator with the tools necessary to optimize the application of the available public resources, considering the environment in which it is inserted. This environment brings subjectivity in the definition of priorities through Participatory Management (made by so-called actors in our model) and imposes constraints, sometimes by the administration's own criteria, sometimes by force of laws.

The proposed model confronts the subjectivity of the problem using the method of analysis of multicriteria, in which the actors define the scale of priorities, by comparing the attractiveness of the Government activities. It treats the constraints imposed through a linear programming modeling, in which the limits of applicability of the budget are decided and the objective function meets the scale of priorities defined by the actors.

The case study showed the applicability of the model, since it defines the value of each endowment, thus distributing the budget resource [7–9]. The model presented was constructed from impositions to the municipal public budget, since we used, as a case study, the data of the City Hall of Fortaleza. But we understand that the proposed method can be applied to any of the spheres of Government, since the federal and state budgets must be correctly distributed by the different and respective Government Programs. The modeling should follow the same principle of use of the two scientific methodologies, through the definition of scale of priorities through the multicriteria analysis, and the definition of limits and legal restrictions based on the norms of the federal or state, respectively, or both, if applicable. We emphasize that the critical point of our proposal is precisely in the construction of the scale of priorities by actors who defend the value system they stand for, since they must, necessarily, reach a consensus so that the considered value is represented in the model.

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Section 3

Practical Case Studies of Management of Information Systems

Chapter 12

Management of Educational Needs of Employees in the Electronics Industry Using English e-Learning Website Programs

Paul Juinn Bing Tan and Ming-Hung Hsu

Additional information is available at the end of the chapter

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Abstract

This chapter explores whether customer satisfaction is achieved by English e-learning websites by investigating the views of the employees of Taiwanese electronics corporations who have taken English e-learning training courses. The service quality model of Parasuraman, Zeithaml, and Berry and the technology acceptance model (TAM) were adopted to examine their satisfaction levels. First, in order to provide indicators for perceived ease of use (PEOU) and perceived usefulness (PU) in the TAM, five elements of intangible service quality were utilized, namely reliability, assurance, tangibles, empathy, and responsiveness, indicated in the SERVQUAL model. Second, in order to measure PEOU, PU, and behavioral intention to use under the TAM, a survey was distributed among electronics industry workers at Taiwan's Hsinchu Science and Industrial Park. The survey data yielded the following key findings: the users' PU was significantly influenced by PEOU, tangibles, and responsiveness; their PEOU was significantly impacted by assurance, tangibles, and reliability; their PU and behavioral intention to use were significantly influenced by PEOU; their system usage and behavioral intention to use were significantly influenced by PU; and their system usage was significantly impacted by their behavioral intention to use. Overall, the study proposed 13 hypotheses, of which 10 were supported.

Keywords: on-the-job training, curriculum for mechanical engineer, need analysis, English for science and technology, satisfaction

1. Introduction

English has become the common language of the world due to trade and politics, which have also promoted the popularity of English usage. The broad usage of English enables a true single market regarding knowledge and ideas [1].

Because Internet technology has become increasingly developed in the twenty-first century, the Internet plays an essential role in our lives. Using the Internet to learn languages is more common than ever before. As Internet technology advances, learning English is not limited to classrooms, and it is more popular to use the Internet to learn English. Through use of the Internet, people can learn English from any location. Instructors can teach English through the Internet instead of traditional teaching methods. E-teaching not only has many advantages and benefits for teaching and learning environments but also provides new directions and new modes of thinking.

1.1. E-learning of English learners in Taiwan

Training is often divided into preservice training and on-the-job training. Most training currently uses the Internet to achieve learning objectives and focuses on language in one of the involved courses. Over the last decade, online learning or e-learning has become an important part of the education agenda around the world. E-learning is becoming an important factor in higher education [2]. Advances in computing and information technology have changed the modes of learning. The development of information technology has influenced the learning flow and reduced the life cycle of learning material as well as learning activities [3]. Information technology is also dramatically affecting the means by which people teach and learn. IT helps people meet, talk, and work together outside of traditional meeting and office spaces. E-learning is the product of digital technology and turns traditional courses into virtual courses. The concept of an online course is the use of virtual environments to replace a part of physical classrooms [4]. E-learning has enabled universities to expand their current geographical reach, to capitalize on new prospective students and to establish themselves as global educational providers [5].

1.2. Motivation of research

1. To understand the differences between e-service marketing and language educational e-training.
2. To understand the differences between on-the-job training and preservice training.

1.3. Purposes of the study

This study aimed to address the need for up-to-date knowledge by focusing on the following objectives:

1. To apply the theory of reasoned action (TRA) and the technology acceptance model (TAM) to investigate their online learning satisfaction.

2. To understand their online English learning satisfaction.
3. To examine the Parasuraman, Zeithaml, and Berry (PZB) and TAM models.
4. To understand electronics corporation employees' basic criteria and demands for excellent English e-learning websites.
5. To understand Taiwanese electronics corporation employees' basic demands for English e-learning website programs.

Broadly, there are two e-learning modes:

1. Computer-assisted instruction
2. Distance learning.

E-learning represents a new generation of electronic teaching methods. By connecting to the network, teachers and learners can experience interactive learning on the Internet. In addition to being a new instruction media, e-learning is a new tool and a completely new learning environment; it also overcomes the limitations of traditional teaching environments.

Table 1 lists the benefits and drawbacks of traditional classroom learning and e-learning.

Researchers have identified many benefits of e-learning:

Web-based learning has been deemed equivalent to traditional methods regarding learners' knowledge achievements. Of the two studies evaluating learning efficiency, only one provided evidence that more efficient learning occurred through web-based instruction [7].

E-learning is highly accessible, which refers to a user's ability to find what is needed immediately.

	Traditional classroom learning	**E-learning**
Benefits	*Instantaneous feedback	*Student-centered and student-paced
	*Well-known by both students and teachers	*Flexible regarding location and time
	*Provides students with motivation	*More affordable for learners
	*Cultivates a community of learners	*Potentially accessible to a worldwide audience
		*Provides knowledge without limitations
		*Capacity for archiving allows reuse and sharing of knowledge
Drawbacks	*Teacher-centered	*Lacks instantaneous feedback for asynchronous e-learning
	*Location and time limitations	*Requires greater preparation time of instructor
	*More costly to provide	*Causes discomfort in some learners
		*Can cause greater confusion, frustration, and anxiety

Table 1. Traditional classroom learning versus e-learning [6].

Internet technologies facilitate the widespread distribution of digital content to many users simultaneously, anytime and anywhere.

Learners have control over the content, learning sequence, pace of learning, time, and media, enabling them to tailor their experience to meet personal learning objectives. E-learning provides a challenging learning environment and individual support to motivate learners and stimulate their curiosity [8].

E-learning provides a challenging learning environment and individual support to motivate learners and stimulate their curiosity [8].

Updating electronic content is easier than updating printed material, and e-learning technologies allow educators to revise their content easily and efficiently. Improved access to educational materials is crucial because learning is often an unplanned experience.

The experience of learning is a personal one, such that an e-learning system that has been effectively designed can inspire learners to engage with the learning content in a more active manner [9].

1.4. Motivation to learn

According to a study by Gardner and Lambert [10], the success in learning a second language depends on both the motivation and aptitude of the learner. In a later study [11], the same scholars suggested that the motivation to engage in language learning can be subdivided into intrinsic-extrinsic motivation and integrative-instrumental motivation. Relatedly, it should be noted that e-learning has been found to assist in enhancing learner motivation, such that accumulating evidence clearly demonstrates that the value of online communication goes beyond that of merely being a useful teaching tool.

1.5. Self-directed learning and its relationship with learning attitudes

Learner-centered methods of learning must be psychologically adapted to by those learners who are more used to teacher-centered approaches. In the view of Holec [13], it is counterproductive to teach learners how to implement self-directed learning because that learning itself would then not actually be self-directed. As such, learners must, according to Holec, teach themselves how to learn in a self-directed manner. In other words, while they may receive some support from their teachers or fellow learners, any training of learner should itself be founded on the method of self-directed learning. In this respect, self-direction can be seen as the cornerstone of both learning *how* to learn languages and the actual learning of languages itself.

In the most basic terms, self-directed learning consists of learning in which the learners themselves determine the specific goals, progress, and means of evaluating the learning. The related concept of self-access learning has come to be viewed as synonymous with technology-based learning, and autonomy has come to be seen as particularly critical in the context of computer-assisted language learning.

Self-access resource centers and the notion of learner training are among the key innovations in the field of self-directed language learning. For example, scholars from the Centre

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de Recherches et d'Applications Pédagogiques en Langue in France have asserted that skills related to self-assessment, self-management, and self-monitoring must be developed by adult learners if they are to effectively engage in self-directed learning. In that view, learner training is seen as something akin to self-access, with such training initiated as a means of supporting self-directed learning [12, 13]. Relatedly, learners who receive computer-based instruction have been found to learn in a more efficient manner and to exhibit higher knowledge retention.

1.6. Research model background

1.6.1. The theory of reasoned action

The TRA, which was first proposed by Fishbein and Ajzen [14], is an extensively studied model of intention that has been shown to be effective in explaining and predicting behaviors across a variety of domains. More specifically, as explained by Davis et al. [15, 16], the TRA is a social psychology model that focuses on the factors that determine all consciously intended behaviors [17, 14]. Because the model is a general one, it does not seek to specify whatever beliefs underlie a given behavior. However, in order to apply the TRA model effectively, it is necessary to identify those beliefs that are seen as relevant by the individuals undertaking the behaviors under investigation. In this connection, the method of conducting free response interviews with individuals who represent the population of interest in order to identify five to nine of their relevant beliefs has been suggested by Fishbein and Ajzen [14, 17] and [15, 16]. At the fundamental level, the conceptual framework of the TRA relies upon understanding the various distinctions among attitudes, intentions, beliefs, and behaviors (**Figure 1**).

1.6.2. Technology acceptance model

The TAM, which was developed and introduced by Davis et al. [15, 16], is essentially an extension of the TRA that has come to be highly influential. Fundamentally, this model addresses the question of how a technology becomes accepted and used by its users. According to the TAM, when a new or unfamiliar technology is introduced to users, they are effectively presented with two specific variables, namely perceived ease of use (PEOU) and perceived usefulness (PU), that are in turn hypothesized to be the key factors in determining whether the technology is accepted by the users [15, 16]. The TRA is used by the TAM as the theoretical basis by which causal associations between these two key factors of PU and PEOU and

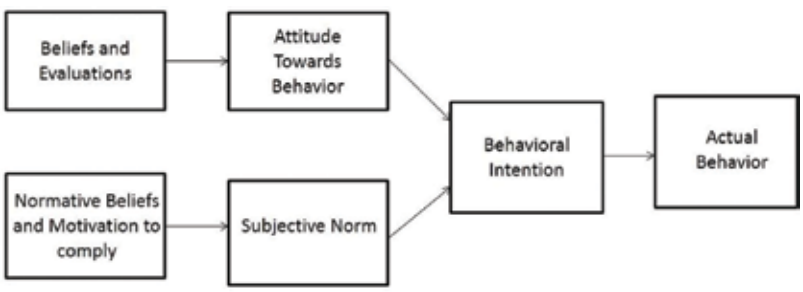

Figure 1. Theory of reasoned action (TRA) [17].

users' intentions, attitudes, and actual computer adoption behaviors are specified (**Figure 2**). Relatedly, the TAM has a much more discrete focus than the TRA because, in spite of the shared use of the term "technology" in their names, the TAM was actually designed to be applied to computer usage behaviors only [15, 16]. That said, it can, in fact, be applied to various types of technology in general.

How PU affects acceptance:

1. According to the TAM, PU can be defined as the extent to which using a particular technology is seen by a given person as a means of enhancing that person's job performance [15, 16]. In other words, it refers to the user's perception of how valuable the technology will be in to performing various job duties, whether by decreasing the time required to complete a given task or enhancing the user's accuracy.
2. The degree to which people use a given application is dependent on the degree to which they think it will enhance their job performance [15, 16].
3. According to Phillips et al. [18], PU can be defined as "the prospective adopter's subjective probability that applying the new technology from foreign sources will be beneficial to his personal and/or the adopting company's well-being."
4. A number of diverse lines of research have demonstrated the theoretical importance of PU and PEOU as factors determining user behaviors [15, 16].
5. Davis et al. [15, 16] ascertained that, overall, the correlation of PU with system usage is significantly stronger than that of PEOU, with subsequent regression analysis indicating that PEOU may, in fact, be an antecedent of PU as opposed to being a direct determinant of system usage. In other words, PEOU only affects technology acceptance in an indirect manner via its effects on PU [19].
6. The TAM hypothesizes that the acceptance of information technology is predicted by PEOU and PU [19].
7. The TAM was specifically designed to show the acceptance of information technology among users. The model's primary aim is to provide, by discerning the effects of external variables on internal attitudes, beliefs, and intentions, an explanation of the factors determining computer acceptance [15, 16, 18].
8. The TAM constitutes a useful means of predicting technology-related usage, attitudes, and satisfaction on the basis of user beliefs and external variables [20].

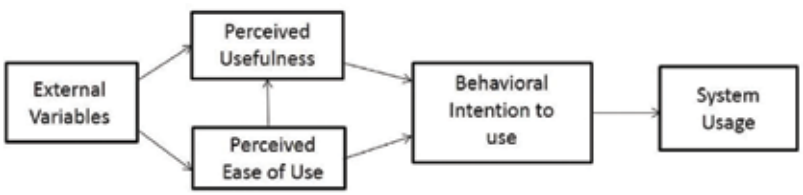

Figure 2. Technology acceptance model (TAM) [15, 16].

How PEOU affects acceptance:

1. According to the TAM, PEOU can be defined as to the extent to which using a particular technology is seen by a given person as effortless or effortful [15, 16].
2. It is possible for users to see a given application as both useful and excessively difficult to use, such that the benefits of using it are overwhelmed by the exertion necessary to use it [15, 16].
3. According to Phillips et al. [18], PEOU can be defined as "the degree to which the prospective adopter expects the new technology adopted from a foreign company to be free of effort regarding its transfer and utilization."

1.6.3. Service quality gap model

The so-called quality revolution that occurred in the 1980s was not limited exclusively to manufacturing; rather, it also influenced various services, organizations, and governmental agencies. The relative importance with which quality management has been viewed since then can thus be easily deduced [21].

The PZB model, which is also known as the service quality gap model, was first proposed by Parasuraman et al. [22]. According to this model, the highest priority of companies with respect to their service outcomes is quality, with quality being directly related to the high expectations of their clients. In this view, the service expectations set by clients are founded upon a company's behavioral decisions or performance [23]. Relatedly, Parasuraman et al. [22] identified 10 criteria that can be used to undertake an evaluation of a service's initial quality, with said quality being defined, essentially, as the difference between the service a customer expected to receive and the service the customer actually received. Those 10 evaluation criteria are (1) understanding (2) reliability (3) responsiveness (4) tangibles (5) courtesy (6) communication (7) competence (8) access (9) credibility, and (10) security. It is noteworthy that these criteria incorporate the five key elements for anticipating, delivering, and measuring the services of a company, namely assurance, empathy, reliability, responsiveness, and tangibility. Relatedly, the SERVQUAL model was developed by applying these criteria and the PZB model, allowing the SERVQUAL model, which is commonly referenced in literature on marketing, to measure the discrepancies between expected and perceived service quality [24]. In fact, usage of both the SERVQUAL and PZB models is currently still widespread in the industry.

The PZB model has five gaps, which are illustrated in **Figure 3**; Bronn [21] also described all five gaps. Notably, respondents with different demographics may have different PU and PEOU due to the five gaps.

In the current study, five factors relating to intangible service quality from the SERVQUAL and PZB models (namely assurance, empathy, reliability, responsiveness, and tangibles) were utilized to establish indicators for PEOU and PU in the TAM. Thereafter, people employed in the electronics industry by companies located at the Hsinchu Science and Industrial Park in Taiwan received a questionnaire designed to measure their PEOU, PU, and behavioral intention to use within the TAM.

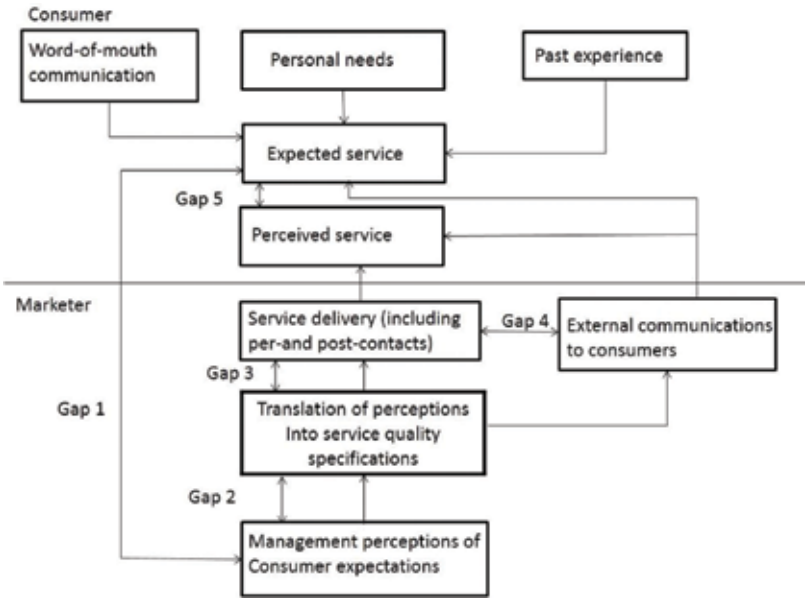

Figure 3. Service quality gap model (PZB model) [22].

2. Method

2.1. Hypotheses

The specific focus of this study was on investigating the satisfaction and motivation of the aforementioned Taiwanese electronics company employees with respect to their use of English e-learning websites. As part of the study, a literature review was performed, and the TAM and PZB models were used to expand upon the five elements of assurance, empathy, reliability, responsiveness, and tangibles. Relatedly, a five-part survey was administered in order to determine the kind of user interfaces preferred by the respondents, to measure the reliability of the English e-learning website services used by the respondents, to determine the specific types of services on the English e-learning websites that were used by the respondents, to investigate the security of said websites, and to measure how satisfied the respondents were with the sites.

Table 2 and **Figures 3-5** present the specific research model and hypotheses that were used in this study.

2.2. Participants

Through the combination of a literature review and a questionnaire survey, this study gathered data from 350 respondents working at 10 different companies. The primary

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NO.	Hypothesis
H1	The PU of e-users is positively affected by tangibles.
H2	The PU of e-users is positively affected by reliability.
H3	The PU of e-users is positively affected by responsiveness.
H4	The PU of e-users is positively affected by assurance.
H5	The PEOU of e-users is positively affected by tangibles.
H6	The PEOU of e-users is positively affected by reliability.
H7	The PEOU of e-users is positively affected by responsiveness.
H8	The PEOU of e-users is positively affected by assurance.
H9	The PU of e-users is positively affected by PEOU.
H10	The learning attitude of e-users is positively affected by PEOU.
H11	The learning attitude of e-users is positively affected by PU.
H12	The learning satisfaction of e-users is positively affected by PU.
H13	The learning satisfaction of e-users is positively affected by learning attitude.

Note: PU = perceived usefulness; PEOU = perceived ease of use.

Table 2. Hypotheses.

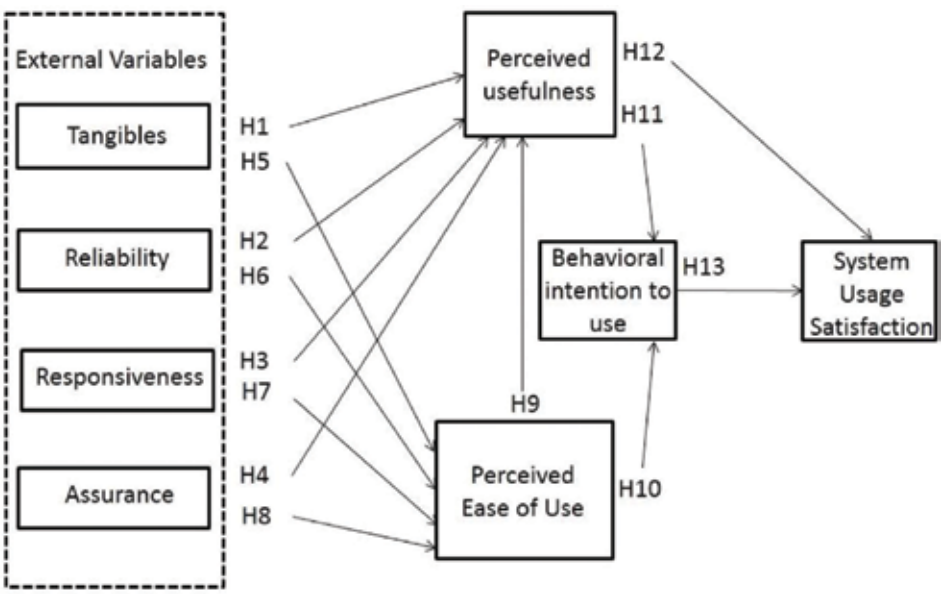

Figure 4. Research model. Note: PU = perceived usefulness; PEOU = perceived ease of use.

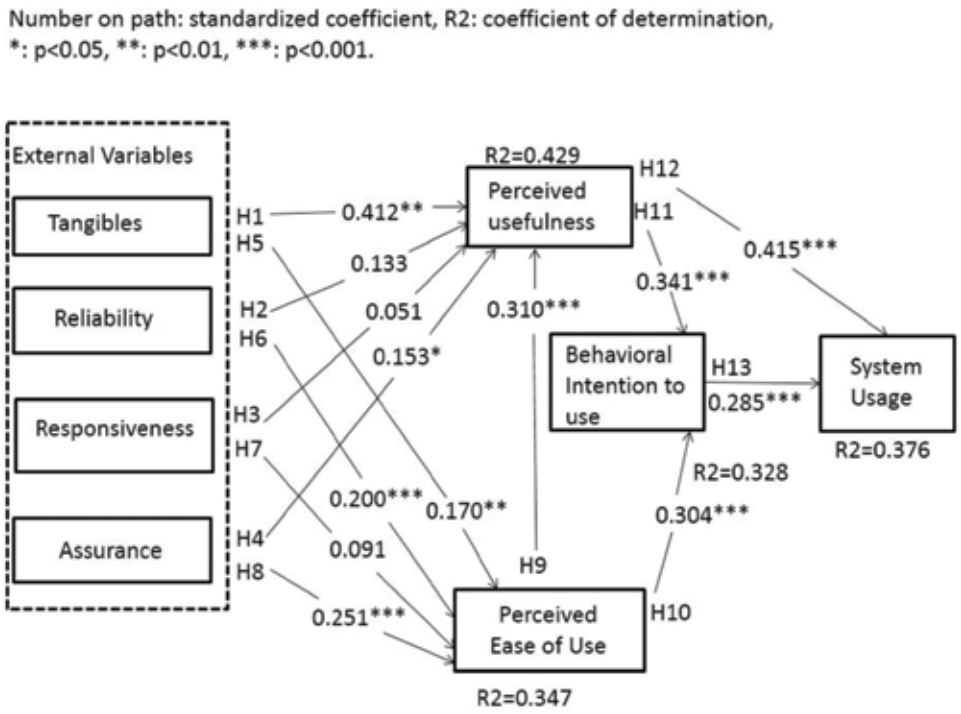

Figure 5. The research model.

aim in doing so was to investigate those Taiwanese electronics corporation employees' perceptions regarding English e-learning educational courses taken during the course of their employment.

