Process Management

Process Management

Edited by

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Preface

Process management is presented as knowledge, skills, tools, techniques and systems to define, visualize, measure, control, report and improve processes with the goal to meet people requirements profitably. We can it apply first and foremost by doing business as well as by management processes in many separate areas of our life. To be successful in this process it is needed continually provide the effectiveness of the results of all processes and their constant optimization. It is necessary to monitor the business performance of all pertinent business processes all the time, detect and report weaknesses and problem situations, ideally even suggest optimization option and evaluate the success of improvement measures. Substantive recommendations for actions, including their chances of success, are needed so that the better decisions can be made more quickly. This book reports about the process management research and development findings and results in many various areas.

The content of the book has been structured into four technical research sections with total of 18 chapters written by well recognized researchers worldwide. These sections are:

1. process and performance management and their measurement methods,
2. management of manufacturing processes with the aim to be quickly adaptable after real situation demands and their control,
3. quality management information and communication systems, their integration and risk management,
4. management processes of healthcare and water, construction and demolition waste problems and integration of environmental processes into management decisions.

The first section is aimed at the historical development of a management process as an integral part of process and organizational management. It helps describe foremost responsibility for all managers, helps drive organizational missions, policies, and objectives. In addition, a management process strengthens organizational capability to overcome current competition and to better prepare for future endeavours in the globalization era as well as in the time of the crisis. The discussion later concentrates on introducing tools, techniques, and practices relating a management process, which is sometimes referred to as performance management. In general, performance management consists of three components as a performance measurement, analysis, and improvement where data from an enterprises information system has a fundamental significance. In the past, personal experiences may overshadow the importance of performance information when making decisions or taking actions. In addition, performance measurement has gradually evolved from merely generating accounting-related to more comprehensive information that contains both financial and non-financial information. Finally, the pressure on good governance and accountability has resulted in the increasing use of performance measurement – continuously generating information based on decisions made and actions taken to improve operational and organizational performance. The descriptions and practical applications of process performance measurement presented by an example of process controlling application in manufacturing area are shown in the second chapter.

To do process management more effectively it is more important not only putting quality into products at the production stage but also improving communication between management and manufacturing processes. It is the aim of the second section of this book. Because the high quality, low cost and short delivery time are demand from customer, delivery to the multi-item small-sized production, the reduction of delivery time is emphasized. For those needs, developing the methods and designs of control chart suitable for today's work situations become a new problem for manager, which is also research theme of the third chapter. Some comments are drawn, which would become useful references for setting the optimal delivery time. Next fourth chapter could be used to reorganize engineers to improve the overall organizational behaviour in terms of "time of response". This chapter presents a systematic approach to re-organize a complex design process to a more manageable one based on its analogy to dynamic systems, which allows chief engineers improve their management skills and provide systematic alternatives to manage a design process.

Modern production should be complex, integrated and constantly adapted to the market requirements by means of the reconfiguration of equipment structure and process changes. The development of such production should be based on evolutionary strategy by successively engaging (eliminating) stand-alone technological systems. The fifth and sixth chapter formulate the purpose of description of the control theory development, with the structural properties of technical systems taken into account, thus creating effective methods to synthesize a supervisor as an instrument to solve the task of consistency and co-ordination control of stand-alone components in a technical system. Thus supervisory (i. e. human) control will always remain necessary until algorithmization of all aspects of technological processes is completed. Such tools help:

- to identify the current state of the process in the controlled object,
- to understand which information must be gathered additionally for this particular state,
- and to generate the correct control incorporating the additional information during assembling procedure.

By using of such control system we can better to manage all processes and have an adaptive potential which helps to cut down maintenance costs. The flow technologies as well as process simulation software are new tools which are widely used for process improvement and to define new control strategies (seventh chapter). It helps to establish direct correlations between the line design and its performance.

Given the comprehensive integration of knowledge management in an organization, the use of information for managerial decisions and actions has become more important. Its impact on management processes is described in the third section of this book. An important part of this form of management is a human factor and ability of a company to utilize possibilities of information technologies the most effectively as well. A problem is a big dependence on employees´ knowledge which must be willing to share it with the others and on their skills and abilities to apply available information technologies and tools supported by them. Eighth chapter describes advantages and disadvantages of a centralized organizational memory system and an informal social network aimed to improve the sharing of tacit knowledge, e.g. expertise and know-how. Management of a system of such networks is very complicated especially when it is a must to consider the balance between costs ratio to solutions effectiveness since this is a very sensitive topic today. The method of process management introduction to the area of company information and communication processes management brings a chance to acquire mathematic apparatus to analyse complicated processes as well as nets – complicated due to the great dependence on human factor share (ninth chapter). The advantages of the models are proposed is that they eliminate as much as possible the influence of human factor. They also allow analysis of its interactivity with other systems and when the map of processes is created negative impacts resulting from superior positions of some employees are not considered. The system also allows management of a system of rapid changes - especially thank to transparency and specification of processes.

When suppliers, manufacturers and retailers in the global economy may be working together or in teams effectively, especially when members are in different locations and at different times, they need to communicate and collaborate and access a diverse set of information sources in multiple formats. Thus, supporting work group emphasizes the important aspects of communications, computer technologies and work methodologies. Other reasons for support are cost savings, expedited decision speed, the need to support virtual teams, the need for external experts, and improving the decision making process. To do such processes more effective it is needed to use some computer-based communication and collaboration technologies. In tenth chapter, discussion and topic of virtual work group collaboration are explored within a real and practical case of a selection and implementation of an integrated web-based IT infrastructure for a manufacturing process. In this collaboration processes have a unified communication technologies based on an open system its substantive importance.

In the eleventh chapter is introduced and discussed Business Process Management with a focus on the integration of heterogeneous systems across multiple organizations. There are identified the problems and the main challenges not only with regards to technologies but also in the social and cultural context. It is also discussed the issues that have arisen in such ways of co-operating. Preliminary evaluation has shown that an intelligent workflow monitoring system using and past experience can help workflow managers to monitor complex business processes in an active way. What the technology needs to do is allow the users to personalize their workflow and define how they want their tasks to be managed - is a key direction for the development of this area.

For a business is the corporate reputation the most important value while is the part of good corporate governance. Crisis that is process is the unexpected situations which affects on corporate reputation. Twelfth chapter is aimed to offer both a logical and proactive process for managing corporate reputation via risk management based perspective. Authors suggest that reputation assets should be managed with risk management based proactive approach since corporate reputation is issue of the risk management to enhance and maintain corporate value.

Next area where it is needed to apply management processes is the area of healthcare as well as integration of environmental processes into management decisions. The new research solutions are included in the last section of this book.

Water scarcity is a worldwide issue. It is defined as the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully.

The thirteenth chapter's aim is to provide an overview of how the planning approaches to water management have been implemented in praxis (in Mexico) and to what extent they have resolved critical issues like scarcity. This overview is basically supported on document review that has been published about water management approaches, as well as in official reports that its government has released. Although this chapter addresses the issue of scarcity in terms of planning, it would be worth exploring it since the social scarcity capacities. Their development will also help to face critical problems related to the ecosystem demands in terms of environmental flow and not least important, the variability climate change will pose on water availability. It is needed to note: actions have been taken by local governments to introduce these programs among their water users.

In the next fourteenth chapter is developed a hydrological model for planning the water supply from different sources and predicting the chloride concentrations in the aquifer water. The model's advantages lie in its multidisciplinary nature and in its practical applicability, as well as in its ability to evaluate and direct scenarios of supply and treatment of different water sources. At this stage, the model includes only the salinity level component of water quality, but the model can be expanded to examine the treatment of other components, such as nitrogen concentrations, and can be developed as a computerized model that will improve the policy-makers ability to make informed decisions in the process of utilizing of wastewater reuse to reduce the environmental impacts of agriculture.

The fifteenth book chapter gives an introduction on process-integration into land-use management decisions, starting with the choice of adequate process-indicators and a condensed overview on process-oriented management support approaches. However, if the evaluation process is managed well under close participation of regional experts and with detailed documentation of the knowledge sources, the evaluation results obtained by specialized software can experience a high regional acceptance.

Next chapter is aimed at the construction industry that is a major contributor to excessive natural resource consumption, depletion and degradation, waste generation and accumulation, and environmental impact and degradation. Nowadays, few measures have been carried out to improve the relationship among construction site activities, the environment and the citizens. Maybe due to the mobility of the construction activity, it is difficult to manage the construction companies' activities due to most construction sites the waste is selected but its destination is not controlled. This chapter presents a strategic actions set necessary to improve and promote the waste construction management in real condition (in Portugal). An effort should be made in order to reduce waste production on site and to increase its recycling value. The reuse, based on deconstruction process, should be considered as a good solution that helps reducing the waste environmental effects, such as air, water and ground pollution. It seems to be as an advantageous way to improve waste management, thus following other European countries' practices.