3. Results

This study investigated employees' satisfaction with their use of English e-learning websites in Taiwanese electronics corporations. We conducted a literature review and described the five main themes of service quality (tangibles, reliability, responsiveness, assurance, and empathy) to produce a 20-question survey. Specifically, we used the SPSS to examine whether a significant difference exists between employee satisfaction and the age, gender, education, company location, years of work, and work experience of employees.

3.1. Questionnaire results

In total, 500 questionnaires were distributed to the employees, and 357 (71.4%) were returned. Seven of these completed questionnaires were invalid; hence, we only examined 350 of them. Several analysis methods were adopted, including frequency and descriptive one-way analysis of variance (ANOVA), to understand the responses to the questionnaires. The results were divided into three parts and are discussed in the following sections.

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3.2. Basic information

Frequency and descriptive analyses were used to obtain statistics regarding the background of the employees. The age, gender, education, company location, years of work, and work experience of the employees are described as follows (**Table 3**).

Male and female respondents accounted for 72 and 28% of the sample, respectively. The respondents were aged between 20 and 70 years; in total, 46.9% of them were 20–30 years old, 35.7% were 31–40 years old, 12.6% were 41–50 years old, 4% were 51–60 years old, and 0.9% were 61–70 years old. Hence, employees aged 20–30 and 31–40 years made up the majority of the companies that we investigated. The studied companies are located in Northern Taiwan (19.7%), Central Taiwan (45.7%), Southern Taiwan (32.9%), and Eastern Taiwan (1.7%). The respondents also had a range of education levels: 7.7% completed senior high school, 8.6% completed junior college, 44.6% had received a Bachelor's degree, 38% had received a Master's degree, and 1.1% had received a PhD. In addition, 18.9% of respondents had worked for less than 1 year, 35.1% had worked for 1–3 years, 22% had worked for 4–6 years, 11.7% had worked for 7–9 years, and 12.3% had worked for 10 or more years.

3.3. Reliability and content (expert) validity

Content validity is a subjective test method developed by C. H. Lawshe [25] and is generally used to review items that comprise questionnaires. Specifically, agreement among raters or judges regarding the need to include a particular item in a survey is gaged. Lawshe [25] suggested that the expert subject matter raters on a panel of judges should each reply to the following question with regard to each individual questionnaire item: "Is the skill or knowledge measured by this item 'essential', 'useful but not essential', or 'not necessary' to the performance of the construct?" A given item would then be considered to have at least a degree of content validity if over half of the raters respond that the item is essential (**Table 4**) [25].

In the present study, four relevant experts were consulted and provided advice regarding the selection of the survey content in light of the study's research objectives. These experts' opinions regarding the validity of the measured items were also requested to make certain that the study questionnaire possessed expert validity.

Sample demographics									
Gender		Age		Work areas		Education		Years of work experience	
Male	72%	20–30	46.9%	Northern region	19.7%	Senior high school	7.7%	> 1	18.9
Female	28%	31–40	35.7%	Central region	45.7%	Junior college	8.6%	1–3	35.1
		41–50	12.6%	Southern region	32.9%	Bachelor's degree	44.6%	4–6	22.0
		51–60	4.0%	Eastern region	1.7%	Master's degree	38.0%	7–9	11.7
		61–70	.9%			PhD	1.1%	< 10	12.3

Table 3. Respondent demographics.

Alpha coefficients exceeding 0.70 indicate that the measured items have an appropriate internal consistency (**Table 5**) [26].

The analysis results show that PU and behavioral intention for system use have a variation of 37.6%; PU and PEOU for behavioral intention to use have a variation of 32.8%; tangibles, reliability, responsiveness, assurance, and PEOU for PU have a variation of 42.9%; and tangibles, reliability, responsiveness, and assurance for PEOU have a variation of 34.7%.

Relationship paths	Standardized coefficients (β)	Sig.	Coefficient of determination
H12 PU → System usage	0.415	***	0.376
H13 Behavioral intention to use → System usage	0.285	***	
H11 PU → Behavioral intention to use	0.341	***	0.328
H10 PEOU → Behavioral intention to use	0.304	***	
H1 Tangibles → PU	0.142	**	0.429
H2 Reliability → PU	0.133	—	
H3 Responsiveness → PU	0.051	—	
H4 Assurance → PU	0.153	*	
H9 PEOU → PU	0.310	***	
H5 Tangibles → PEOU	0.170	**	0.347
H6 Reliability → PEOU	0.200	**	
H7 Responsiveness → PEOU	0.091	—	
H8 Assurance → PEOU	0.251	***	

*p < 0.05, **p < 0.01, ***p < 0.001. Note: PU = perceived usefulness; PEOU = perceived ease of use.

Table 4. Relationship paths.

Item	Cronbach's alpha	Number of item
Tangibles	0.761	4
Reliability	0.806	4
Responsiveness	0.792	4
Assurance	0.792	4
Empathy	0.793	4
Satisfaction	0.819	4
Total	0.942	24

Table 5. Reliability statistics.

		Sum of squares	df	Mean square	F	Sig.
The English e-learning website is neat and appealing.	Between group	6.295	4	1.574	2.775	.027
	Within group	195.659	345	.567		
	Total	201.954	349			
The services on a remarkable website are presented in a way that is visually appealing.	Between group	12.112	4	3.028	5.599	.000
	Within group	186.563	345	.541		
	Total	198.674	349			
The English e-learning website has an up-to-date information technology service.	Between group	11.393	4	2.848	4.834	.001
	Within group	203.295	345	.589		
	Total	214.689	349			
The appearance of the physical services on the English e-learning website is consistent with the types of services provided to clients.	Between group	15.312	4	3.828	6.526	.000
	Within group	202.357	345	.587		
	Total	217.669	349			

Table 6. Relationship between age and tangibles.

		Sum of squares	df	Mean square	F	Sig.
The English e-learning website provides services at the promised time.	Between group	11.802	4	2.950	4.896	.001
	Within group	207.912	345	.603		
	Total	219.714	349			
The English e-learning website performs the service correctly the first time.	Between group	26.070	4	6.518	9.994	.000
	Within group	224.984	345	.652		
	Total	251.054	349			
When you have a problem, the English e-learning website shows a sincere interest in solving it.	Between group	30.518	4	7.629	11.014	.000
	Within group	238.980	345	.693		
	Total	269.497	349			
The English e-learning website uses specific English e-content and error-free hardware.	Between group	13.643	4	3.411	4.564	.001
	Within group	257.811	345	.747		
	Total	271.454	349			

Table 7. Relationship between age and reliability.

		Sum of squares	df	Mean square	F	Sig.
The English e-learning website serves clients precisely when English programs are performed.	Between group	4.516	4	1.129	1.455	.216
	Within group	267.738	345	.776		
	Total	272.254	349			
The English e-learning website provides rapid service.	Between group	11.896	4	2.974	4.800	.001
	Within group	213.764	345	.620		
	Total	225.660	349			
The English e-learning website is never too busy to respond to requests and provides 24-h service.	Between group	20.995	4	5.249	8.198	.000
	Within group	220.880	345	.640		
	Total	241.874	349			
The English e-learning website is always willing to help.	Between group	18.771	4	4.693	7.546	.000
	Within group	214.546	345	.622		
	Total	233.317	349			

Table 8. Relationship between age and responsiveness.

		Sum of squares	df	Mean square	F	Sig.
The English e-learning website has specific knowledge to answer employees' questions.	Between group	8.505	4	2.126 .695	3.059	.017
	Within group	239.852	345			
	Total	248.357	349			
The English e-learning website is consistently courteous.	Between group	12.072	4	3.018	4.744	.001
	Within group	219.496	345	.636		
	Total	231.569	349			
The behavior of the English e-learning website instills confidence in employees.(functioning)	Between group	12.083	4	3.021	4.157	.003
	Within group	250.685	345	.727		
	Total	262.769	349			
Employees feel safe when interacting with a remarkable English e-learning website.	Between group	11.382	4	2.846	4.023	.003
	Within group	244.046	345	.707		
	Total	255.429	349			

Table 9. Relationship between age and assurance.

		Sum of squares	df	Mean square	F	Sig.
The English e-learning website gives clients individual attention.	Between group	7.203	4	1.801	2.866	.023
	Within group	216.765	345	.628		
	Total	223.969	349			
The English e-learning website is focused on your best interests.	Between group	13.532	4	3.383	5.077	.001
	Within group	229.885	345	.666		
	Total	243.417	349			
The English e-learning website understands your specific needs.	Between group	17.267	4	4.317	6.699	.000
	Within group	222.322	345	.644		
	Total	239.589	349			
The English e-learning website motivates your interest.	Between group	13.230	4	3.308	4.567	.001
	Within group	249.867	345	.724		
	Total	263.097	349			

Table 10. Relationship between age and empathy.

3.4. One-way ANOVA

We used a one-way ANOVA to determine the relationship between the questionnaire items and the demographic characteristics of the employees. The questionnaire comprised 24 questions regarding tangibles, reliability, responsiveness, assurance, empathy, and satisfaction, and each item had 4 questions. The results of our analysis are detailed in **Tables 6–10**.

3.5. Conclusion

The following key findings were indicated by the data collected:

- Hypothesis 2 was not supported.
- Hypothesis 3 was not supported.
- Consistent with results previously reported by Tan [27], Hypothesis 7 was also not supported.
- Most of the respondents in the study consisted of men aged 20 to 40 years old.

In this study, research hypotheses were derived and tested by examining past studies and results from the statistical analysis of empirical data. The primary focus of the study is the learning satisfaction of students in digital technical English courses, and the antecedent variable in this case is service quality. The study examined English e-learning educational training courses to determine whether English e-learning websites provide customer satisfaction. In contrast to most tangible learning approaches, learners who participate in digital learning come from a more diverse range of backgrounds. The employees of a technology company can receive training via professional digital courses and achieve customer satisfaction through digitized learning.

This study verified the relevance of the technology acceptance and PZB models to digital learning research. When digital learners perceived that the digital learning system did not require time and effort to understand, and was also easy to master and use, they started to feel that the use of the system could help them to gain the knowledge that they were seeking and to believe that the system was useful. When users perceived that the digital learning system was useful, they started to adopt a positive attitude toward the system, which led to a willingness among users to continue using the system. When digital learners perceived that the digital learning system was easy to use, they started to adopt a more positive attitude toward the system, which led to a willingness among learners to continue using the system. Overall, the attitude of users with respect to the use of the digital learning system was influenced by their subjective perceptions of the system. This study did not uncover any significant relationship between reliability and perceived usefulness, or between responsiveness and perceived ease of use and perceived usefulness. The study proposes the prioritization of a simple and clear design during the planning stage of the digital learning system [28]. This should cover the design of the interface and the provision of clear instructions to users in order to increase the system's ease of use. As discussed above, company employees who participate in digital learning have to develop solutions that take into account the customer's point of view. These employees need to respond to the demands of customers enthusiastically. Through the digital learning interface, employees can interact with customers and guide them on the use of the interface, thus making it easier for these customers to familiarize themselves with the interface. Through these two approaches, the implementation of professional English education and training courses can be further improved [29].

4. Suggestions

4.1. Suggestions for web designers

Web designers should develop websites that are easy to use and that provide service information immediately as it is updated [27]. Clients are also interested in personal security and privacy, which should be protected. Many adults do not understand how to use a computer; however, because these people are also target customers, a teaching plan for using a company's website should be provided to them. Moreover, an optimal website must be well-designed [27, 29].

4.2. Suggestions for future researchers

English e-learning websites have become important tools for companies across the globe. However, the English e-learning quality must be improved for users. Current learning strategies not only utilize traditional education methods but also use English e-learning websites. The following suggestions are for future researchers:

(1) Thoroughly research clients' satisfaction with the crucial factors of English e-learning websites.

(2) Seek to understand employees of electronics corporations regarding their use of English e-learning websites and provide solutions when problems are encountered.

(3) Investigate whether English e-learning websites are effective and satisfactory for learners.

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Chapter 13

CREAMINKA: An Intelligent Ecosystem for Supporting Management and Information Discovery in Research and Innovation Fields in Universities

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Additional information is available at the end of the chapter

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Abstract

This chapter presents a new proposal for supporting the management of research processes in universities and higher education centers. To this aim, the authors have developed a comprehensive ecosystem that implements a knowledge model that addresses three innovative aspects of research: (i) acceleration of knowledge production, (ii) research valorization and (iii) discovery of improbable peers. The ecosystem relies on ontologies and intelligent modules and is able to automatically retrieve information of major scientific databases such as SCOPUS and Science Direct to infer new information. Currently, the system is able to provide guidelines to create improbable research peers as well as automatically generate resilience graphics and reports from more than 17,000 tuples of the ontological database. In this work, the authors describe in detail an important aspect of support systems for research management in higher education: the development and valorization of competences of students collaborating in research process and startUPS of universities. Furthermore, a knowledge model of entrepreneurship (startUPS) as well as an analyzer of general and specific competences based on data mining processes is presented.

Keywords: ontologies, acceleration of knowledge production, higher education, student research competences, entrepreneurship

1. Introduction

Entrepreneurial spirit is an old field, but it is continuously emerging and it attracts the attention of scholars, politicians and professionals in different fields of economics, finance, management and sociology [1]. In the last decades, it has been studied as a driving force for development and a key factor to attain economic growth, the creation of employment and the increase of productivity [2, 3]. Nowadays, the theory of entrepreneurship has extended to new concepts where entrepreneurial spirit is not only known for its business success and benefits, but also for subjective welfare and noneconomic welfare that people can obtain through their skills. Politicians seek to promote entrepreneurial spirit at a macrolevel through education in hopes that a greater understanding will likely create more adept entrepreneurs [4]. In this regard, there is a debate going on related to the academic field if it is really possible to teach students how to be entrepreneurs [5].

Besides creativity and innovation to develop entrepreneurial projects and meet its goals, due to current and fast changes in society, a wide range of skills and competences are needed [6]. In the last few years, higher education institutions at an international level have introduced competences in its educational programs. For example, during the last 5 years, Spain has produced significant advances in the treatment and evaluation of competences, especially in the field of language teaching [7]; Universidad Politecnica de Madrid (UPM) applied the project-based learning (PBL) approach and analyzed the acquisition of regional and global competences by having industrial engineering students complete a course on project management [8]; they even suggested a framework of learning and evaluation based on competences to facilitate the learning of skills in the development of projects [9]; a study to support the skills and competences under the European Union Framework and the Bologna Agreement was also conducted, assisting its evolution through guidance documents that seek to integrate the European systems of higher education and improve employability of European graduates [10].

Regarding tools to analyze competences, there are solutions suggested through the use of questionnaires along with information technologies. In [11], the COMET test is suggested, it was developed by the TVET research group from the University of Bremen and it is based on a model of competence and measurement through open task tests that have a variety of solutions and the evaluation of its results. As part of the TECH project, students from the universities of Seville and Malaga presented the improvement of their competences of collaborative work, efficient use of time, management of online resources and others by carrying out collaborative work in mixed groups on the online learning platform [12]. ComProfits is a project financed by the EU which analyzes the concept of a profile platform of adaptive competences where its main objective is to (i) strengthen the analysis of competences and (ii) improve the quality of staff selection and work performance in the field of IT [13]; another innovative concept for teaching competences with entrepreneurial spirit is open educational practices that work jointly with a StarUp model and seeks to identify the competences that a person has obtained by carrying out the analysis of open educational resources (OER) that have been used through a recommendation system [14]. Another approach applies KIPSSE, which is a self-reporting instrument to be used in the evaluation of competences of projects developed by university students that take part in online learning projects, which tries to identify knowledge integration skills, project skills and self-efficacy based on the results of the qualitative and quantitative analysis of interviews with the project consultants [15].

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In this context, the present work presents a computing strategy for the analysis of competences and the networks that an individual (student/entrepreneur/professor) has developed. Such strategy is based on a previous work suggested by Salgado et al. [16] for the evaluation of an individual's competences when developing a project through a trifocal model "auto/hetero/coevaluation." The computing model is made up by an ontology that explains the basis of knowledge of the StartUPS ecosystem and makes it possible to generate inferences, and a schematic and mathematical model to approximate a qualitative and quantitative evaluation of the valuations of the competences applied to the different individuals of the innovation ecosystem.

2. Related work

Among the first studies about an evaluation through competences to individuals and applying computing, there is a debate on how to generate the dissemination of relevant information to users according to knowledge generated within an institution or organization, an aspect highlighted in [17], where it explains that "*one of the challenges of knowledge management is the active and smart dissemination of knowledge to users, without bothering them with information unrelated to their competencies or fields of interest*" and suggests a first approximation of an ontology system based on competences that intend to provide assistance in order to increase productivity of users during their activities according to their profile. In [18], the objective is to design an ontological model, based on the competences of each enterprise, to support decisions at the time of creating collaborative networks within virtual environments called virtual breeding environment (VBE) whose aim is to enhance the competences of employees. A similar case occurs in [19], where manufacturers and distributors need to cooperate and create production networks; therefore, they suggest an approach for the configuration of teams based on profiles by competences applying management of ontologies, management of contexts and elaboration of profiles, and with the aim of identifying the members of the team that are the most suitable to carry out a task.

When it comes to finding a job, developing a project, implementing a business, etc., one of the concerns of employers, investors, and project managers is to identify qualified and committed personnel. How to solve this enigma, and the concern also goes through the educational model, which besides teaching theory, should also assess the performance of students in life by addressing a new approach, through skills or competences as mentioned above. Bodea and Dascălu [20, 21] suggest e-learning as an appropriate activity for the development of competences. Based on the PM competence catalog, which is based on the IPMA competence basis (ICB), they defined an educational ontology for their SinPers e-learning platform, which is structured by a collection of different educational objects (EOs) as elements for the supervision and evaluation of new competences.

As analyzed previously, and as mentioned by Hochmeister and Daxböck [22], "*Competence management systems are increasingly based on ontologies that represent competencies within a given domain,*" and as part of the SeCoMine project, they seek to value user competences based on their contribution and social interactions in online communities by developing a user interface for profiles of semantic competences. And regarding work in the field of research, in [23], they suggest the use of the linked open data (LOD) format to describe the competences of researchers, developing the first work flow to generate profiles of semantic users through the analysis of scientific articles by processing natural language, which makes it possible to carry out personalized searches of articles and competent researchers in specific topics.

Regarding competence "measurement" models, there are no generic standards or procedures to evaluate or value, and each proposed model is tailored to a specific context and can be extrapolated to others by making appropriate modifications. As emphasized in [24], for the evaluation of leadership competences under a hypothetical hierarchical scheme, the partial least squares (PLS) trajectory models are used, where to collect information, they use questionnaires that are based mainly on the Likert scale and weightings. Like the previous case, in [25], the procedures and tools used for the evaluation of competences in Erasmus nurse students (ENS) clinics are made up of questionnaires, where each competence is valued in different scale metrics such as Likert. Schelfhout et al. [26] are based on a model of levels where they contemplate domains, subcompetences and scaled behavioral indicators as the basis for giving concrete feedback to students rather than using Likert-scale surveys. Therefore, a mixed study method that combines qualitative and quantitative research techniques (self-assessment/evaluation questionnaires) was used; the evaluation of the validity of this model was done through a confirmatory factorial analysis (CFA).

According to what has been analyzed, formulating an ontological system of the coworking UPS ecosystem and based on that applying metrics to assess the competences of the agents that are actively involved in it are possible and applicable.

3. StartUPS: an entrepreneurship background

The culture of innovation at Universidad Politécnica Salesiana (UPS) seeks to develop a new more complex and formulated concept in [27], which explains that "the university just like a jungle (ecosystem) takes inert and inorganic elements such as knowledge and science to create thriving ecosystems of living organisms whose interactions make up society." This innovative concept seeks to change the educational linearity that governs classrooms toward the productivity of innovation and creativity in spaces or associative groups that share common and multidisciplinary interests (cowork), that break what is conventional, and maintain the center of interest in people, basis of UPS's culture and a primary agent in the interaction and collaboration with diverse talents that seek to transcend social barriers in favor of connectivism [28–30], learning to learn [31–33] and the common good [34].

The ecosystem of innovation at UPS is intended to be something like a free zone, where the flow of ideas, talents and capital can be maximized in a network of collaborative work. The importance of creating places within the institution to encourage this new university culture has been hard and fundamental work in order to "generate" a new educational model based on an individual's life project; therefore, one of the aims of the StartUPS project is that students/professors from the university integrate all the knowledge they have acquired in real-life projects and that they develop behavioral, contextual and technical competences [6] within spaces like the "coworks."

The coworking UPS project is part of UPS's strategy, to become a university of research and innovation, and the culture of entrepreneurship represents a fundamental factor in the achievement of these objectives in the short and long term. In 2015, a series of agreements to integrate the culture of "project work" were adopted in order to develop measures to promote innovation in UPS. This process of change has been accompanied by training for UPS agents (teachers

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and students) to develop a culture of entrepreneurship and their project management competences. The idea of fostering entrepreneurship from project management competences was aimed at creating an Innovation and Entrepreneurship Ecosystem (coworking StartUPS project). This strategy is part of the implementation processes of Research Groups and Educational Innovation Groups (EIG) at UPS, jointly promoting Research and Educational Innovation, based on the participation of students and teachers who are competent for project management.

As mentioned in [6], "the methodology used within the ecosystem to generate the coworking experience is based on the Working with People (WWP) model, aimed at building dynamics of innovation and learning based on projects"; therefore, the executing and catalytic axis of the entire competence assessment within the coworking StartUPS ecosystem has a project key point. The main idea is to incubate and enhance the abilities of each individual based on the activities that he/she performs within a project or in different proposed events such as: boot camps (RECREATE/RETHOS), mini-boot camps, hackathons, workshops, training courses, research groups and others.

The components discussed in [6] to sustain the ecosystem mention four, a socio-ethical component, a technical-business component, a political-contextual component and an integrating component, which is social learning, oriented to developing a network of entrepreneurship among the university's entrepreneurs, through spaces of learning, discussion and reflection generated in different areas of the university with the participation of faculties and courses. This component is mainly undertaken by the entrepreneurship centers, or coworking spaces, which serve as support to the entrepreneur and allow their interaction. This way they find the physical space of work and the necessary advice so that their ideas and learnings are connected with the national and international market. This connects the UPS entrepreneurship ecosystem with the local, national and international level.

4. Ecosystem approach

The computing model being suggested is part of a more complex system called CREAMINKA, which is a tool designed to support strategic decision-making regarding R + D + i (research + development + innovation) in the university. This component seeks to carry out a specific task, the analysis of competences/skills of the agents that make up this ecosystem by applying the corresponding metrics of these skills through indicators that are valued through a mixed evaluation mechanism.

As shown in **Figure 1**, the structure of the ecosystem is organized in four clearly defined layers: (i) the transactional system for StartUPS, (ii) the microservices component, (iii) the triplet repository and (iv) the mobile/web application. The microservices component is the main layer that supports the entire subsystem; its function is to provide the necessary services so that the flows of information can be matched to the different components. The "StartUPS" transactional system stores information of the agents in the ecosystem, such as data of their competences, projects, evaluation/valuation questionnaires, etc. The triplet repository stores the knowledge model of the innovation ecosystem and previously treated data from the transactional system. The mobile/web application is in charge of the interaction with the different

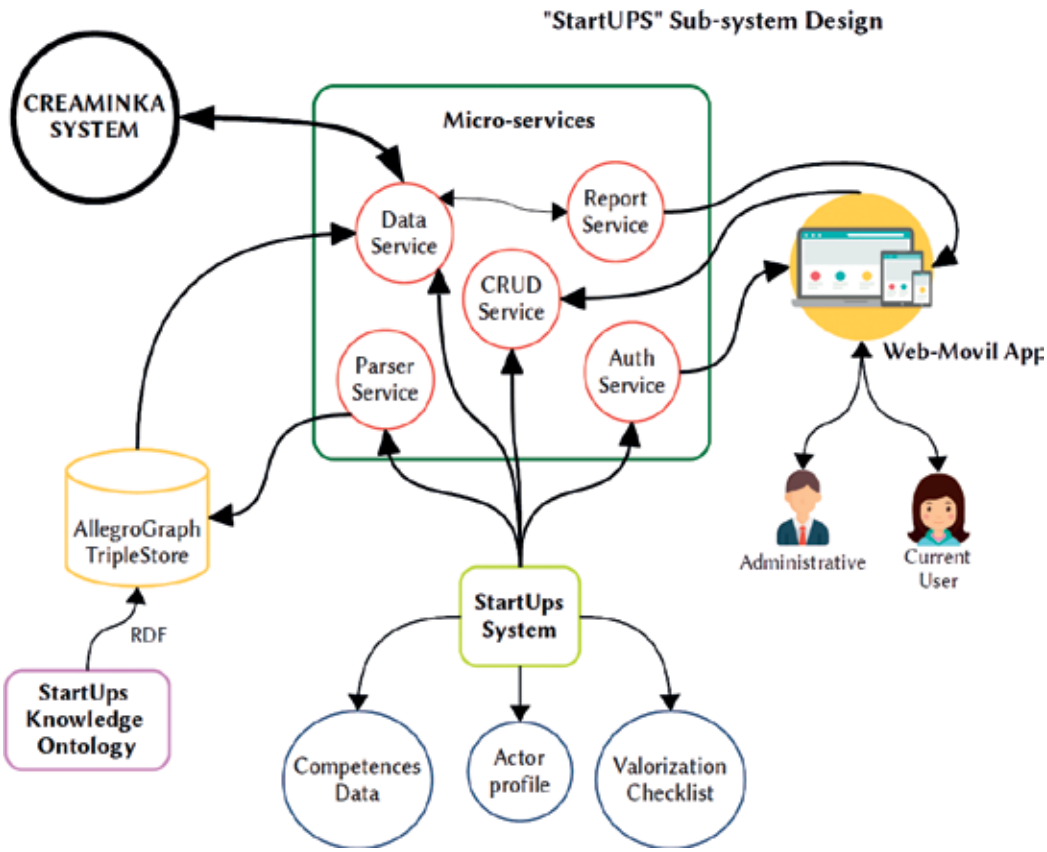

Figure 1. General structure of the StartUPS innovation subsystem.

agents and the mechanism of information input and output. The microservice component has five specific services; the "parser service" microservice, which is responsible for the translation/transformation of data obtained from transactional/nontransactional data sources to data for the ontological model of triplets; the "auth service" microservice has the necessary logic to support the processes of authorization and authentication; the "CRUD service" microservice has the task of creating, reading, updating and deleting information; the "report service" microservice is responsible for creating the different reports using the data provided by the "data service" microservice, which provides all the information processed thanks to different inference mechanisms, mining data and artificial intelligence.

4.1. Competence evaluation model

As mentioned in the related work section, there are several models for the analysis or "measurement" of competences. The suggested model is basically based on four "hierarchical" levels and their weightings relations. The levels are made up by: (i) the general competences (generic) and (ii) the specific competences [35–38], (iii) the indicators and (iv) the trifocal evaluation (auto-hetero-co).

The competence evaluation diagram as illustrated in **Figure 2** starts by carrying out the "trifocal" evaluation of competences of an agent in the ecosystem after having developed a project

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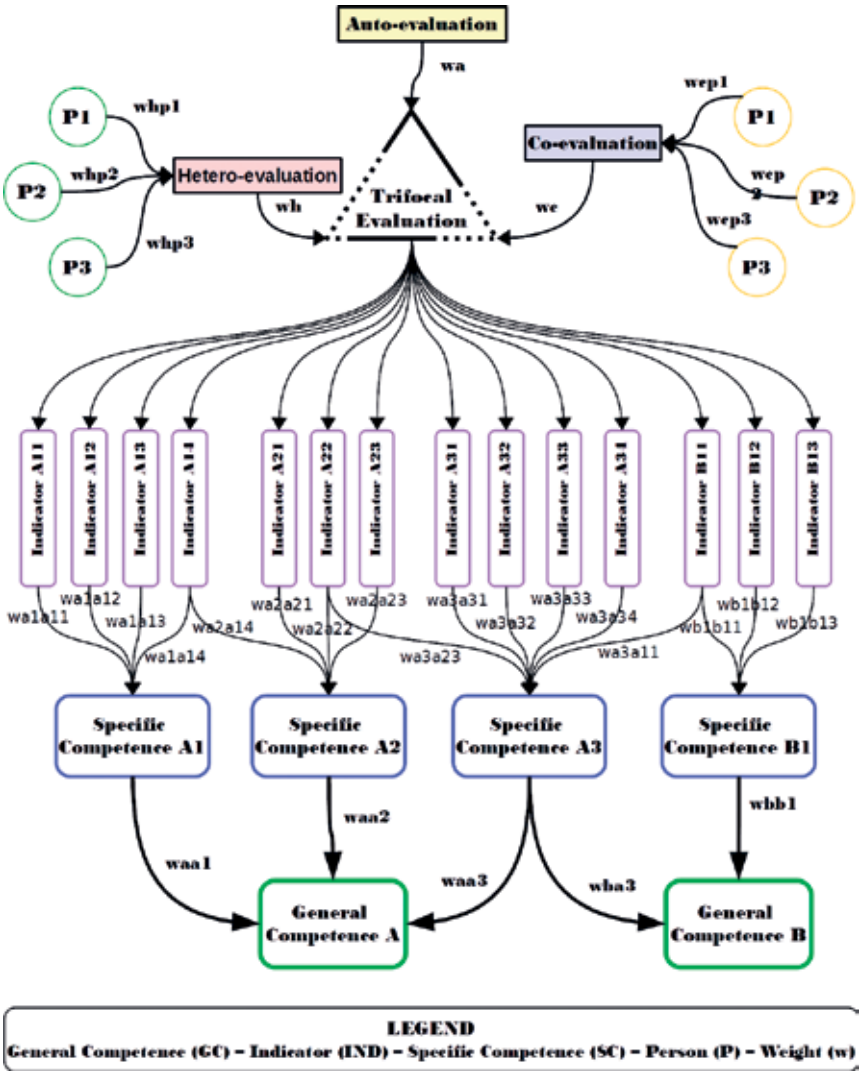

Figure 2. Modular schema of competence evaluation.

or completing a set of activities in an event, training course or workshop within the different innovation spaces created by the university. The evaluation model has two instances, it starts from a qualitative valuation that is subjective toward an attempt of a quantitative valuation that is objective, all this through the use of weights in the relations that exist between the different levels of the competence diagram.

The trifocal evaluation/valuation contains three concepts: (i) heteroevaluation, (ii) coevaluation and (iii) self-evaluation. To begin, there is a questionnaire that contains the battery of indicators to evaluate/value, either for a project or a set of activities; it should be noted that these indicators have already defined a weighting that refers to their specific competence, in addition to having their respective scale of measurement, whether a value scale, Likert scale

and others. The heteroevaluation is given by one or more valuators, who also have a weight when completing their questionnaire, regarding the set of questionnaires that are generated or completed; a similar case occurs with the process of carrying out the coevaluation questionnaires. Since the self-assessment is filled in by the valued individual, it has its respective weight. It is important to highlight that each type of evaluation has its respective weighting in the trifocal model; therefore, the heteroevaluation, coevaluation and self-evaluation have their weight. The partial results when completing this trifocal measurement of the indicators depend on the sum of their scaled values by their weights and the weights given to both the three types of questionnaires and the valuators or evaluators.

Therefore, the weighted values of the indicators maintain different weighted relations or connections with the different specific competences of the model; in other words, an indicator can be related to one or more specific competences; and in turn, these specific competences, like the previous case, have one or more connections with the general competences. The final result obtained in each branch of the suggested competence evaluation/valuation model depends on the sum of the evaluated results found when using the different mathematical operations.

With the information mentioned above, it is suggested that "the sum of subjectivities (qualitative measurements) enable the attainment of objectivity (quantitative measurements)."

Within the process of evaluation of competences performed by the subsystem of CREAMINKA, the skills that a person has can be qualified based on a scale. In **Figure 3**, it can be observed how a user of the system has a score for their general skills based on a scale represented by measure scale (MS); and on the right side, we present the process of how the calculation of the weighting for a general competition is performed. Starting from the right side, the assessment score (fs) are related to the indicators, considering that the scale of each fs is within the MS elements. Each of the fs scores has a weight v for the calculation of the weighting of specific SCS competences that can also take a value within the MS scale. Finally, each score of the specific competences has a weight for the calculation of the general GCS competences.

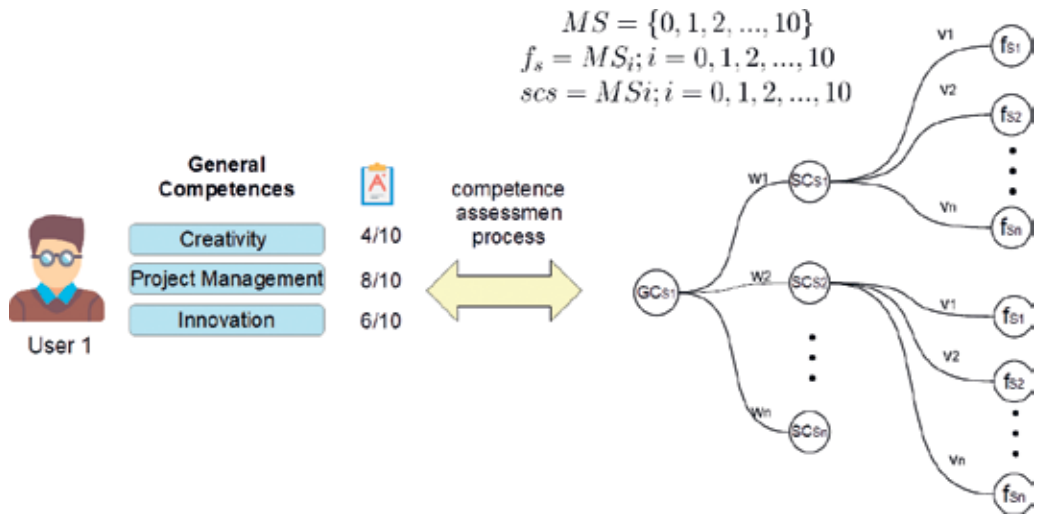

Figure 3. Evaluation process schema of general competences.

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4.2. Ontology

CREAMINKA's ontology, with its CO prefix, models ecosystems immersed in scientific research and coworking. It is an ecosystem where students, teachers and external collaborators interact within different internal and external processes and events, generating different types of scientific products. In the case of this ontology, all concepts related to the coworking ecosystem will be analyzed, a module that extends the functionalities raised in the preliminary phases of CREAMINKA's ontology, where only scientific research was considered within the research groups.

Within the framework of the ontology development, it was considered to reuse ontologies such as FOAF [39], which describes various concepts related to individuals and groups; BIBO [40], which describes bibliographic information of the documents that will be generated; VIVO [41], which describes the research community model and extends some of the ontologies named above; BFO [42], which describes a high level ontology for the categorization of concepts and used very frequently in the ontologies reuse phase, when combining. In the case of the CREAMINKA ontology, concepts such as processes and generic independent entities were used to have a grouping reference framework.

4.2.1. Definition of the ontology

The discourse universe D as seen in Eq. (1) contains all elements of the coworking ecosystem that hold evaluation process, events, classification of knowledge, scalar measures units, projects and participation roles.

$$\begin{aligned} D = \{&Process, Concept, Keyword, ResearchLine, Role, EvaluatorRole,\\ &EntrepreneurshipProject, Prototyping, MarketEvaluation, AssessmentProcess,\\ &Grant, Person, Group, Team, Organization, Competence,\\ &GeneralCompetence, SpecificCompetence, Evet\} \end{aligned} \tag{1}$$

The main unary relations defined in the ontology are:

- Process: indicates the entities that are occurring over time referring to a material entity.
- Keyword: represents a keyword related to a concept.
- Research line: specific investigation topic of an area.
- Role: quality of a material entity that carries a special circumstance within a context.
- Entrepreneurship project: a process that takes place over time to carry out an entrepreneurship of an idea.
- Research project: a process that occurs over time, to carry out an idea related to the research area.
- Prototyping: subprocess of a project in which a subproduct to be valued is obtained as purpose.

- Assessment process: process in which the assessment of different indicators is carried out, which has as output the scores of the indicators in relation to a scale.
- Competence: represents the abilities that a person has to develop something.
- Measurement weight: represents the weight relationship that exists between two concepts.

The main binary relationships that were modeled are described below:

- Has weight: indicates the weight relationship that exists in a class and its weight-class quantifier.
- Evaluated: indicates the evaluation process that was carried out on another process.
- Apply evaluation format: specifies the evaluation format on which the evaluation process is based.
- Score for: specifies the score that an indicator or test has.
- Has measurement unit: indicates the unit of measurement used as a reference in a score.
- Has indicator: specifies the indicator to which a concept is linked.
- Has subprocess: indicates the belonging of a process to a higher process.
- obo: participates in: defines the relationship between continuous objects and occurring objects.
- obo: barer of: specifies the relationship between a dependent entity and a dependent entity.

The set of relations R is defined as seen in Eq. (2):

$$R = \{hasWeight, evaluated, applyEvaluationFormat, scoreFor, hasMeasurementUnit, hasIndicator, hasSubProcess, participatesIn, bearerOf\} \tag{2}$$

Specification of the subconcepts of unary relationships in ontology as seen in Eq. (3):

$$\begin{aligned} O_0 = D \cup \{ & Process(x) \rightarrow Project(x), Project(x) \rightarrow \\ & EntreperneurshipProject(x), Project(x) \rightarrow ResearchProject(x), Process(x) \rightarrow \\ & Prototyping(x) \rightarrow Process(x) \rightarrow MarketEvaluation(x), Process(x) \rightarrow \\ & AssessmentProcess(x), AssessmentProcess(x) \rightarrow \\ & CoEvaluation(x), AssessmentProcess(x) \rightarrow \\ & HeteroEvaluation(x), AssessmentProcess(x) \rightarrow \\ & AutoEvaluation(x), Competence(x) \rightarrow SpecificCompetence(x), Competence(x) \rightarrow \\ & GeneralCompetence(x) \end{aligned} \tag{3}$$

Specification of domains and ranges of binary relations as seen in Eq. (4):

$$O_0 = O_0 \cup \{bearerOf(x, y) \rightarrow Person(x) \wedge Role(y) participatesIn(x, y) \rightarrow Roles(x) \wedge Process(y) hasWeight(x, y) \rightarrow Thing(x) \wedge WeightMeasurement(y) Evaluated(x, y) \rightarrow AssessmenteProcess(x) \wedge Process(y) applyEvaluationFormat(x, y) \rightarrow AssessmentProcess(x) \wedge Test(y) scoreFor(x, y) \rightarrow Score(x) \wedge Test(y) scoreFor(x, y) \rightarrow Score(x) \wedge Indicator(y) hasMeasurementUnit(x, y) \rightarrow Thing(x) \wedge MeasurementUnit(y) hasSubProcess(x, y) \rightarrow Process(x) \wedge Process(y)\} \quad (4)$$

4.2.2. Conceptualization of competence assessment

In order to analyze how the different concepts of the developed ontology for the CREAMINKA subsystem interact, we have to separate the several concepts associated at different levels, starting with the conceptualization of the weights that work as a complex relationship between concepts of the different levels of the competences evaluation model. Then, an analysis of how such levels are related within the evaluation model is addressed, in an evaluation process, and the actors involved. Finally, the approach is based on the analysis of how assessments take place within the different processes that normally take place within the ecosystem of a StartUPS.

Within the competence assessment model, we intend to move from a qualitative assessment to a quantitative assessment attempt, as mentioned above, whereby the concept that links the different components between levels of the model that are represented as classes is referred to as weight measurement. This is a complex concept since it works as a link entity that qualifies the relationship between two classes, giving weight to the different associated concepts as it can be observed in **Figure 4**. When analyzing the domain of the relation has weight, we discovered concepts that were implicit in the scheme of the competence evaluation model, the ontology has to consider the evaluator role within the assessment process and link it to a weight.

The "assessment process", as seen in **Figure 5**, includes both the "person" or "persons" who have been evaluated and the evaluator, distinguishing these persons by the role they have within the process. That is how the CO ontology extends the roles raised in VIVO ontology, adding the "Assessed Entity Role" and "Evaluator Role". Evaluator role is not directly related to assessment process, since, as we saw in the previous section, the relationship between these two concepts is complex and they have to quantify that relationship through "Weight Measurement". This evaluation process has to evaluate a process that, within the StartUPS ecosystem, is usually an entrepreneurial project or a subprocess of it, considering the members of the project. The evaluation process must "have outputs" that in this case are "scores" of the indicators or "tests" evaluated with reference to a "measurement unit". To classify directly if a score belongs to a partial score or total score, equivalence rules were made in the ontology since if the range that passes through the "score for" is an indicator, it is known that the entity must belong to the partial score; but if the rank entity is test, it is known that it is the total score of the test. The outputs of the evaluation process that are scalar measures have to be referenced

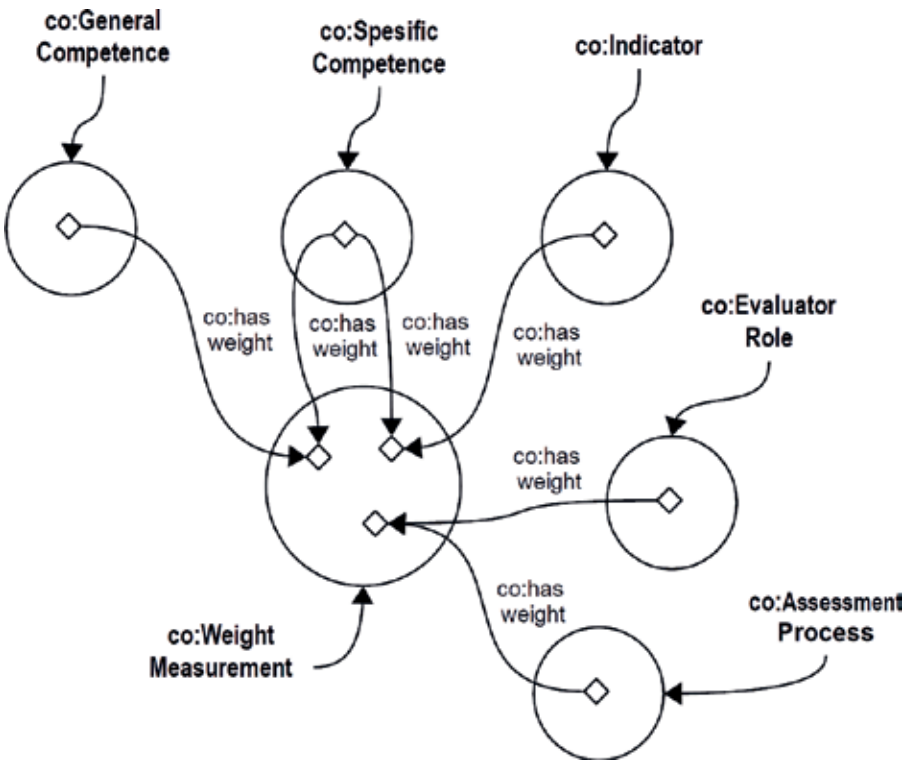

Figure 4. Conceptualization of weights at the levels of the competence assessment model.

with a scale as mentioned above; this role is fulfilled by the concept of measurement unit in which there can exist instances such as Likert scale. When performing an evaluation process, a test that links indicators through the relationship "has indicator" is always taken as reference.

Previously, we discussed about the different types of evaluations that formed trifocal evaluation/assessment. Within the CO ontology, this knowledge is inferred through the definition of axioms within the equivalences, to distinguish between three types of processes that are subclasses of assessment process, these equivalence rules are:

- Coevaluation: the person who is the bearer of an evaluator role participates in a process by means of a role and the process is evaluated by an assessment process that is linked to the evaluator role, and that person does not have a role that participates in the assessment process.
- Self-evaluation: the person who is the bearer of an evaluator role participates in a process through a role and the process is evaluated by an assessment process that is linked to the evaluator role, and that person has a role that participates in the assessment process.
- Heteroevaluation: the person who is the bearer of an evaluator role does not participate in a process through a role and the process is evaluated by an assessment process that is linked to the evaluator role, and that person does not have a role that participates in the assessment process.

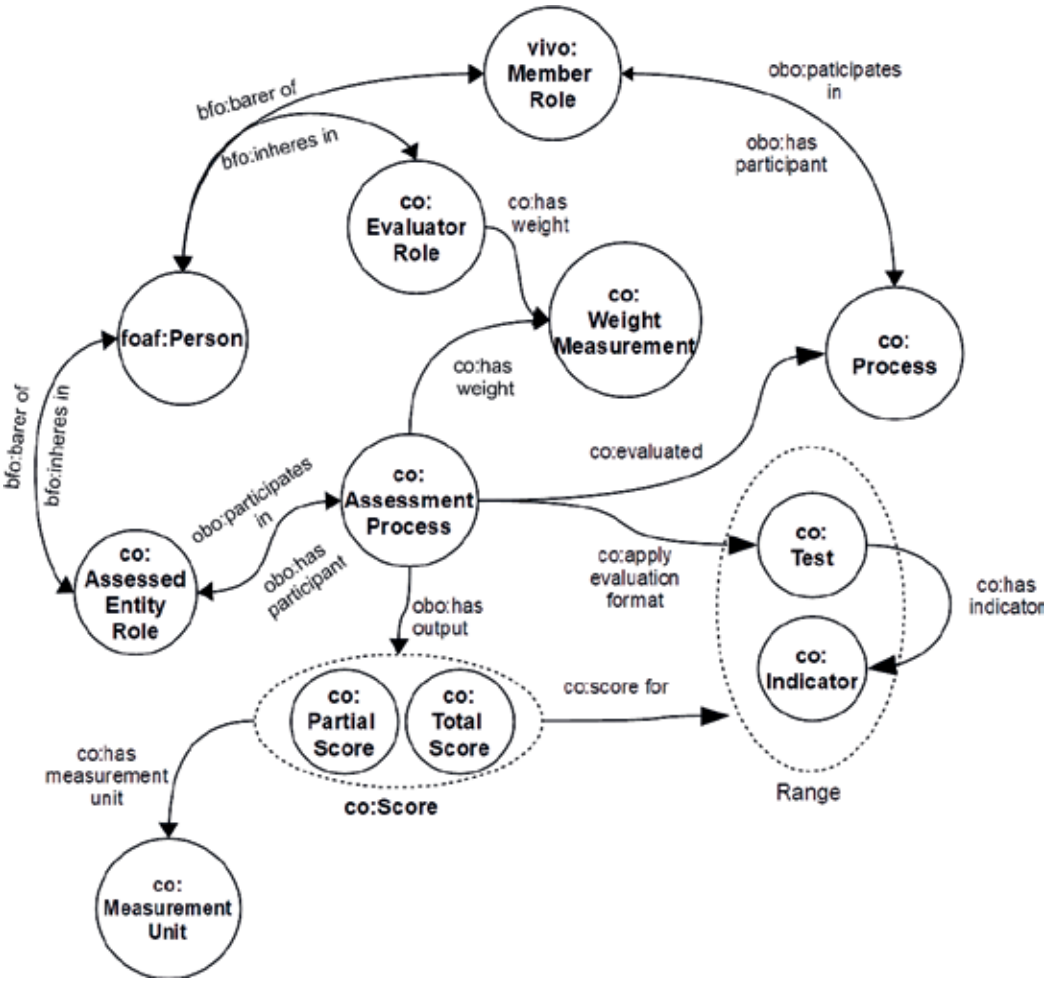

Figure 5. Schematic diagram of the competences evaluation process in the ontology.

The relationships that the evaluations have within the coworking ecosystem were modeled on the ontology and can be observed in **Figure 6**, where it can be seen how people fulfill different roles within the ecosystem through a participation relationship within events that can be the different workshops, training courses, boot camps or other instances that match the different events in which the skills acquired through assessment process are evaluated. Added to this, within the processes, we can find the entrepreneurship projects in which people fulfill a role, from these projects subprocesses like prototyping can be broken down, where the entrepreneurship project as the prototyping process can be evaluated.

As discussed in this section, each of the approaches from the relationship of weights to the different levels of the competence assessment model, the actors within the evaluation process and the relationship of the evaluation process with the different occurrences of which they are part of, the actors of the coworking ecosystem allow us to give an approximation of the competence assessment of an actor who participates in different events and entrepreneurship projects modeled on an ontology.

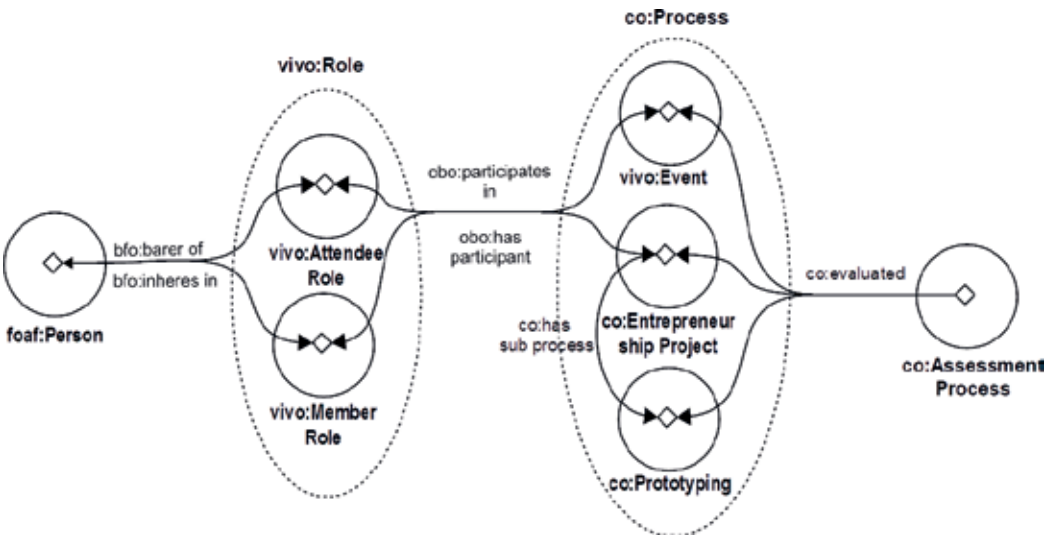

Figure 6. Schematic diagram of the evaluations of the different process performed in the coworking ecosystem in the ontology.

5. Experimentation and preliminary results

In order to check the traceability of people within the different processes that are performed in the coworking ecosystem modeled as a part of the CREAMINKA ontology, a SPARQL as shown in **Figure 7** is tested on the database where it can be observed as a result in **Table 1** the person next to the role which he participates with, in a process, such as entrepreneurship projects, boot camps and training workshops.

SPARQL consultation on actor's participation in the coworking ecosystem processes:

Obtained results:

In order to provide a tool to analyze the development of both general and specific competences of students/participants involved in entrepreneurship and/or research processes, we have designed two metrics. The first metric to determine the level of development that achieves a student/participant for a general competence as seen in Eq. (5):

$$GC_s\left(St_i, GC_j\right) = \frac{1}{\sum_{w \in \vec{W}_j}(w \cdot H1)} \sum_{k=1}^{N} w_k \cdot S\left(St_i, SC_k^j\right) \tag{5}$$

where:

- $GC_s\left(St_i, GC_j\right)$ represents the score achieved by *i*th-student St_i for the *j*th-general competence GC_j. The number of general competences is defined by the experts in higher education, entrepreneurship and research.
- $\vec{W}_j$ is a vector of weights related with the *j*th-general competence GC_j.

```
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX co: <http://www.creaminka.org#>
PREFIX vcard: <http://www.w3.org/2006/vcard/ns#>
SELECT DISTINCT  ?person ?roleClass ?titleProcess
WHERE {
    ?bearerOf rdfs:label ?labelBearerOf;
    filter(str(?labelBearerOf)="bearer of").
    ?participatesIn rdfs:label ?labelParticipatesIn;
    filter(str(?labelParticipatesIn)="participates in").
    ?person ?bearerOf  ?role.
    ?role ?participatesIn ?event;
        rdf:type ?roleClass.
    ?roleClass rdf:type owl:Class.
    ?event vcard:title ?titleEvent.
}
```

Figure 7. Query SPARQL of the traceability of a person in the coworking ecosystem.

- $H1$ represents the maximum score for each specific competence SC_k^j.
- $\frac{1}{\sum_{w \in \vec{W}_j}(w \cdot H1)}$ is a normalization factor used to scale the sum of weighted scores.
- $S(St_i, SC_k^j)$ is the score achieved by the ith-student St_i for a specific competence SC_k^j, whereas w_k is the kth-weight used to define the importance of this score. Each specific competence SC_k^j is related to the jth-general competence.
- N is the total of specific competences considered in the study.

On the other hand, the second metric allows us to know the level of development that students/participants achieve for each of the specific competences that make up a general competence. For this, the following equation is used as seen in Eq. (6):

$$S(St_i, SC_k^j) = \frac{1}{\sum_{v \in \vec{V}_j}(v \cdot H2)} \sum_{f \in \vec{F}, v \in \vec{V}_j} f \cdot v \tag{6}$$

where:

- f is the value assigned by the expert team according to the development level reached by the student/participant in this indicator.
- $H2$ represents the maximum score for each specific indicator f.

First name	Last name	Role class	Title event
Sofia	Agua	Attendee role	Boot camp 2017
Sofia	Agua	Attendee role	Training Course Artificial Intelligent
Sofia	Agua	Member role	Project SIRO
Andrés	Mena	Member role	Project SIRO

Table 1. People traceability results obtained with the execution of the SPARQL queries (coworking ecosystem).

- $\vec{V}_j$ is a vector of weights related with the *j*th-specific competence SC_k^j.
- $\vec{F}_j$ is a vector that contains all the indicators related with the *j*th-specific competence SC_k^j.

On this basis, we have used the metrics described above to create a module that allows performing clustering analysis. This module allows system users testing different values of weights as well as generating dendrograms and cluster graphics. This information is useful in decision-making for managers and research/entrepreneurship group directors.

In **Figure 8**, we can see an example of a dendrogram generated by the system from the specific competences and indicators retrieved from 20 participants in entrepreneurship projects,

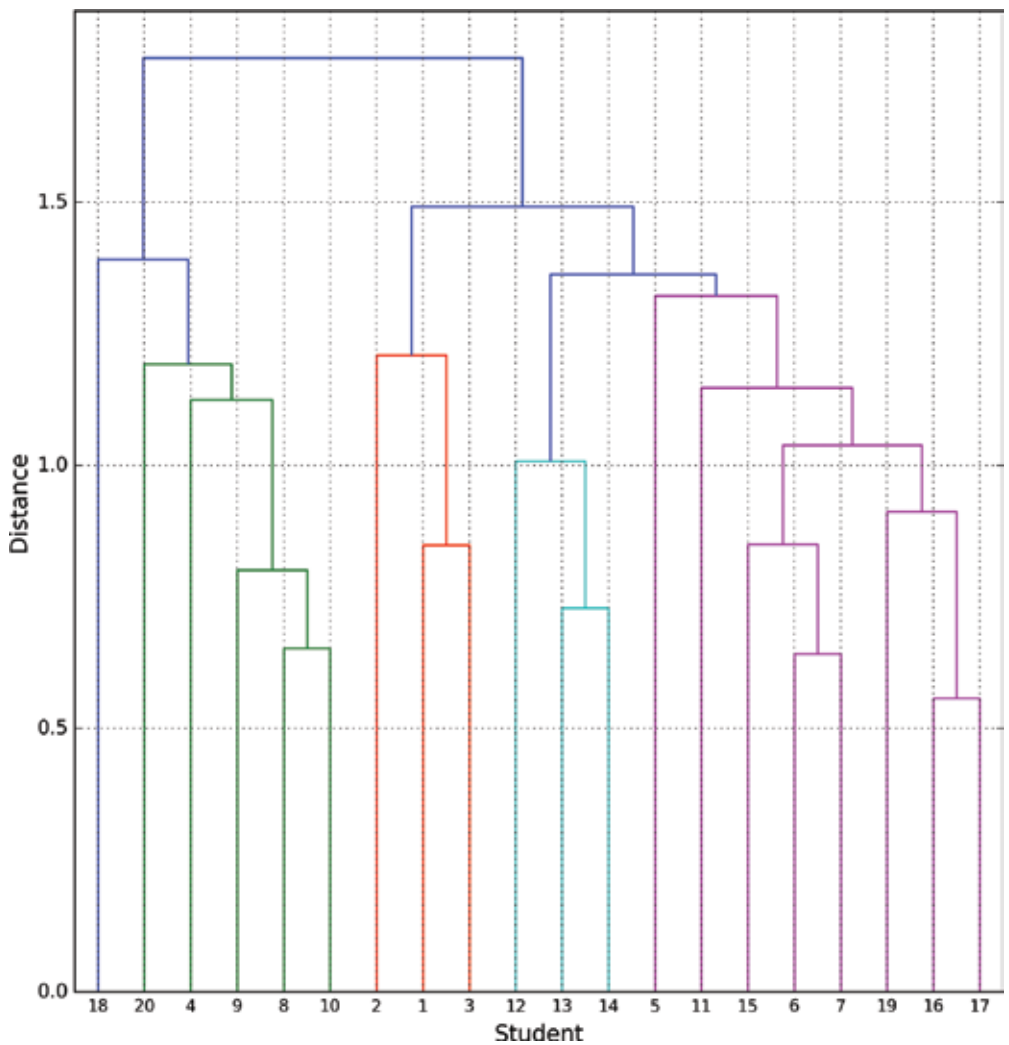

Figure 8. Dendrogram that is generated from the analysis of indicators of the participants and students of research and entrepreneurship groups.

boot camps and training workshops. The information feed to the clustering analysis module is described below:

- Three general competences for each participant ("*creativity*," "*project management*," "*entrepreneurship and innovation*").
- Nine specific competences per participant considering the following number of indicators (for each competence): $\vec{f} = \{3, 3, 3, 4, 4, 3, 3, 3, 2\}$. The specific competences consider aspects such as "*Design a work project without reaching its execution*," "*Find and propose new procedures and solutions to a given problem with forward thinking and leadership attitudes*," etc.

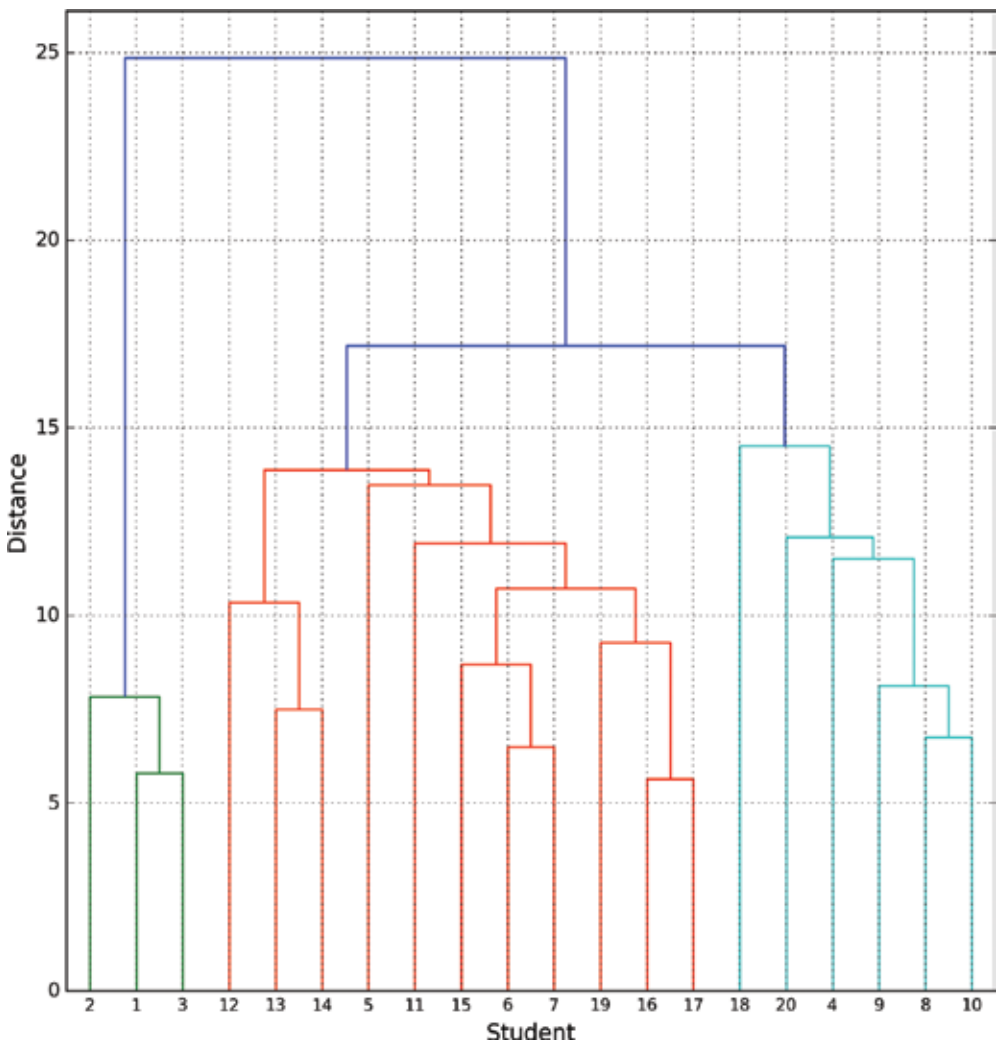

Figure 9. Dendrogram that is generated from the analysis of indicators of the participants and students of research and entrepreneurship groups.

- The participants are enrolled in different careers such as systems engineering, electrical engineering, business administration, etc.

As shown in **Figure 8**, if we cut the dendrogram at a distance of 1.33, four groups are formed. For example, with this information, we can observe that participants 8 and 10 have a similar profile in general in their specific competences, although they are from different careers (social communication and mechanical engineering).

On the other hand, in **Figure 9**, we can observe how new groups are formed when the specific competences are considered. As we can see, there are three perfectly defined groups where you can establish leadership, vision, entrepreneurship, etc. characteristics.

6. Conclusions

We present a set of knowledge that describes the coworking ecosystem in which several actors participate in various processes that pretend to generate competences in the participants; in that way, it is possible to give a traceability of how an actor gets involved through different roles in the coworking ecosystem, as described in the results phase; and it is even more important, the fact that each of the competences at different levels is developed, and at the same time, they are being evaluated within the processes in which the actors participate. This assessment within the set of knowledge of the ontology allowed to link the concepts of competences and the processes that form these competences in the actors. This link includes the trifocal valuation approach with weights in each of the arcs that join the concepts. This whole set of knowledge was built by reusing ontologies with different approaches in the research, extending some of the concepts to adapt them to the needs of the ecosystem that was searched to model.

On the other hand, it is important to mention that the development of competences by students/participants of entrepreneurship or research groups is an area that has not been adequately addressed at the present time. However, this area is very important in any organization conducting research and/or entrepreneurship processes, given that the participant human talent should develop competences which can substantially enrich the performance and production of knowledge.

As lines of future work, we propose the following:

- To develop a deep learning approach to suggest reinforcement strategies to develop some specific competences related with leadership training.
- To develop an intelligent module that allows combining profiles of students and participants in work groups focused on solving problems that require different types of skills (both general and specific).

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Chapter 14

Geological-Geotechnical Database from Standard Penetration Test Investigations Using Geographic Information Systems

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Rafael Augusto dos Reis Higashi

Additional information is available at the end of the chapter

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Abstract

The study describes applications of Geographic Information Systems (GIS) associated with Standard Penetration Test (SPT) reports as a support tool for planning and decision-making in public and private spheres. The chapter begins with a bibliography compilation showing recent applications carried out around the world. Following this, the description of the geological-geotechnical method using SPT information applied in two case studies is presented in particular. For that, an extensive detailing of SPT reports treatment is done to enable the composition of a geological-geotechnical database. Two cases are shown to exemplify the method application and its results, including the characterization of the topographic relief through Digital Elevation Model (DEM), slope and hydrographic map and the development of soil, groundwater and foundation maps using a geological-geotechnical database composed basically by SPT data. The cases approach a larger scale using 507 SPT boreholes to analyze a university campus with 1 km^2 and on a smaller scale using 537 SPT boreholes to analyze a city with 207.2 km^2 of urban area. Different possibilities of applications for information management are discussed over the chapter.

Keywords: information management, Geographic Information Systems (GIS), Standard Penetration Test (SPT), geological-geotechnical analysis, foundation maps

1. Introduction

In recent years, Geographic Information Systems (GIS) has allowed the improvement of works involving georeferenced data due to enabling complex spatial analysis. Graphic and

alphanumeric data are combined and processed simultaneously with agility and efficiency. The application of GIS tools in soil studies has been consolidated around the world, because of the advance of the data analysis for professionals, and since modeling results, expressed in maps, provide a better interpretation for the decision makers.

Digital maps have a great manipulation potential and high dynamism in the analyses, allowing to work with a large number of data and providing flexibility for updates and adjustments. [1] point out that the technological environment which the tool is inserted provides, in addition to the collection and treatment of spatial information, the development of new systems and applications.

Considering that the advent of numerical models for spatial inference of the variations of soil types or their properties allows the digital mapping of the soils [2], GIS is a powerful tool for performing innovative analyses inherent to the physical environment. Thus, the results obtained from geotechnical investigations present an interesting alternative to analysis, since they provide valuable subsidies to geological-geotechnical understanding.

According to [3], records of geotechnical logs, stratigraphic profile, and water wells are extremely useful reference data for geologic, hydrologic, and geotechnical applications. Among the soil reconnaissance tests, the Standard Penetration Test (SPT) is the most popular, useful and economical test in practically all over the world [4]. In Brazil, SPTs have specific legislation and are regulated by [5]. Recently, different publications are looking for improvement in geological-geotechnical information management through association of spatial location with soil parameters obtained by means SPT reports. Therefore, this chapter presents how to structure SPT reports in a geological-geotechnical database to apply it as a tool to assist planning and management actions.

In addition, in order to present geotechnical applications in GIS environment, digital maps are shown for two cases in Brazil: one in the head campus of the Federal University of Santa Catarina (UFSC) and other in the urban area of Blumenau city. Besides contributing to the establishment of guidelines for the region expansion planning by its managers, the results demonstrate that the prior knowledge of the geological and geotechnical parameters makes possible to supervise the next SPT services to be contracted. This because it has organized and spatialized pre-existing data of several SPT reports already executed, making possible the estimation of the information contained in these data for the entire study area.

2. GIS and geological-geotechnical information: recent applications

Currently, different studies seek to represent soil surfaces taking advantage of parameters obtained from SPT reports. Commonly, these researches occur in countries where seismic activities are present with severe consequences, such as India. Studies to define the dynamic properties of the soil, through the use of SPT data to obtain the shear-wave velocity (V_S), are essential in terms of engineering to predict soil responses under earthquake. Correlations

between N-value and V_S were applied and studied in 2006 in Yenişehir/Turkey [6], in 2008 in Bangalore/India [7]; in 2011 in Mumbai/India [8]; in 2012 in Hamedan/Iran [9]; in 2013 [10] and 2016 [11] in the city of Guwahati/India.

Countries such as Malaysia, Thailand, India, Turkey, Iraq, Iran, Brazil, United States of America (USA), and Australia carry out researches using SPT data to create surfaces of soils with different goals. In 2013, [12] conducted a soil characterization study using 110 SPT reports in the city of Hilla/Iraq. As a result, soil resistance trend was presented as a function of the N-value, and an empirical equation was developed to represent the region. In southern Chennai/India, in 2014, [13] developed water level, N-value contour lines and bearing capacity maps at different depths. Foundation suitability map was developed by using weighted overlay analysis.

In 2001, in Bangkok/Thailand, using 200,000 STP boreholes, [14] performed a three-dimensional soil profile generation, proposing the composition of a database for that. N-value contour lines at Surfers Paradise/Australia, based on 35 SPT reports, were developed in 2014 [15]. In 2012, [16] developed a map of N-value contour lines to assist in the design of foundations projects in the city of Rajshahi/Bangladesh, with the purpose of assisting in the design of small and low-cost structures. In 2013, [10] proposed the mapping of N-value and groundwater depth in the city of Guwahati/India. This study was carried out from a database of 200 SPT boreholes, covering 262 km^2.

In João Pessoa/Brazil, in 2011, impenetrable layer, admissible stress, N-value, foundation suitability maps, as well as temporal analysis of the water table (reflecting the seasonality of rainy and dry periods) were developed [17]. In 2015, in Fortaleza/Brazil, N-value contour lines for three different depths and groundwater level map were generated [18].

In 2016, [19] identified and mapped the Blumenau/Brazil soil characteristics through 537 SPT reports. In this study, maps were developed portraying: SPT impenetrable layer depth, groundwater level, allowable stress for shallow foundation and N-value contour lines oriented for the deep foundation, from which the maximum length for common types of piles were calculated. The prediction of the foundation type (shallow and deep), admissible stress, type and the approximate length of piles, was performed using semi-empirical methods available in the literature. Complementary, geotechnical engineering mapping was associated with geomechanical information from SPT reports, resulting in stratigraphic reference profiles for the geotechnical soil units of the city.

In 2016, [20] collected 507 SPT boreholes from the head campus of the Federal University of Santa Catarina (UFSC) to analyze the geological-geotechnical profile of the study area, through the development of soil maps for each depth layer and foundation suitability maps. Impenetrable layer surface, groundwater level (considering the seasonality), as well as N-value contour lines were developed. Furthermore, through empirical and semi-empirical approaches available in the literature, this study produced orientation maps regarding foundation type: shallow or deep, allowable stress of the soil and maximum length of the piles commonly performed in the region. In the end, the theoretical results were validated by means of the information contained in 20 foundation designs executed at UFSC.

The methods and results of these two studies will be detailed as cases in this chapter. While [19] is focused on a large-scale analysis, the [20] is applied to a smaller one.

Considering the above, it is verified that studies related to geotechnical investigation associated with geospatial analyses have been carried out worldwide and have been aroused interest in practical and academic scope. A fact that encourages the growth of the works is the existence of numerous investigation reports already carried out in urban areas, becoming a potential subsoil characteristic database [21]. So, in order to stimulate further studies in the field, this chapter intends to clarify some ways to take advantage of pre-existing geotechnical data (SPT reports) and the methods of mapping and data processing, exemplifying the results by means of two cases.

3. Method

This section consolidates the processes used to analyze geological-geotechnical profile, through pre-existing soil data obtained via SPT reports, applied in the studies of [19, 20]. The method includes data collection, digitization and treatment (pre-processing), in order to compose a geotechnical database, further processed in GIS environment. The steps are schematically shown in a diagram (**Figure 1**) and detailed in the sequence.

3.1. Data collection

The first step of the method is the data collection. They can be obtained from different sources, such as official agencies, companies, previous publications and, when the required data is not available, it can be collected by the researcher. The accuracy of the results is directly related to the initial data input; therefore, data collection becomes an essential step for optimal results.

The process of data collection, together with the data treatment (next step), might be one of the most time-consuming steps, and it requires an advance planning. It is interesting to elaborate list of contacts, schedule the activities and establish goals for assisting in this step.

3.2. Data treatment

After gathering all the necessary data, the data treatment step begins. As shown in **Figure 1**, for the presented case studies (Section 4), the data treatments (pre-processing) are mainly done on the graphical data and on the SPT data, which are detailed hereafter.

3.2.1. Graphic and vector data

Using secondary data, a careful data treatment may be necessary. Data processing allows a fine-tuning of the data according to the required results. Much effort can be applied in this step, particularly when data obtained is not prepared to be handled in a GIS environment.

The routine previously published [22] guides the compatibility of the DGN or DWG (vectorial extension used by AutoCAD®) formats for SHP (extension used by QGIS® and ArcGIS®). For the presented cases, the following adjustments can be performed:

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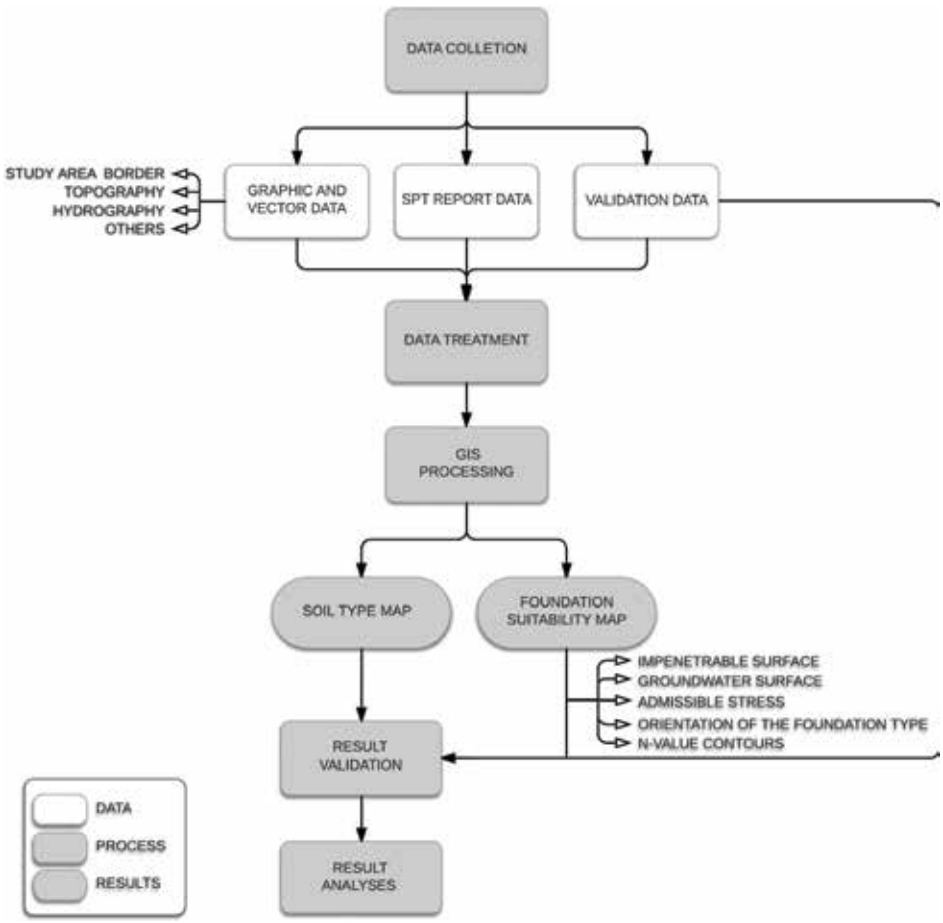

Figure 1. Work method diagram.

- Grouping thematically homogeneous elements;
- Merging broken lines (creating a single line from multiple lines);
- Resetting elements that were represented as lines into polygons;
- Closing polygons;
- Eliminating duplicate elements;
- Georeferencing of graphic elements.

Parallel to the treatment of graphic data, SPT reports are digitized and organized in a database, as described in the following subsections.

3.2.2. SPT report data

The composition of SPT reports database depends directly on the required results. Thus, this chapter emphasizes the data treatment processing for some applications of SPT report data

regarding groundwater level, impenetrable depth to SPT percussion, soil resistance and types of soil according to the particle size, used in the case studies.

All information available in the SPT report can be utilized. However, some inputs are important for basic analyses. **Table 1** lists the information available in the SPT report associated with some possible applications, mostly used in the case studies (Section 4).

Since SPT reports are often available in individual notes (usually printed or in PDF format), normally the data digitalization is required. Furthermore, specifically for the SPT data on the cases, it was performed a preliminary treatment prior to the database composition. This preprocessing was proceeded for each individual SPT borehole.

The location of the SPT boreholes (i) was not available directly on the report. The georeferencing of each SPT borehole was carried out using Google Earth®, through the indirect information of the reports (such as address, sketch, name of the enterprise). This information was used as a reference to obtain the most probable location of the borehole. The Google Earth® timeline tool, combined with the date of the SPT investigation, can also be useful. Since it was obtained indirectly, this SPT borehole georeferencing was not as accurate as a topographical georeferencing, however good enough to proceed some analyses.

SPT borehole data	Applications
(i) Location of the SPT borehole	The location of the SPT borehole is essential to proceed a geospatial analysis of all SPT report data. This step always includes the use of a coordinate reference system, to be chosen by the researcher, and the identification of the horizontal location of each borehole
(ii) Borehole depth	The depth reached by the SPT borehole up to the impenetrable is essential to develop the impenetrable to SPT percussion surfaces
(iii) Groundwater depth	The groundwater depth is used to obtain the groundwater level. This information allows understanding the behavior of the water table among the studied region and, associated with the topography, to understand the directions of the groundwater flow. It can be used to construct a potentiometric map, for example
	It can be associated with other information and/or can help to understand lacks of other data sources
(iv) N-value of each depth	For more detailed analyses, such as foundation maps or iso-stress maps, it is necessary to have the N-value resistance for each meter of depth
(v) Geotechnical investigation date	For a temporal analysis, the date of the SPT report is required. For instance, it can be used to get a seasonal variation of the groundwater level
(vi) Soil stratigraphy	Soil characteristics by depth provide information such as type (clay, silt, sand), color, compactness and consistency. This information can be associated with empirical correlations which allow associating new information and new analysis for each layer of soil, such as: to simulate shallow and deep foundations for each type of soil; to associate a specific weight to the soil, to analyze the stress according to soil type

N-value: abbreviation of the standard penetration resistance, the determination is given by the corresponding number of hits to driving 30 cm of standard sampler after an initial driving of 15 cm [5]

Table 1. SPT report data and its applications.

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Borehole depth (ii), groundwater depth (iii), N-value of each depth (iv), geotechnical investigation date (v) and soil stratigraphy (vi) had their raw data digitized in electronic spreadsheets, along with the coordinates of each borehole (**Figure 2**), without preliminary treatments or filters. Spurious data can be removed during this process, according to the researcher's interpretation.

The SPT digitization and database organization aims to structure geological-geotechnical information in order to enable processing and data interpolation in GIS environment. In this sense, for the propose of all SPT borehole are considered in the interpolations, an N-value equal to 50 was inserted for the depths below the impenetrable. The idea is to establish a high N-value below of the SPT borehole last layer (the impenetrable layer) to prevent empty data, which could undermine the numerical modeling. As a simplification, the name rock was inserted after the impenetrable layer.

Subsequently, considering that reliable data are fundamental for database composing, the reports are analyzed to identify discrepancies in their information. A dry borehole near a water body or a shallow impenetrable depth near a deeper one is examples of possible inconsistencies. Furthermore, depending on the spacing between the SPT boreholes and the data application, it can be necessary and recommended to filter the SPT boreholes, aiming to save time and processing resources. In the case of [19], for example, to benefit data interpolation since clusters of SPT boreholes does not favor numerical modeling, for each cluster of SPT borehole it was selected one single borehole to represent the terrain. Thus, in order to obtain a better spatial distribution of SPT boreholes, the selection of the representative borehole of each cluster occurred in a more conservative scenario, considering the critical information in terms of foundation. The filtering was defined according to the steps [19]:

Step 1. Select the borehole with the greatest impenetrable depth;

Step 2. In the case of similarity of impenetrable depth, from the boreholes with the greatest impenetrable depth, select the hole with lower groundwater depth;

Step 3. In case of similarity of the greatest depth of impenetrable and lower groundwater depth, select the borehole with the lowest sum of N-value along the length of the borehole.

Name	X	Y	SPT_date	h_borehole	h_groundwater	n-value_1m	n-value_2m		n-value_25m	soil_1m	soil_2m		soil_25m
ID_292	744817	6944599	05/11/2009	12	1,1	4	2		50	Sand	Sand		Rock
ID_293	744576	6944828	19/07/2003	25,35	8,1	8	10		43	Sand	Sand		Pebble
ID_294	744564	6944814	21/07/2003	25,4	8,3	14	14		41	Clay	Clay		Pebble
ID_295	744546	6944829	18/07/2003	24,35	8,3	6	6		50	Clay	Clay		Rock
ID_296	744559	6944843	17/07/2003	25,35	8,15	5	5		40	Clay	Clay		Pebble
ID_297	744561	6944827	21/07/2003	25,38	8,7	6	7		40	Clay	Clay		Pebble
ID_298	744943	6944357	20/11/2010	3,07	1,1	16	46		50	Clay	Clay		Rock
ID_299	744933	6944369	21/11/2010	1,2	1,12	50	50	(...)	50	Clay	Rock	(...)	Rock
ID_300	744916	6944377	21/11/2010	6,39	1,2	9	7		50	Clay	Sand		Rock
ID_301	744946	6944390	21/11/2010	1,27	1,1	50	50		50	Clay	Rock		Rock
ID_302	744973	6944376	20/11/2010	4,07	1,4	14	8		50	Silt	Silt		Rock
ID_303	744954	6944366	21/11/2010	3,08	0,9	9	15		50	Clay	Clay		Rock
ID_304	744969	6944357	21/11/2010	3,41	0,8	7	7		50	Clay	Sand		Rock
ID_305	744536	6944351	20/11/2010	18,4	1,8	9	13		50	Clay	Clay		Rock
ID_306	744535	6944341	19/11/2010	14,38	2,3	8	5		50	Clay	Clay		Rock
ID_307	744515	6944341	19/11/2010	22,03	3,7	8	11		50	Clay	Clay		Rock

Figure 2. Geological-geotechnical database.

With the structured data, it is possible to start the data processing in a GIS environment, by consolidating and georeferencing the acquired data (graphical and SPT data), developing thematic maps and a geodatabase (associated with the boreholes location).

3.3. GIS processing

In this step, based on the graphic and vector data, the objects referring to each layer (administrative limit and hydrography, for example) are isolated in their own layer and georeferenced. Graphic and vector data and SPT borehole locations are imported to a GIS environment. All data must be handled to the same coordinate reference system and imported to the same GIS environment.

Through georeferenced data, thematic maps are developed for the understanding of the characteristics of the study area, which will assist in the geotechnical analyses and data validation. As an example of thematic maps, **Figure 3** presents the Digital Elevation Model (DEM), the slope map, and the hydrographic map produced by [20].

These maps are a basis for the characterization of the topography. In addition, they contribute to the identification of the soil type in each borehole analyzed (sedimentary or residual, for example). The hydrographic map, in turn, is used to aid the consistency analyses of the SPT groundwater level and can improve the groundwater data, as performed in [19, 20], who incorporated fictitious SPT groundwater data along the main river of the study area.

The geological-geotechnical database developed (**Figure 2**) outside of the GIS environment can be incorporated into the SPT borehole already in GIS, using the ID of each borehole as a reference. Thus, each row of the database, which refers to a single SPT borehole, begins to contemplate the information of its report and location.

When the altimetry information is not available on the STP report, since the database is georeferenced, the elevation of each borehole can also be added by crossing the altimetry information arranged in the DEM with the location of the points. Additional columns can be created

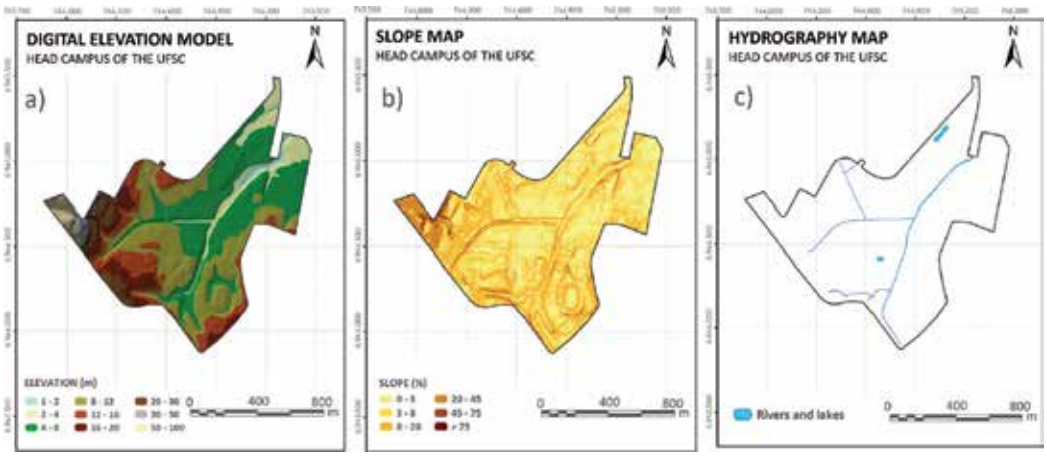

Figure 3. Thematic maps [20].

in the database for calculating the impenetrable and groundwater elevation, subtracting the altimetry value from the respective depths of impenetrable and groundwater. Likewise, other information can be added to the database, depending on the available data and analysis interest, such as the terrain steepness (from a slope map) and the geotechnical unit (from the geotechnical engineering map).

The database can be handled to create secondary information. For instance, to generate admissible stress (σa) surface from N-value, [23] performed the analysis soil stress with an empirical model. The admissible soil stress for the shallow foundation is defined in [24] as:

$$\sigma_a = 0.02 \times \text{N-value (MPa)} \quad (1)$$

Valid for natural soils with $5 \leq$ N-value ≤ 20.

It is necessary to prepare the database for creating an elevation map of specific admissible stress: setting up the N-value corresponding to the desired stress and identifying the depth of each borehole where this N-value is found. Since coordinates are associated with these depths, a spatial interpolation can be carried out to obtain the elevation of the desired stress (isobaric).

Another possibility is to generate the surfaces of admissible stress isovalues. In order to do it, for each meter of depth, the values of admissible stress are calculated according to Eq. (1). Since the equation is valid for a certain range, the isobaric of 0.4 MPa (4 kgf/cm^2 or 400 kN/m^2) is adopted as the upper limit of admissible stress, and 0.1 MPa (1 kgf/cm^2 or 100 kN/m^2) as the lower limit.

Also handling the database, [19, 20] used the N-value to create an orientation map of the foundation type (shallow or deep). The authors proposed criteria to guide the foundation type algorithm based on the precepts of economic feasibility exposed in [25] for shallow foundations and the limitations of the Eq. (1). The adopted criteria were:

- Maximum limit of two meters depth for shallow foundation settling. [19] adopted four meters, instead of two, in order to contemplate the possibility of an excavation of a subsoil up to two meters;
- N-value ≥ 5 in the analyzed depth and below it, in order to avoid shallow foundation laying on soft soil;
- Zones not consistent with previous criteria were directed to the deep foundation;
- Considering that the groundwater level is fundamental for the evaluating the foundation type, for each depth analyzed, the groundwater was plotted on the maps.

Finally, with the database consolidated in the GIS environment, the information generated can be used for management and analyze of the registered data. In this context, geostatistics is indicated to transform a database into maps that enable the geological-geotechnical characterization of the study area. Geostatistics is distinguished from the conventional statistics because it considers the spatial or spatiotemporal location of the data in the analyses. The cases presented in the chapter made use of interpolations, applying ordinary kriging

processes since it is a consolidated method in the soil science literature [26]. However, for each type of map elaborated, it is necessary to verify the semivariogram that best conforms to the data, i. e., the one which results in a smaller average error.

3.4. Result validation

This section intends to clarify briefly some ways to validate the results and to understand their coverage. The first approach for validating the results is through numerical analyses. It can be done using a subset (training set) to build the map, and a test set to analyze it by comparing the predicted results with the test set. This holdout concept is highly applied in machine learning and can be used to geotechnical data as well. The holdout method is shown in **Figure 4**.

Some maps can be validated through on-site information collection. In addition, the foundation suitability map and a study about foundation characteristics, such as pile lengths, can be validated by analyzing the foundations executed in the study area.

[19] used on-site information to validate the soil units of Blumenau with experts of the city hall, while [20] carried out validations through the analysis of the executed foundation reports provided by the University. Based on the type and length of the foundations executed in 20 buildings distributed along the study area, the foundation suitability and the pile maximum length maps could be validated [20].

Another possibility is defining the number of the dataset and its distribution according to the spatial resolution required for the study. However, when working with pre-existing data, usually it is not possible to choose the dataset. In this case, the spatial resolution analysis can help to understand the coverage of the dataset.

In [27] (as cited in [28]), the spatial resolution of georeferenced data is defined as the content of the geometric domain divided by the number of observations, as shown in the Eq. (2).

$$R = \sqrt{\text{area}/\text{number of observations}} \tag{2}$$

Where R is the spatial resolution.

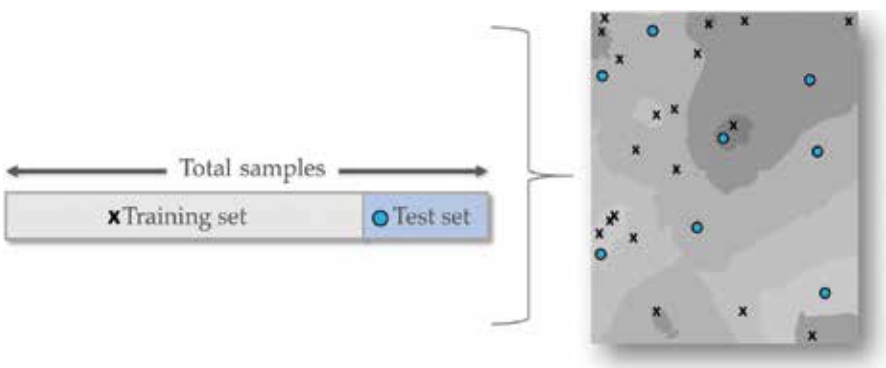

Figure 4. Data validation—numerical analyses using the holdout approach.

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[19] applied this spatial resolution approach to visualize the data distribution and coverage and to calculate, through literature comparison, the scale of the developed maps (**Figure 5**).

An analysis based on the background knowledge and visual inspection is also effective to understand the coverage of the dataset qualitatively. The resulting information is increasingly closer to reality when in possession of a robust database, that means a larger number of SPT boreholes distributed throughout the study area associated with a validation process. As part

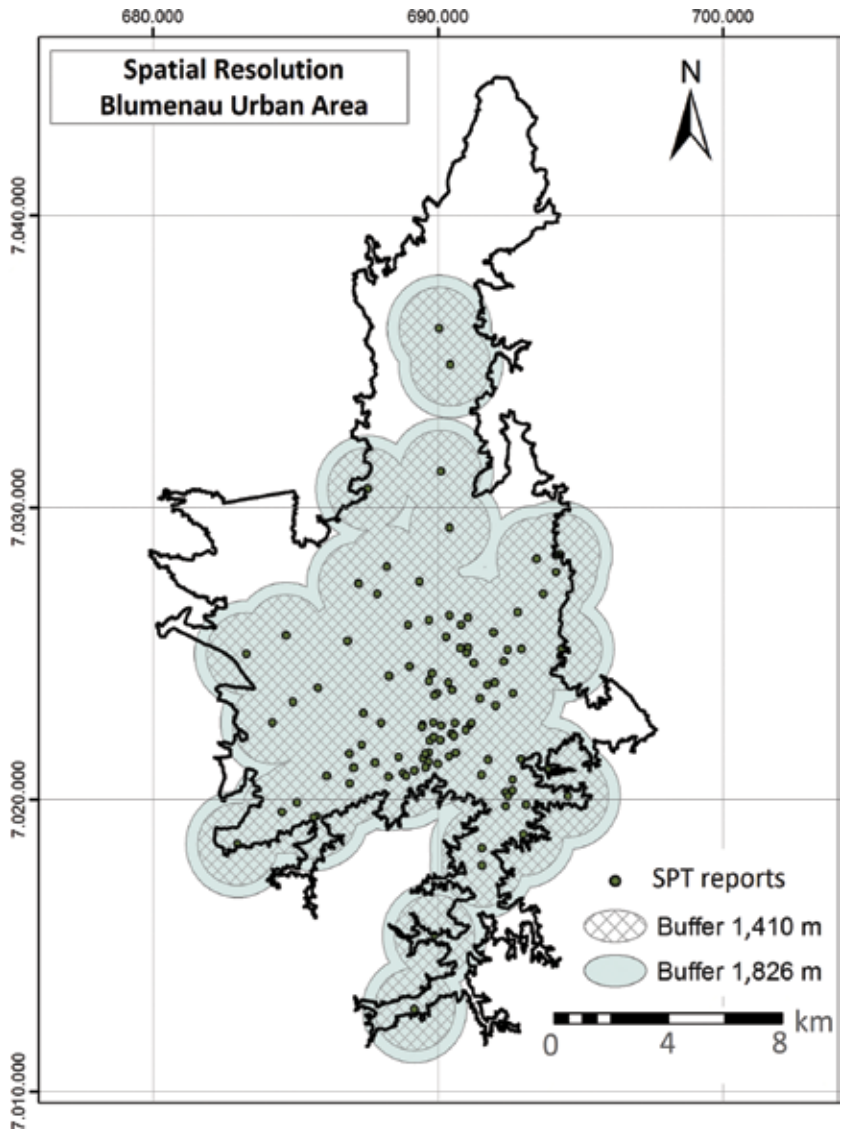

Figure 5. Coverage of the dataset—spatial resolution [19].

of the visual analysis, [19] exemplifies the comparison between the elevation surface modeled from SPT reports (**Figure 6b**, developed with limited dataset) and from one modeled from contour lines (**Figure 6a**, developed with a rich dataset).

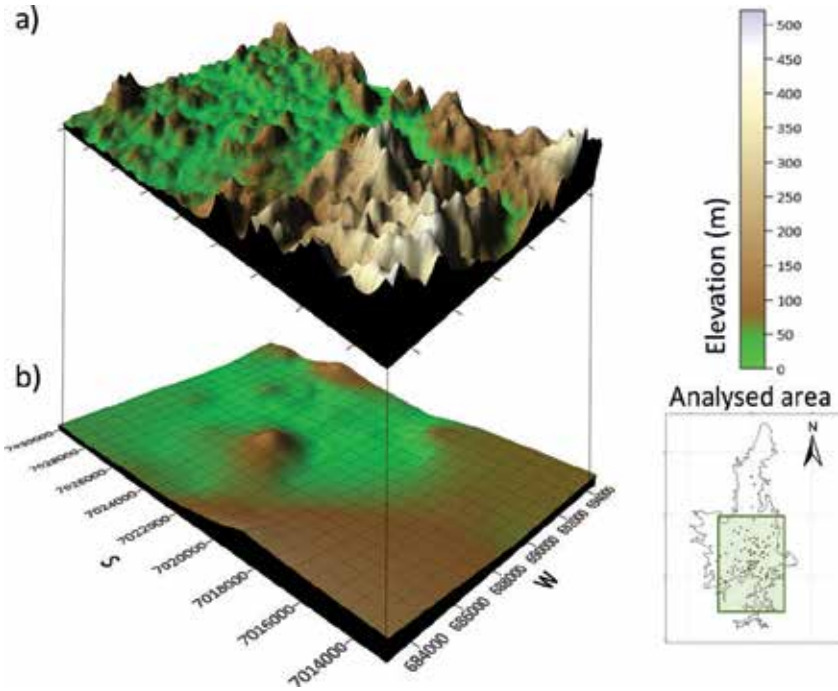

Figure 6. 3D Digital Elevation Model. Surfaces modeled from contour lines (a) and from SPT borehole coordinates (b) [19].

The data validation is an essential step because it helps to improve the results and prevent the elaboration of maps with unreal results. This stage can provide a better comprehension of the solution developed, and clarify the strengths and limitations of the study.

4. Results and cases

This section introduces some examples of the results achieved with the application of the presented method. The two cases discussed are deeply detailed in [19, 20].

4.1. Soil type map

Soil type maps were developed in [20] using the kriging technique exclusively from the data of SPT reports, starting at 1-m depth and ending at 25-m depth. **Figure 7** shows a compilation of all generated maps, in order to simultaneously visualize the variation of the soil composition along the layers.

Visually, it was verified that the subsoil of the head campus of UFSC has an increase of soil granulometry from northwest to southeast and along the depth. By calculating areas according

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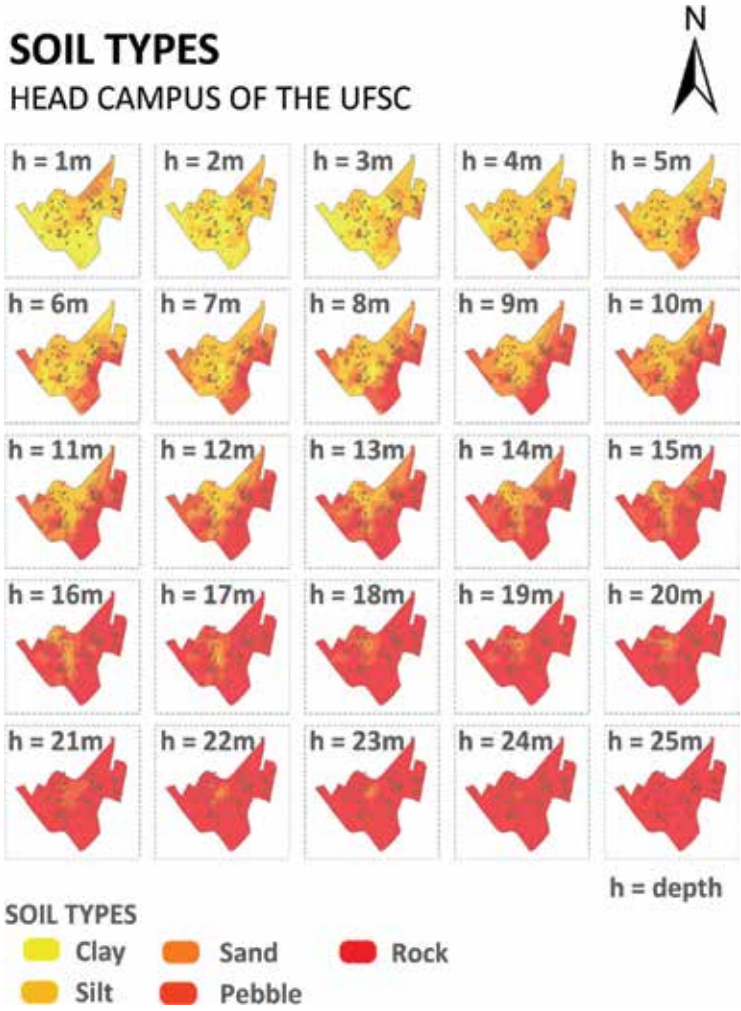

Figure 7. Soil types maps [20].

to the type of soil, quantitatively, up to the depth of 11 m, there are 50% or more of the area covered by clay, silt and sand, while in the following layers, there is a predominance of pebble and rock.

4.2. Impenetrable surface

The surface of the impenetrable to the SPT percussion was generated by interpolating the values in each SPT borehole. As one of the results, the impenetrable map available in [20] is displayed in **Figure 8**.

It is verified that the regions with fewer SPT boreholes (map boundaries) present a contour for the impenetrable depth zones with fewer details, covering larger areas and having a shallower impenetrable when compared to regions with more SPT boreholes.

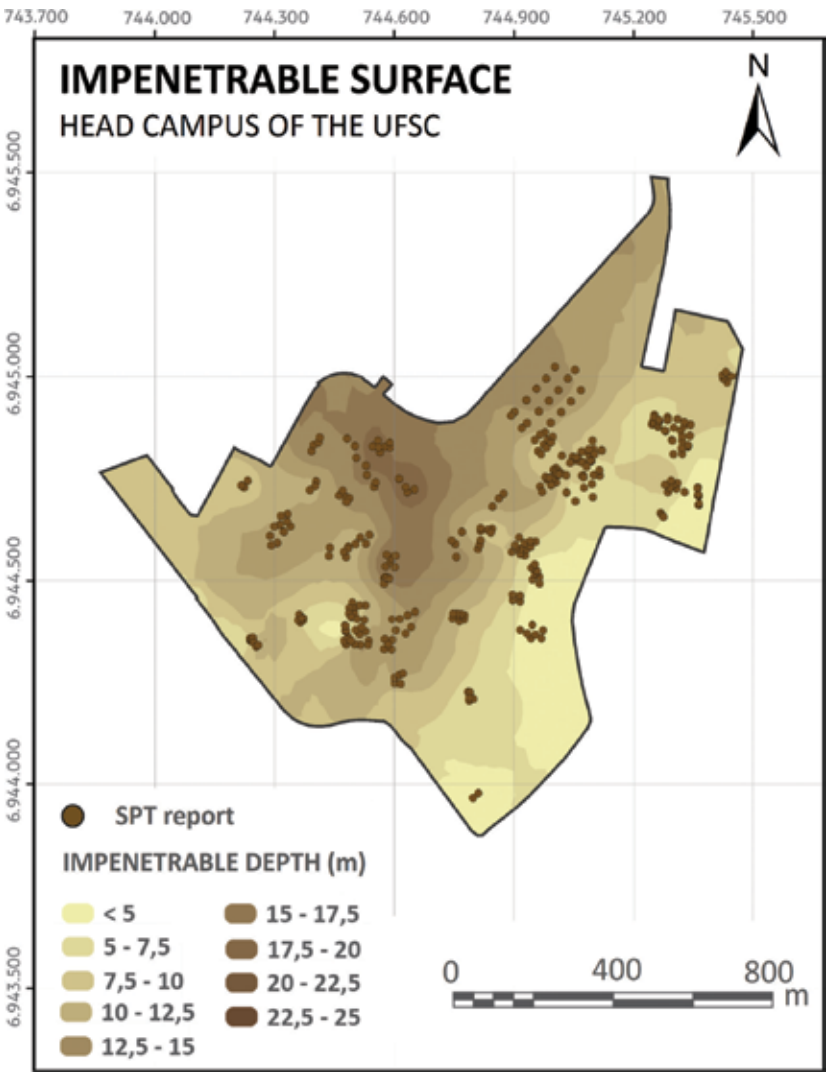

Figure 8. Impenetrable to SPT map [20].

4.3. Groundwater surface

The maps generated by the interpolation of the groundwater elevation in each SPT borehole allow to understand the behavior of the water table and can be used to verify the groundwater flow. A **Figure 9** shows the groundwater surface generated [19].

In this case, it is observed that groundwater flows from the higher elevations to the lower elevations, tending to flow to the main river of the city. The shorter the color shade transition in **Figure 10**, the greater the hydraulic gradient is.

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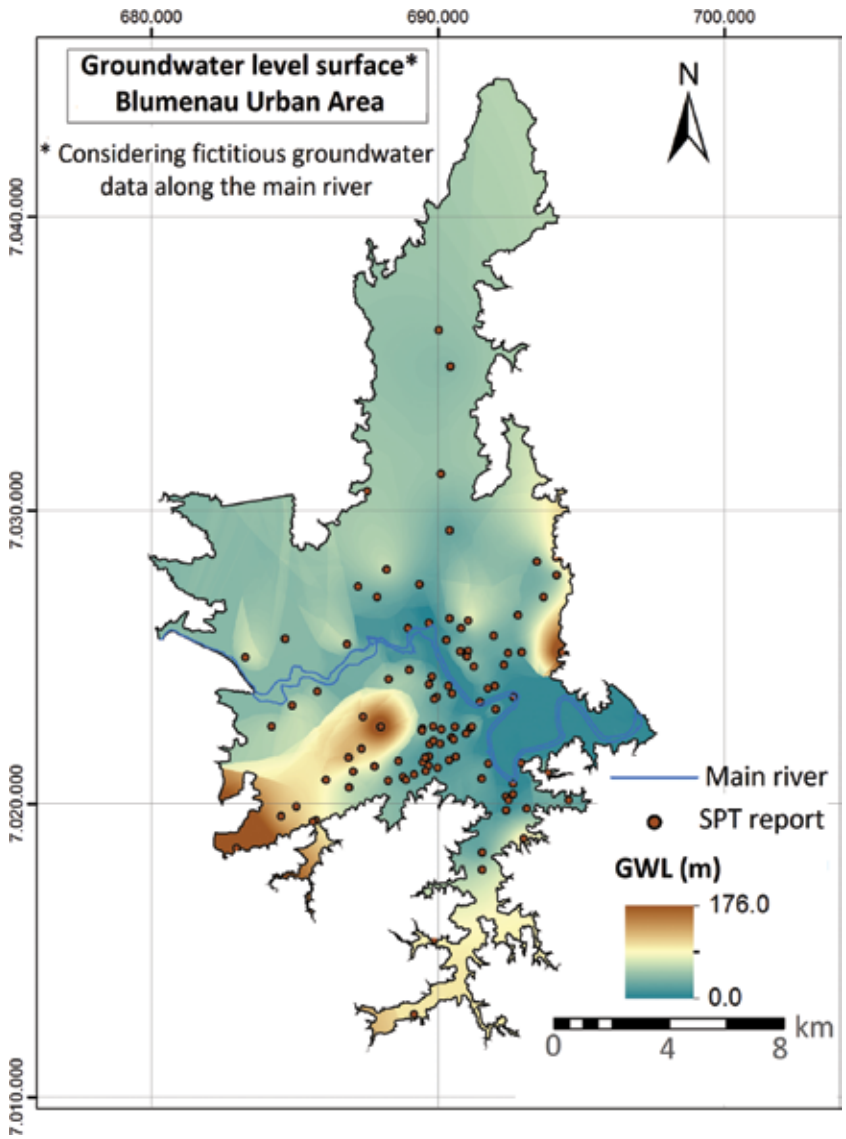

Figure 9. Groundwater map [19].

For an analysis of seasonality, the groundwater data can be separated according to the rainy and dry periods of the year. [20] performed a historical series analysis of daily precipitation data to obtain the rainy and dry seasons, and based on it the SPT boreholes were classified as belonging to the rainy season (**Figure 10a**) and dry season (**Figure 10b**).

The comparison between the two maps makes it possible to evaluate the temporal variation of the water table. In the case presented, it is possible to understand the difference between the

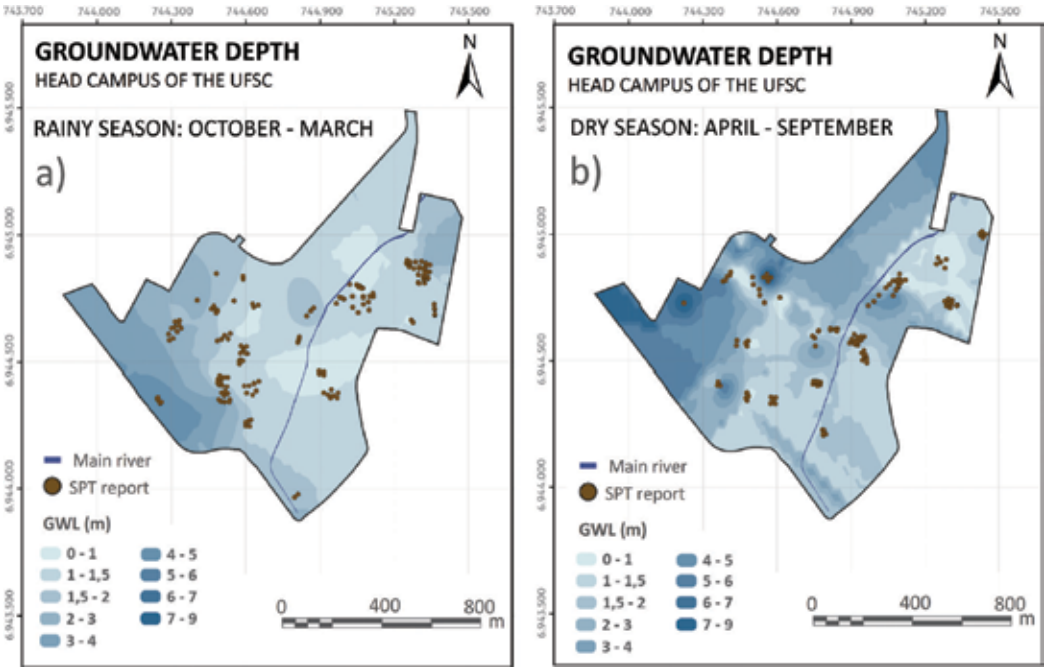

Figure 10. Groundwater seasonality map. Rainy season (a). Dry season (b) [20].

water table level in each period, with higher groundwater level during the rainy season and smaller one in the dry season, as expected. These maps are a valuable tool to plan schedules for foundation execution, for example.

4.4. Admissible stress map

The maps developed by means of the admissible stress values of each borehole, at the required depths, guide the design of direct foundations. Based on Eq. (1), the regions where the admissible stress (σa) is smaller than 100 kN/m^2 are not valid, because they correspond to areas where the N-value is smaller than 5 (lower limit of the Eq. (1)). Likewise, the N-value greater than 20 (higher limit of the Eq. (1)) corresponds to 400 kN/m^2 of admissible stress, also a limit range to create the map for safety reasons. **Figure 11** displays an example of a map generated for three different soil depths in [20].

In this case, there is a tendency to increase the stress supported by the soil along the depths, growing from west and southeastern regions to north-central areas.

4.5. Orientation of the foundation type map

The orientation of the foundation type maps indicates the propensity to execution shallow or deep foundations. They are generated by means of the interpolation of the values assigned to the SPT boreholes according to the established criteria. It is recommended to include information about water table, considering that the presence of groundwater can guide the decision-making regarding the foundation type to be adopted.

An example developed in [19] of these maps is showed in **Figure 12**, for the Blumenau urban area.

The maps developed to one and two meters of depth divides the Blumenau urban area into two large regions, the southwest, orientated to shallow foundations, and the northwest, tending to deep foundation mostly. Due to the higher resistance of the deeper soil layers, the susceptibility to shallow foundation covers 39.1, 45.9 and 79.0% of the total area, to the depths of 1 (**Figure 12a**), 2 (**Figure 12b**), 3 m (**Figure 12a**), respectively.

4.6. N-value contours map

N-value contours maps can be elaborated through the established database in order to allow an orientation according to the type of deep foundation to be used. Through the interpolation of

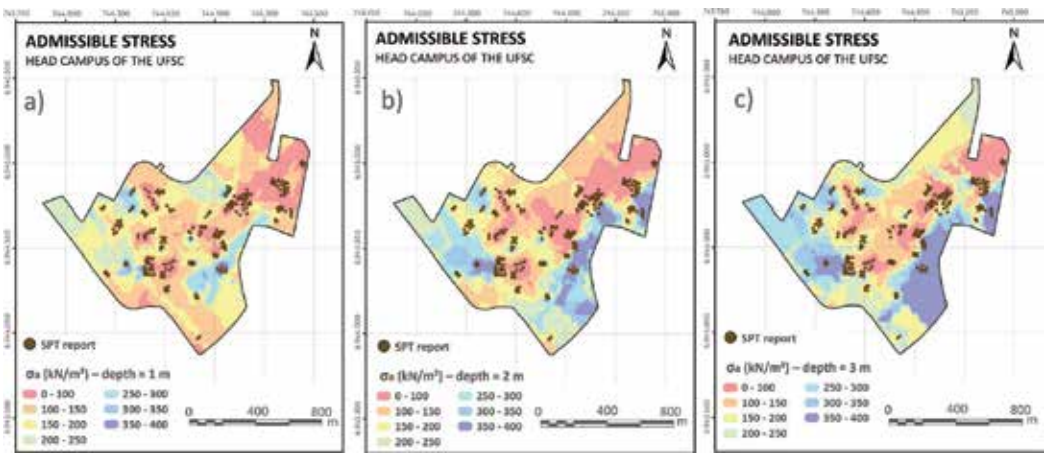

Figure 11. Admissible stress for depths equal 1 m (a), 2 m (b) and 3 m (c) [20].

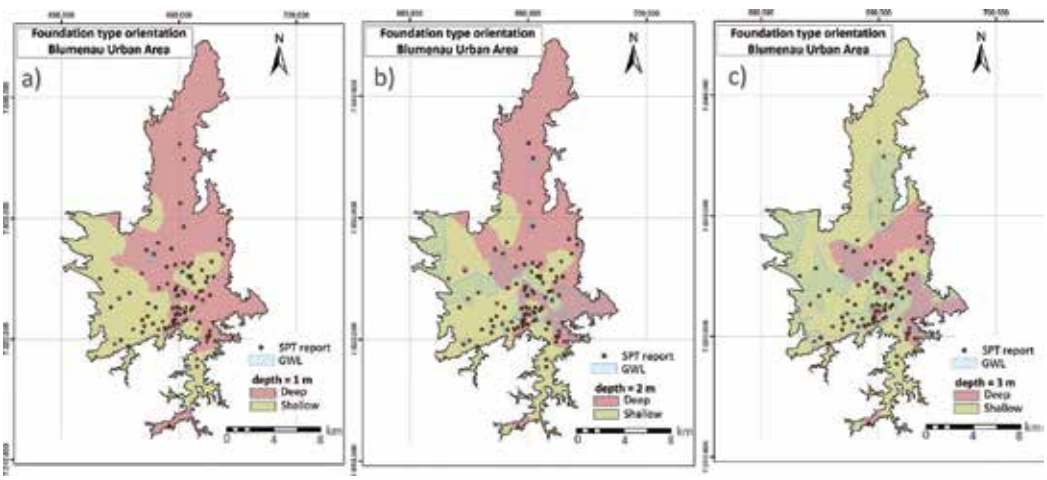

Figure 12. Foundation type orientation for depths equal 1 m (a), 2 m (b) and 3 m (c) [19].

the N-value in each analyzed depth, curves of the soil resistance for the study area are obtained. This kind of maps, for instance, enable to evaluate the geotechnical soil profiles in various sectors of the study area, in order to observe the occurrence of layers with lower resistance index and the evolution of the soil resistance with increasing depth.

Figure 13 shows a compilation of all generated N-value maps presented in [20], in order to simultaneously visualize the variation of the soil resistance along the depths.

It is verified in **Figure 13** that there is a growing tendency of the areas containing high N-values (darker color) with the increase of the analyzed depth. The analysis was performed until 25 m deep, where the impenetrable to percussion layer is completely achieved. The UFSC subsoil shows that the N-values decrease from the east, west and south regions to the central-north portion, which contains soft soils and, consequently, with lower resistance.

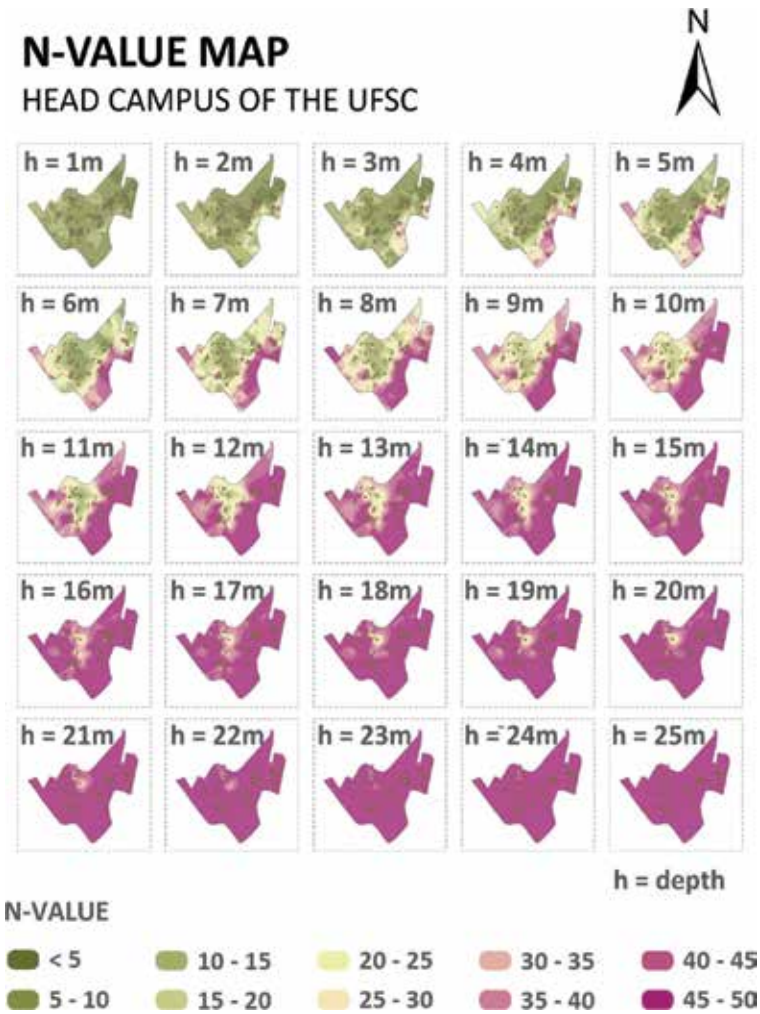

Figure 13. N-value map—matrix of comparisons [20].

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5. Conclusion

This chapter described practical applications of modeling and processing of database in GIS environment, using pre-existing data such as Standard Penetration Test Investigations. It detailed the process behind the elaboration, treatment and application of a geological-geotechnical database, through a method description and display of practical results using two case studies [19, 20].

The operations using geological-geotechnical data can bring important information for planning and decision-making. In this way, N-value contour lines, soil types and groundwater level maps were developed to guide land use and occupation policies, due to their strategic information for elaboration of risk and flooding maps, for example. Knowledge of the depth of the impenetrable to SPT percussion, groundwater, admissible soil stress for shallow foundation and N-value contour lines are fundamental information regarding technical designs, foundation costs planning and services validation, and so they were also addressed in the chapter.

Since working with a digital database, there is also the possibility of the further addition of information in the analyses, such as soil and rock mechanic and dynamic properties. This is a significant advantage of the method because the analyses can be repeated countless times, complemented and updated according to interest.

Due to the flexibility of digital database, the possibilities of analyses and results are countless. Different results than those presented in this chapter can be explored. Pile maximum length map and stratigraphic reference profiles for the geotechnical units are examples presented in greater details in [19, 20]. The diversity of results depends on the interest and creativity of the researcher.

Finally, the organization of different applications and methods to treat geological-geotechnical information in GIS environment intended to show the efficiency of to take advantage of pre-existing data. The results presented can assist decision-making providing strategic information in the public sphere and in the private sector.

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Chapter 15

A Few Processor Cache Architectures

Srinivasan Subha

Additional information is available at the end of the chapter

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Abstract

Data from main memory are processed in the CPU of computer in any application like database-management system (DBMS), numerical applications. The computation time can be improved by the addition of processor caches. The cache takes advantage of the locality of reference in any application/calculation. This chapter discusses the two prevalent cache architectures, namely inclusive and exclusive. A new cache architecture for data only called two-type data cache proposed in the literature is presented in the following section. The performance of two-type data cache model is compared with inclusive and exclusive architectures. The energy consumed by inclusive and exclusive caches is mentioned. Methods to reduce the energy consumption are proposed for inclusive and exclusive cache architectures. The hardware and software methods for energy saving are proposed. The proposed models are simulated using SPEC2000 benchmarks. The benchmarks are for compression, combinatorial optimization, word processing, place and route simulator, object oriented database, field-programmable gate array (FPGA) circuit placement and routing. The results are presented.

Keywords: average memory access time, exclusive cache, inclusive cache, two-type data cache

1. Introduction

The computer has three major parts, namely, processor, memory and input–output. The modern computer is based on Von Neumann architecture of stored program concept. Any application/program is fetched into main memory and executed. The program has instructions. Any instruction is fetched into the processor (CPU) and executed based on pipeline concepts. The instructions act on data. Any program has 80% of its instructions in loops. Repeated access of data gives the concept of locality of reference. If any data is accessed repeatedly it has temporal locality. Data that are in vicinity of access are said to have spatial locality. Taking advantage of

locality of reference, the concept of caches was introduced in computers. The data/instruction from main memory is fetched into cache before accessed by the CPU. This improves the performance. The memory hierarchy thus runs from registers, caches, main memory, secondary memory, tertiary memory, etc. The performance of memory system is measured as average memory access time (AMAT). Various cache levels are prevalent in modern processors.

A processor cache is denoted by the tuple (C, k, L) where C is the capacity, k the associativity and L the line size. Based on the various values of k, three types of caches are known. These are direct mapped cache with k = 1, set associative cache with k > 1, fully associative cache with one set and n blocks. An address a is mapped to set given by a mod S, with tag value a div S for S sets. If a line is present in cache, it is cache hit, else it is cache miss. Cache misses are of three kinds: cold, capacity and conflict. A cache miss for first occurrence is called cold miss. The difference between misses in cache and fully associative cache of same capacity is the capacity miss. If a line maps to occupied set or way, it is called conflict miss. A computer system usually has many cache levels. A line can reside in cache level and higher cache levels in inclusive caches. A line resides in only one cache level in exclusive caches. Usually processors have caches dedicated to instructions and data separately. These are called instruction cache and data cache, respectively. Certain systems have same cache for both instruction and data. These are called unified caches. A system with caches of two or more kinds (direct mapped, set associative, fully associative) is called multilateral or hybrid cache. As the address mapping may vary with each cache level, the average memory access time (AMAT) is used to measure the cache performance.

As the number of computer components active increases, the energy consumed also increases. The power consumed by cache depends on number of active components. The energy is given as E = power $\times$ time. The energy is given by the formula $E = \frac{1}{2}cv^2f$ for electronic component where c is the capacity, v the voltage and f the frequency.

The performance of CPU caches is measured by execution time for various applications. Benchmarks are used to measure the CPU performance. The SPEC2000 benchmarks are one of standard benchmarks. The integer benchmark suites of SPEC2K are given as follows:

Name	Description
256.bzip2	Compression
181.mcf	Combinatorial optimization
197.parser	Word processing
300.twolf	Place and route simulator
255.vortex	Object-oriented database
175.vpr	FPGA circuit placement and routing

The memory performance is improved by adding caches. The inclusive, exclusive and two-type data cache models are presented in this chapter. The proposed models are simulated using SPEC2000 benchmarks. The benchmarks are run using Simplescalar Toolkit for simulations.

2. Inclusive caches

Consider cache system of n cache levels, main memory. Let the cache levels are $L_1, L_2, .., L_n$. Let the cache be inclusive. Then, $L_1 \subseteq L_2 \subseteq L_3 \subseteq \ldots \subseteq L_n$. Denote this system as C_{incl}. This is shown in **Figure 1**. The cache sizes grow with the level number [1, 2]. Consider three-level cache system.

Let the levels be L_1, L_2, L_3. Let an address trace have R references. Let h_1, h_2, h_3 be number of hits in level one, level two, level three, respectively. Let $t_1, t_2, t_3, t_{21}, t_{32}$ be the access time to level one, level two, level three, transfer time between level two and level one and transfer time between level three and level two cache levels, respectively. Let M be the miss penalty. The average memory access time is given by

$$AMAT(C_{incl}) = \frac{1}{R}(h_1 t_1 + h_2(t_1 + t_2 + t_{21}) + h_3(t_1 + t_2 + t_3 + t_{32} + t_{21}) + (R - h_1 - h_2 - h_3)M) \tag{1}$$

The first three terms in Eq. (1) are the access time of level one, level two and level three cache hits. The last term is the miss penalty. This expression can be extended to any number of cache levels.

Energy consumed in cache depends on number of active components. The individual lines can be selectively switched on in caches using certain software techniques or hardware circuits. The total power consumed can be reduced through this technique. Consider w-way set associative cache of S sets. Let the power consumed per line be p watts. The total power consumed is wpS. Consider a circuit which enables lines if occupied. This is shown in **Figure 2**. If the power consumed by the circuit is q watts, the number of occupied lines is y, the total power consumed is q + yp. An improvement in power consumption is observed if q + yp < wpS.

Power saving using software techniques involves mapping lines to fixed ways by address mapping techniques [4].

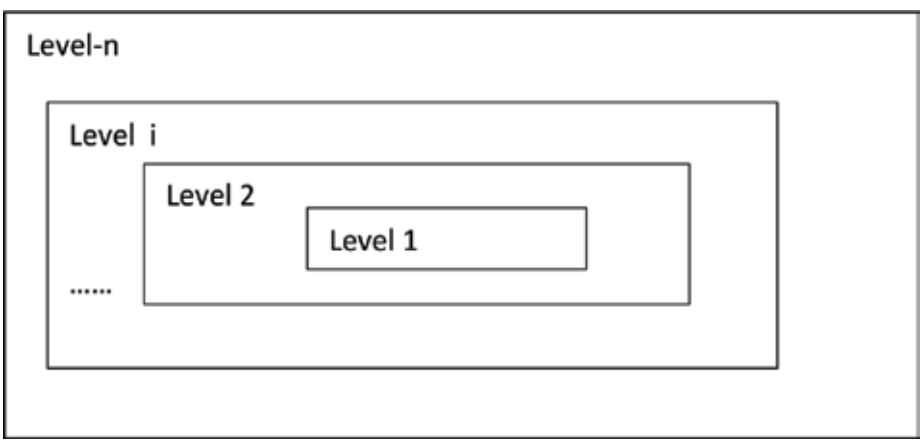

Figure 1. Inclusive cache of n levels.

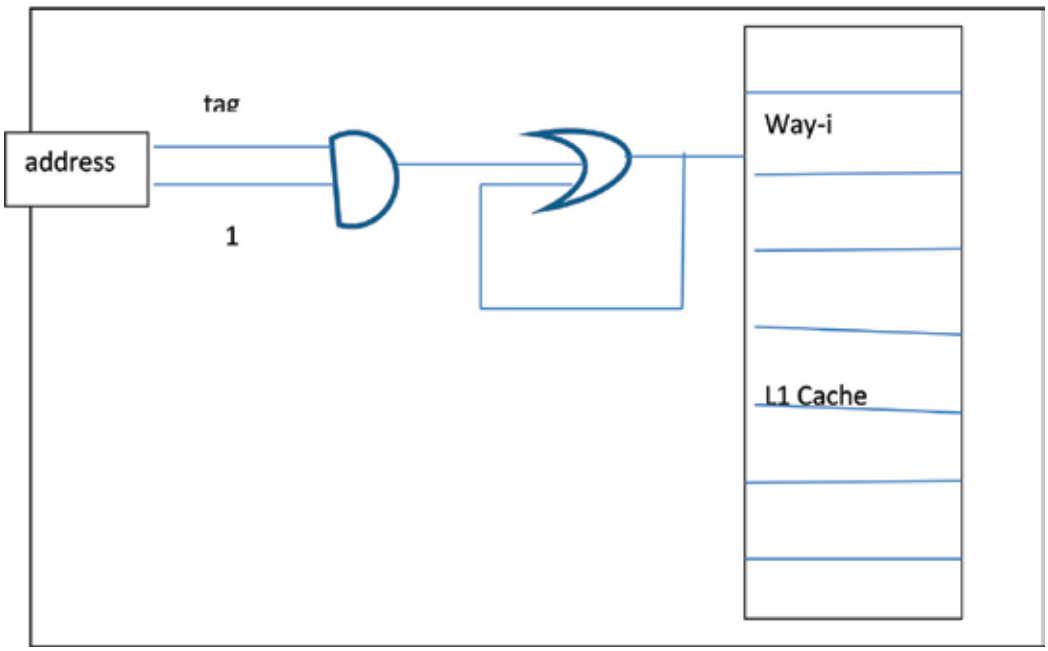

Figure 2. Sequential circuit in cache way to save power consumption. For details, refer [3].

3. Exclusive caches

Exclusive caches have a line in one cache level only. There is no containment property of the inclusive caches. Let the cache levels be $L_1, L_2, .., L_n$.The exclusive cache has the property that $L_i \cap L_j = \phi$, for i not equal to j. The exclusive cache is depicted in **Figure 3**.

Consider cache with two cache levels. The placement, replacement algorithm as proposed by Jouppi and Wilton [5] is given as follows:

1. Check if line is present in level one. If present, access the line and stop.
2. Check if line is present in level two. If present, swap with level one cache line, access and stop.
3. If line is not present in cache, put the line in level one cache evicting the victim in first level cache to second level cache.

The number of sets in both levels has to be equal in the abovementioned design. Let h_1, h_2 be level one hits and level two hits in trace of R references. Let t_1, t_2, t_{12}, t_{1m} be access time to level one, level two, transfer time between level one and level two caches, transfer time between level one and main memory. Let M be miss penalty. Denote this exclusive cache system as C_{excl}. The average memory access time is given by Eq. (2).

Figure 3. Exclusive cache of n levels.

$$AMAT(C_{excl}) = \frac{1}{R}(h_1 t_1 + h_2(2t_1 + t_2 + 2t_{12}) + (R - h_1 - h_2)(2t_1 + t_2 + t_{1m} + t_{12})M) \quad (2)$$

The first term in Eq. (2) is level one hit time. The second term is level two hit time. The factor of 2 in this expression is because of swapping of the lines. The third term is the miss penalty.

Another logic to realize exclusive caches is proposed by Subha [6]. Consider two-level cache system. The placement, replacement logic is given as follows:

1. Initialize all lines to be in level zero.
2. If the line is present in level one or level two cache (cache hit), let the line be in logical level one and stop.
3. Check if level one cache line is free. If so, place the line in level one cache, consider it as logical level one cache and stop.
4. Check if level two cache line is free. If so, place the line in level two cache; consider it as logical level one cache and stop.
5. Check the status of physical level one and physical level two caches. If physical level one cache has status of logical level two and vice-versa, place the block in level one cache and change its status to logical level one, change the status of physical level two cache to logical level two cache and stop. Else, place the block in physical level two, treat physical level one as logical level two, physical level two as logical level one and stop. [Put in logical level two, flip the level indices].

The abovementioned model does not require the two cache levels to have equal sets. There is a path between main memory and level two. Let β, γ, t_{2m} be the decrease in level one hits from model proposed in [5], increase in level two hits from model proposed in [5], transfer time between level two and main memory. Let this exclusive cache system be denoted as C_{excl2}. The average memory access time of this system is given by Eq. (3).

$$AMAT(C_{excl2}) = \frac{1}{R}(H_1 - \beta) + (H_2 + \gamma)(t_1 + t_2) + 2xt_{1m} + 2yt_{2m} \quad (3)$$

where H_1, H_2 are level one and level two hits and $x + y = R - H_1 - H_2 - \beta - \gamma$. An improvement in AMAT is observed given by Eq. (4).

$$\frac{1}{R}(h_1 t_1 + h_2(2t_1 + t_2 + 2t_{12}) + (R - h_1 - h_2)(2t_1 + t_2 + t_{1m} + t_{12})M) > \frac{1}{R}(H_1 - \beta) + (H_2 + \gamma)(t_1 + t_2) + 2xt_{1m} + 2yt_{2m} \tag{4}$$

The simulations of exclusive cache proposed in [6] using SPEC2K benchmarks are presented in the following section. **Table 1** gives the configurations and **Table 2** gives the AMAT.

The AMAT is depicted in **Figure 4**.

The power consumed by exclusive depends on the number of active cache lines. One method to reduce the number of active lines is to have separate cache called tag cache [7]. The tag cache contains the tag values of all cache levels. The address mapping proceeds as follows in the tag cache.

1. Compute the following

Set1 = a mod S_1.

Tag1 = a div S_1.

Set2 = a mod S_2.

Tag2 = a div S_2.

2. Check in tag cache for the matching of Tag1. If match is found, the line is present in level one cache as it is level one hit condition. Access the line in level one cache and stop. If there is level one cache miss, check for level two cache hit by inspecting match of Tag2. If there is level two cache hit, access the line in level two cache and stop.

3. This step is for cache miss condition. Place the least recently used line in Set2 of level two in main memory. Transfer the least recently used line of Set1 in level one cache in the evicted level two line. Place the line with address a in level one cache. Update the entries in the tag cache.

S.No	Configuration	L1 Size(sets)	L2 size (sets)	L1 access time(cycles)	L2 access time(cycles)	L1-memory access time(cycles)	L2-memory access time(cycles)	L1-L2 access time(cycles)
1	SIM1(direct-direct)	1024	4096	3	12	50	65	NA
2	SIM2(direct-set assoc)	1024	1024x4	3	12	50	65	NA
3	SIM3(set assoc-set assoc)	256x4	1024x4	3	12	50	65	NA
4	SIM4(direct-set assoc)	1024	1024x4	3	12	50	65	20

Table 1. Simulation configurations for two-level exclusive cache.

Name	SIM1	SIM2	SIM3	SIM4
256.bzip2	12.30354166	89.87282913	11.8696322	86.28267447
181.mcf	35.56382442	77.60141271	35.83299697	86.49583649
197.parser	15.17529205	88.39877944	16.93835532	96.49734912
300.twolf	33.12386439	74.00487373	35.36552946	80.44703014
255.vortex	24.04549228	63.56599701	30.74182301	50.67853881
175.vpr	26.9259936	71.23640932	33.29396985	59.29468875
Average	**24.5230014**	**77.44671689**	**27.34038447**	**76.61601963**

Table 2. AMAT values of two-level exclusive caches.

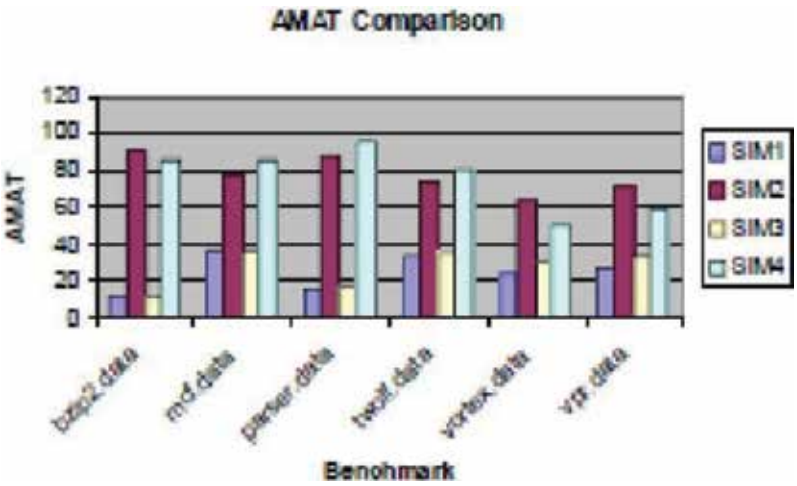

Figure 4. AMAT comparisons of two-level exclusive caches.

4. Stop

In the abovementioned algorithm, a level one cache line or higher level cache line is enabled only on cache hit or cache miss in all levels. This saves the energy consumed by the cache system. The cache is exclusive in nature and the exclusive algorithm proposed by Jouppi and Wilton [5] is used. The proposed model has scalability. The architecture is shown in **Figure 5**.

Let trace be R references. Let h_1, h_2, *cmiss*1, *cmiss*2, *miss* be he hits in level one cache, hits in level two cache, misses filled in vacant level one cache, misses filled in vacant level two cache, conflict misses in level one and level two caches, respectively. Let t_0, t_1, t_2, t_{1m}, t_{2m}, t_{12} be tag cache access time, level one cache access time, level two cache access time, transfer time between level one and main memory, transfer time between level two and main memory,

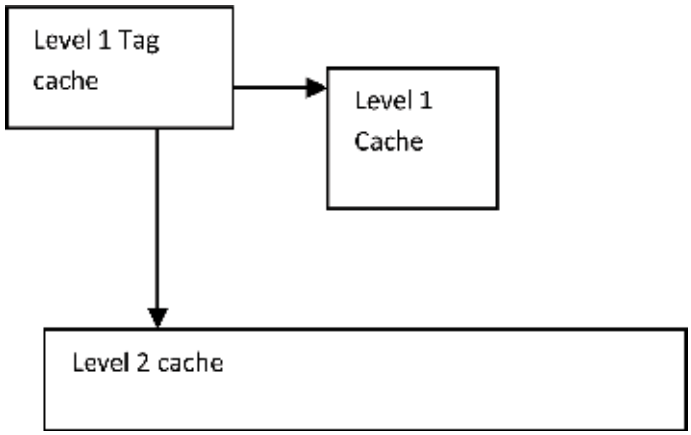

Figure 5. Exclusive tag cache architecture [6].

transfer time between level one and level caches, respectively. Let the tag cache system be denoted as $C_{excltag}$. The average memory access time is given by Eq. (5).

$$AMAT(C_{excltag}) = \frac{1}{R}\begin{pmatrix} Rt_0 + h_1t_1 + h_2t_2 + \\ cmiss1(t_1 + 2t_0) + \\ cmiss2(t_2 + 3t_0) + \\ miss\begin{pmatrix} 4t_0 + t_1 + \\ t_2 + t_{12} + t_{2m} + t_{1m} \end{pmatrix} \end{pmatrix} \tag{5}$$

The tag cache access time is the first term in Eq. (5). The hit time accesses to level one and level two caches are given by second and third terms, respectively. The time taken to fill vacant way in level one cache is given by the fourth term. This involves accessing tag cache in level one, fetching the line to level one cache and updating the tag cache entry. The time taken to fill vacant second level cache line is given by the fifth term. This includes accessing the tag cache to check for match in level one cache and level two cache and placing the line in level two cache, updating the tag cache entry. The time taken to replace existing line is given by the sixth term. This involves checking for tag match in level one cache, level two cache, replacing the level one cache line and updating the tag cache entries. As the tag cache contains the tags in consecutive locations, it may be the case that the tag entries in level one and level two are in two different cache blocks.

The energy consumed in exclusive tag cache is calculated in the following section. Let us assume that the cache operates in two modes: high-power mode and low-power mode. On accessing cache way, its corresponding set is placed in high-power mode from low-power mode. Let E_{high}, E_{low} be the energy consumed by the cache way in the proposed tag cache model in high-power mode and low-power mode, respectively. Let W_{high}, W_{low} be the energy consumed by one cache line in tag cache in high-power mode and low-power mode, respectively. Let $E_{delta,}$ W_{delta} be the difference in energy level for cache way and tag cache way between the two modes of operation, respectively. When no cache operation is performed, the

energy consumed in the cache system is $(w_1S_1 + w_2S_2 + T)E_{low}$ for w_1-way set associative cache at level one and w_2-set associative cache in level two. For level one cache hit, the energy consumed is $W_{delta} + w_1E_{delts}$. This is because the tag cache entry and the set in level one cache are enabled in high energy mode. For level two cache hit, the energy consumed is $2W_{delta} + w_2E_{delta}$. This is because the tag cache is searched for match in level one cache and level two cache and the level two cache set containing the line is enabled. For the unfilled level one cache situation, the energy consumed is $W_{delta} + w_1E_{delta}$ as the tag cache is searched to confirm that it is a free level one cache and the way in the level one cache is filled with the block. For the free level two cache way, the energy consumed is $2W_{delta} + w_2E_{delta}$. This is because the tag cache entry in level one and level two caches are searched to confirm that there is free level two cache way, and the corresponding level two cache set is enabled to fill the way. For a miss, the total energy consumed is given by $2W_{delta} + w_1E_{delta} + w_2E_{delta}$. This is because the tag entries for level one and level two caches are enabled, and the line replaces a filled level one cache set and level two cache set. Consider a program with R references. The total energy consumed for this address trace is given by Eq. (6).

$$\begin{aligned} &R(S_1 + S_2 + T)E_{low} + h_1(W_{delta} + w_1E_{delta})+ \\ &h_2(2W_{delta} + w_2E_{delta})+ \\ &cmiss1(W_{delta} + w_1E_{delta})+ \\ &cmiss2(2W_{delta} + w_2E_{delta})+ \\ &miss(2W_{delta} + w_1E_{delta} + w_2E_{delta}) \end{aligned} \tag{6}$$

The first term in Eq. (6) is the energy consumed when the cache is not accessed. The second term is the energy consumed in level one hits. This is equal to enabling the line in tag cache and accessing the ways in the level one cache for the set. The third term gives the energy consumed for level two cache hits. The fourth term is the energy consumed for filling a vacant level one cache line. The fifth term is the energy consumed to fill a vacant level two cache line. The sixth term is the energy consumed to replace an existing line in level one cache on a conflict miss. Consider a traditional exclusive cache with the same algorithm given in Section 3. The energy consumed for R references is calculated as follows. Let E_{high} be the energy consumed per way in the cache system. All the sets in both the cache levels are enabled in high energy power mode for all references. The energy consumed is given by Eq. (7).

$$(S_1 + S_2)E_{high} \tag{7}$$

A saving in energy consumption is observed as given by Eq. (8).

$$\begin{aligned} &R(S_1 + S_2 + T)E_{low} + h_1(W_{delta} + w_1E_{delta})+ \\ &h_2(2W_{delta} + w_2E_{delta})+ \\ &cmiss1(W_{delta} + w_1E_{delta})+ \\ &cmiss2(2W_{delta} + w_2E_{delta})+ \\ &miss(2W_{delta} + w_1E_{delta} + w_2E_{delta}) \\ &\Leftarrow \\ &(S_1 + S_2)E_{high} \end{aligned} \tag{8}$$

S.No	Parameter	Value
1	Cache Level one size	128KB
2	Associativity of Level one cache	4
3	Cache Level two size	2048KB
4	Associativity of Level two cache	64
5	Access time of Level one cache	3 cycles
6	Access time of Level two cache	18 cycles
7	Transfer time between Level one and level two caches	18 cycles
8	Transfer time between Level one and main memory	60 cycles
9	Transfer time between Level two and memory access time	90 cycles
10	Cache block size	32 bytes

Table 3. Simulation parameters for Exclusive Tag cache model.

The simulations for the above proposed tag cache model of exclusive cache is presented in the following section [7]. The simulation parameters are given in **Table 3**. The energy consumed in low-power mode is 5 J and high-power mode is 15 J. The AMAT was calculated using C routines. **Figure 6** gives the AMAT and **Figure 7** gives the energy consumed. As seen from **Figure 6**, the AMAT performance is comparable with traditional exclusive cache. The energy is saved by 23% as seen from **Figure 7** when compared with traditional exclusive cache.

A hardware method [8] to improve the power consumption is to enable level one and level two cache lines based on the contents of the tag cache. This is depicted in **Figure 8**.

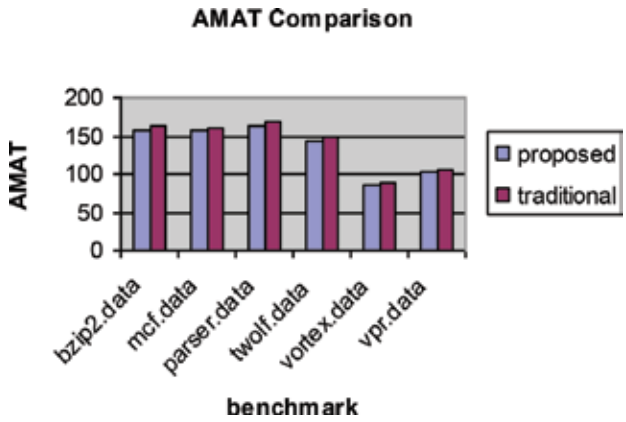

Figure 6. AMAT comparison for tag cache model of exclusive caches.

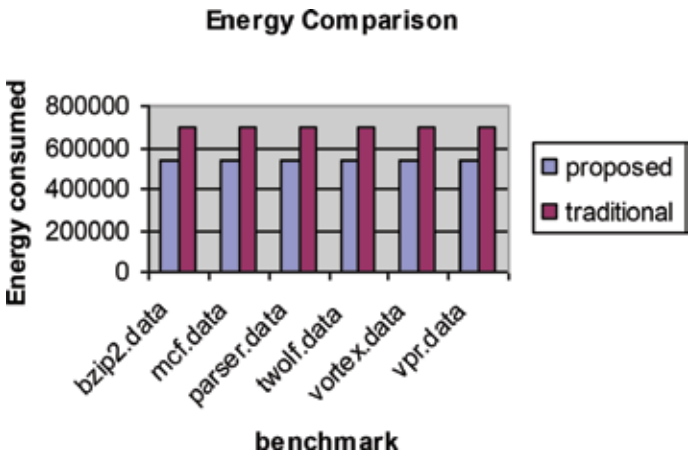

Figure 7. Energy comparison of tag cache model of exclusive caches.

The simulations for the model presented in [8] are presented in the following section. The simulation parameters are shown in **Table 4**. The power consumed is shown in **Table 5**. The AMAT is shown in **Figure 9**. The t is traditional model and p is the proposed model. There is 49% improvement in power consumption with no change in AMAT for this model compared

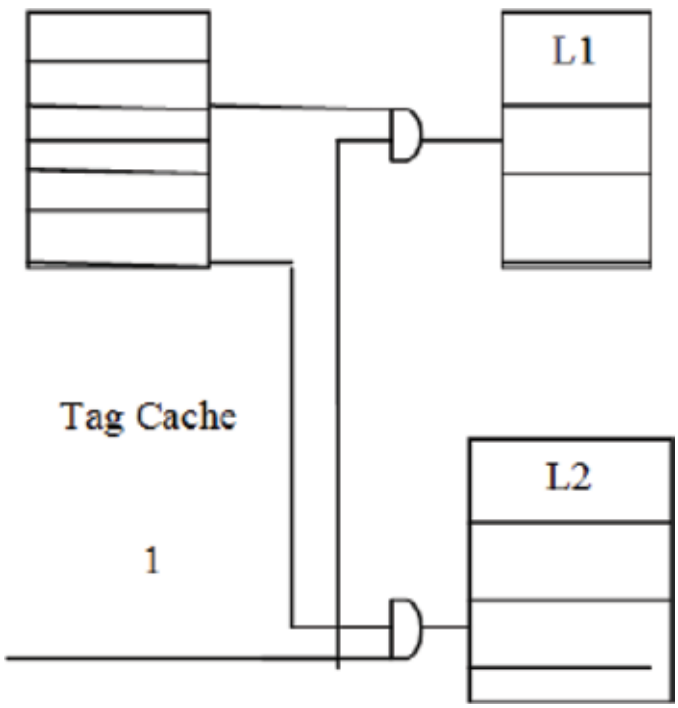

Figure 8. Proposed hardware for power saving in exclusive tag cache architecture of two levels [9].

S.No	Parameter	Value
1	Level one cache size	128KB
2	Level one associativity	4
3	Level two cache size	256KB
4	Level two associativity	8
5	Level one access time	3 cycles
6	Level two access time	18 cycles
7	Level one to level two transfer time	18cycles
8	Level one to memory access time	60 cycles
9	Level two to memory access time	90 cycles
10	Line size	32 bytes
11	Power per cache way	$8332.8\mu W$ 8334.8

Table 4. Simulation parameters of sequential circuit for exclusive caches.

Name	Power(t)KW	Power(p)KW	%improve
256.bzip2	73271.56	73271.56	0
181.mcf	621.5154	229.5009	63.07398015
197.parser	5086.737	2716.116	46.60396242
300.twolf	707.5931	262.1133	62.95705823
255.vortex	1888.692	710.3674	62.38839366
175.vpr	1372.853	516.3521	62.38839118
Average			**49.56863094**

Table 5. Power consumed in sequential circuit of exclusive cache.

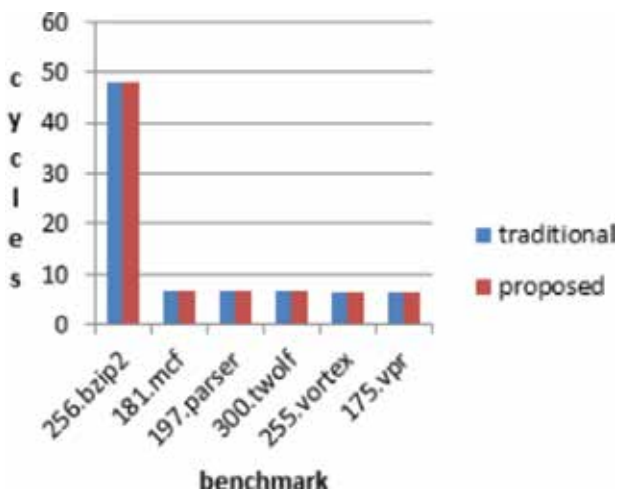

Figure 9. AMAT comparison of sequential circuit model for exclusive caches.

with the exclusive model proposed in tag cache model of exclusive cache (t in this discussion) as proposed in [7].

4. Two-type data cache model

The caches discussed so far in this chapter are inclusive and exclusive. A two-level data cache model [9] which selectively makes the cache ways in various levels as inclusive or exclusive is presented in the following section. This model makes the cache ways inclusive based on access. A two-level data cache is chosen for discussion. Initially, both cache levels are exclusive. The first occurrence of address places the data in one of cache levels making the occupied way exclusive. Preference is given to place the data in level one in this case. On consecutive access to data in level one cache, cache way is made inclusive with level two cache. During this process, data in level two cache may be replaced. The least recently used algorithm (LRU) is used for data replacement in level two cache. If the data have temporal access in level two cache, the way is made exclusive. On a cold miss with both the levels occupied, the block is placed in level one cache making it exclusive. As the number of ways to place the data increases, the performance increases in terms of the average memory access time (AMAT). **Figure 10** shows this architecture.

The algorithm for two-type data cache model is given in the following section.

Algorithm for two-type data cache: Given two-level data cache, this algorithm places the line in the cache system. Input is the address. An index array is maintained per cache for each way. It is zero to indicate inclusive and one to indicate exclusive.

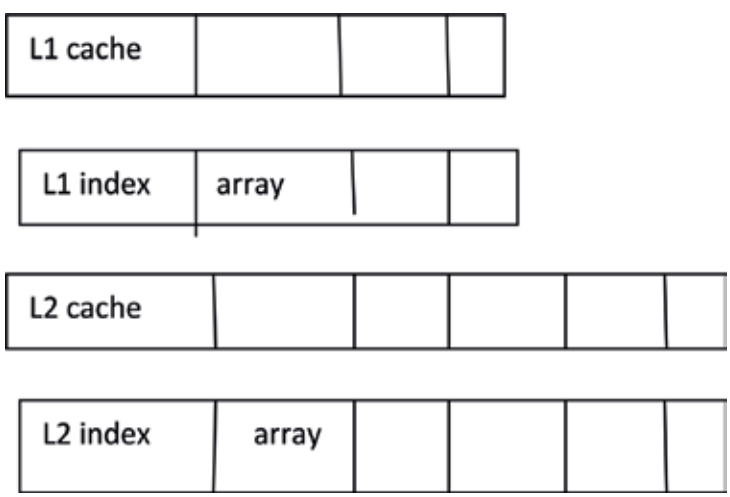

Figure 10. Two-type data cache model [5].

1. A level one hit occurs if the address is found in level one. The block is made inclusive by placing a copy of it in level two cache. The index array entry is set to 00 to indicate this in both the levels. The block is accessed and the process stops.

2. A level one miss and level two hit occurs if the address is not found in level one but is found in level two cache. The block is made exclusive in this case. This is indicated by setting index array entry of block to 11. The block is accessed and the process stops.

3. A cache miss occurs if the block is not present in level one and level two cache. If level one cache is vacant, it is placed in level one cache. Else, if level two cache way is vacant, it is placed in level two cache. The block is made exclusive. The block is accessed and process stops. If the level one set is full, the block replaces an existing block based on least recently used algorithm. The corresponding index array entry is made exclusive by setting it to 11. The mapping process stops. **Table 6** gives the algorithm.

Let R, H_1, H_2, x_1, x_2, y be the number of references, number of hits in level one, number of hits in level two, number of hits in level one after first hit, number of new level one hits, misses that are filled in vacant level two ways, respectively. Let t_1, t_2, t_{12}, t_{2m}, t_{1m} be level one access time, level two access time, transfer time between level one and level two, transfer time between level two and main memory, transfer time between level one and main memory, respectively. Let the proposed system be denoted as $C_{twotype}$. Let k be the time taken to update index array. The AMAT is given by Eq. (9).

$$AMAT\left(C_{twotype}\right) = \frac{1}{R}\begin{pmatrix} x_1(t_1 + 2k) + x_2(t_1 + t_{12} + 2k) + \\ H_2(t_1 + t_2 + 2k) + \\ y(t_1 + t_2 + t_{2m} + 2k) + \\ (R - x_1 - x_2 - H_2 - y) \\ (t_1 + t_2 + t_{1m} + 2k) \end{pmatrix} \tag{9}$$

where $H_1 = x_1 + x_2$.

Level one	Level two	Similarity with	Action
Miss	Miss	Exclusive	Put in level one, make level one exclusive
Hit	Miss	Inclusive	Put in level two, make the way inclusive
Hit	Hit	Inclusive	Do nothing as it is inclusive already
Miss	Hit	None	Make level two exclusive

Table 6. Two-type data cache algorithm.

In Eq. (9) the first term gives inclusive cache type hits, the second term indicates first time level one hits. The third term indicates the level two hits. The fourth term indicates placing a block in vacant level two way/set. The fifth term indicates either placing a block in free level one cache set/way or replacing a level one cache set/way on cache full scenario. It is assumed that exchange of a block from level one to memory can be done in parallel. The term 2 k is to update the index arrays of both the cache levels. The first term gives the hit time in level one cache. The second term gives the hit time in level two cache. This involves accessing level one and level two caches. The third term gives the time to service the misses. This involves accessing level one and level two caches, determining if it is missed in both levels, accessing main memory and fetching the block into level one. The level one block is written to the memory before the new block is fetched. Simultaneously, the requested block is sent to the processor.

Denote the inclusive cache as C_i and exclusive cache as C_e. Let $H_{i1}, H_{i2}, H_{e1}, H_{e2}$ be the number of level one hits and level two hits in inclusive cache, number of level one hits and number of level two hits in exclusive cache, respectively.

The AMAT for inclusive cache is given by Eq. (10).

$$AMAT(C_i) = \frac{1}{R}\begin{pmatrix} H_{i1}t_1 + H_{i2}(2t_1 + t_2 + t_{12}) + \\ (R - H_{i1} - H_{i2}) \\ (2t_1 + 2t_2 + t_{1m} + t_{12}) \end{pmatrix} \tag{10}$$

The first term is the level one hit time. The level two hit time is given by second term. This involves accessing level one, level two and transferring data from level one to memory and data from level two to level one cache. The miss time is given by third term. This involves accessing level one, level two to determine it is a miss in both levels, write from level one to memory and level two to memory the existing blocks. The new block from main memory is fetched into level two cache and from there to level one cache. Simultaneously, it is given for processing. An improvement in performance is observed as given by Eq. (11).

$$\frac{1}{R}\begin{pmatrix} x_1(t_1 + 2k) + x_2(t_1 + t_{12} + 2k) + H_2(t_1 + t_2 + 2k) \\ +y(t_1 + t_2 + t_{2m} + 2k) + \\ (R - x_1 - x_2 - H_2 - y) \\ (t_1 + t_2 + t_{1m} + 2k) \end{pmatrix} \Leftarrow \frac{1}{R}\begin{pmatrix} H_{i1}t_1 + H_{i2}(2t_1 + t_2 + t_{12}) + \\ (R - H_{i1} - H_{i2}) \\ (2t_1 + 2t_2 + t_{1m} + t_{12}) \end{pmatrix} \tag{11}$$

The AMAT for the exclusive system is given by Eq. (12).

$$AMAT(C_e) = \frac{1}{R}\begin{pmatrix} H_{e1}t_1 + H_{e2}(t_1 + t_2 + t_{12}) + \\ (R - H_{e1} - H_{e2}) \\ (t_1 + t_2 + t_{1m} + t_{12} + t_{2m}) \end{pmatrix} \tag{12}$$

The first term in Eq. (12) is the level one hit time. The second term is for level two cache hits. This needs access of level one cache, level two cache and exchange the contents. On a miss in

both the levels, the contents of level two are updated in the main memory, level one cache block is sent to level two and new block is fetched from main memory to level one cache. Simultaneously, the requested block is sent to the processor. The terms in Eq. (9) and Eq. (12) differ due to the architectural differences. A performance improvement in the proposed model over exclusive cache is seen as given by Eq. (13).

$$\frac{1}{R}\begin{pmatrix} x_1(t_1+2k)+x_2(t_1+t_{12}+2k)+ \\ H_2(t_1+t_2+2k)+ \\ y(t_1+t_2+t_{2m}+2k)+ \\ (R-x_1-x_2-H_2-y) \\ (t_1+t_2+t_{1m}+2k) \end{pmatrix} \Leftarrow \frac{1}{R}\begin{pmatrix} H_{e1}t_1+H_{e2}(t_1+t_2+t_{12})+ \\ (R-H_{e1}-H_{e2}) \\ (t_1+t_2+t_{1m}+t_{12}+t_{2m}) \end{pmatrix} \tag{13}$$

In all the models, it is assumed that the cache block when fetched into the cache is simultaneously sent to the processor.

The proposed two-type data cache model is simulated using SPEC2000 benchmarks. The proposed model is compared with inclusive, exclusive caches described in this chapter. The simulation parameters are given as follows (**Tables 7** and **8**):

The AMAT values are given in the graph in **Figure 11**. It is compared with inclusive and exclusive caches.

S.No	Parameter	Value
1	Cache level one size	32KB with line size 32B
2	Associativity level one	4
3	Cache level two size	128KB with line size 32B
4	Associativity level two	8
5	Cache level one access time	3 cycles
6	Cache level two access time	12 cycles
7	Transfer time between level one and memory	50 cycles

Table 7. Simulation parameters of proposed two-type data cache and inclusive cache.

S.No	Parameter	Value
1	Cache level one size	32KB with block size of 32B
2	Cache level two size	32KB with block size 32B
3	Access time of level one cache	3 cycles
4	Cache level one to memory access time	50 cycles
5	Transfer time between level one and level two	20 cycles
6	Access time of level two cache	65 cycles

Table 8. Simulation parameters for exclusive cache in two-type data cache.

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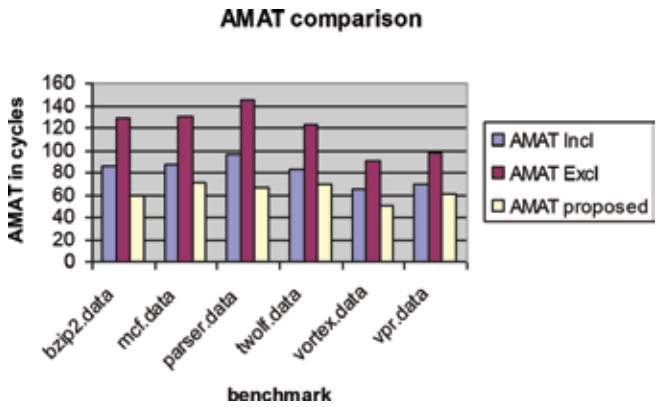

Figure 11. AMAT comparison with inclusive cache.

Name	AMAT(incl)	AMAT(excl)	AMAT(prop)	%Improvement (Incl)	%Improvement (Excl)
bzip2.data	86.285727	129.212955	59.034869	31.58211555	54.31195812
mcf.data	86.973512	129.696266	70.372351	19.08760566	45.74064993
parser.data	96.926332	145.059242	67.089295	30.7832107	53.75041667
twolf.data	83.424551	122.8655	69.034788	17.24883482	43.81271553
vortex.data	64.570065	90.905944	49.918977	22.69021721	45.08722444
vpr.data	69.496117	97.652581	60.053221	13.58765987	38.50319123
Average				22.4966073	46.86769265

Table 9. AMAT values for two-type data cache simulations.

As observed from **Figure 11**, improvement in AMAT in proposed system compared with inclusive cache is seen. There is a decrease in AMAT by 3% compared with exclusive caches. The proposed model has better performance for systems where elements of set are accessed more than two times after a sequence of other cold misses mapped to the same set such that the number of total misses is a multiple of number of elements of level one cache.

The AMAT values are shown in **Table 9**.

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Management functions were developed first as a systematic step to carry out management activities, while implementation of the information components followed as part of management elements. The authors point out that the use of the possibilities and advantages of quantitatively supported managerial decisions gives managers the ability to quantify the impacts of both technical (hard) and subjective (soft) constraints and improve managerial decision-making processes that would otherwise be based mostly on personal intuition and experience.

To achieve the goals and benefits of excellent performance, it is necessary to design and develop integrated models that would coordinate management functions and information system components as an integrated process. These facts are presented in various case studies.

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