The last two chapters are aimed to achieving of better quality of healthcare. The first one is attended to resource management program and its using for accreditation process at the medical laboratories applied to many aspects of quality management including personnel, basic facilities, equipment, security and safety. There is described a comprehensive program that includes management commitment, effective training, and regular audits of critical functions to identify potential problems, implementation of corrective action and establishment of priorities for improvement benefits the medical laboratory in many ways. The related policies and procedures were developed to provide guidance for workers when implementing the process.

Second one – the last chapter illustrates a sustained conceptual service quality improvement process for management of software development within a healthcare enterprise. The more organized the system modules in a healthcare enterprise are, the higher is the resulting quality of care. The healthcare quality management centre and system analysts can utilize the statistical survey results to promote and constitute the service quality. Here proposed process provides a high-assurance service-oriented requirement mechanism that can engage the information technology department to obtain sufficient and essential demands from all users. The process can compass, improve the software service quality of software development and maintenance, including sophisticated patient care and security, in a healthcare enterprise environment.

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Process Management

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1. Introduction

When dealing with the term process management, people often focus on operational and technical aspects such as production, maintenance, calibration, delivery, and inventory. Nevertheless, the importance on a management process has been recognized more in recent years. For examples, ISO 9001: 2008 specifically focuses on a management process as one of its key requirements. The European Foundation for Quality Management or EFQM Excellent Model explicitly acknowledges the importance of key performance results in the areas of people, customer, and society as well as learning from these results for continuous improvement. The Baldrige Criteria for Performance Excellence Framework highlights the significant contributions from the measurement-analysis-knowledge management component with the results from operational processes and workforce. The Process Classification Framework, proposed by the American Productivity and Quality Center or the APQC, separates process management into two groups; i.e., operating and management/ support categories.

A management process is sometimes referred to as performance management. In general, this term consists of three components. They are performance measurement, analysis, and improvement. A management process has become more important due to the following attributes. In the past, personal experiences may overshadow the importance of performance information when making decisions or taking actions. Given the comprehensive integration of knowledge management in an organization, the use of information for managerial decisions and actions has become more prominent. In addition, performance measurement has gradually evolved from merely generating accounting-related to more comprehensive information that contains both financial and non-financial information. More managers have become more familiar with the roles of performance measurement. Furthermore, due to the improvement in information and communication technology, databases have become more flexible and robust. Information generated from these databases has become more user-friendly. Finally, the pressure on good governance and accountability has resulted in the increasing use of performance measurement—continuously generating information based on decisions made and actions taken to improve operational and organizational performance.

To further underline the importance of having an effective management process, other popular models for supplier management such as Capability Maturity Model or CMM have adapted this term extensively. Specifically, the CMM Level 4 indicates all processes have to be quantitatively measured and controlled while its Level 5 highlights the need to use quantitative information to ensure continuous process improvement. It should be noted

that the CMM has been widely used for the aerospace and defense industries for system and software development and has been part of supplier or contractor risk management.
This chapter is structured and organized as follows. Initially, the focus is on the historical development of a management process as an integral part of process and organizational management. The discussion will later concentrate on introducing tools, techniques, and practices relating a management process, especially for performance measurement. Finally, other standards or frameworks in different industries will be highlighted such as the Control Objectives for Information and related Technology (COBIT) for information-technology management will be discussed to help broaden the importance of a management process. Included in this discussion are the trends and the future roles of a management process.

2. Background

American Productivity and Quality or APQC earlier developed the Process Classification Framework or the PCF to highlight the importance of process management and continuous performance improvement through benchmarking[1]. In addition to operations (e.g., production, manufacturing, delivery, new product/ service development, marketing and sale of products/ services, etc.), the term management process has been specifically highlighted. The reason is that, without an effective management process, it is difficult for an organization to drive and fulfill its missions, policies, and objectives (Deming, 1986; Sink & Tuttle, 1989; and Kursteadt, 1992). A management process indicates a general process in which a manager regardless of his/her level of responsibility within an organization needs to adhere to so that he/she can visualize ongoing problems and forecast future challenges to the workplace. Some of the key activities in the PCF's management process include managing knowledge, improvement, and changes. There are many reasons for its emerging importance. First of all, ISO 9001:2000 drastically changed its structure from the 1987/1994 version with the focus more on an effective management process. The specific requirement dealing directly with this issue was established and was referred to as Measurement, Analysis, and Improvement in its 2000 version. It is important to point out that its most recent version of 2008 maintains this requirement as part of management responsibility[2].
To highlight the importance of a management process further, several worldwide awards and accepted models have underlined the significance of a management process due its impacts on performance excellence. The Malcolm Baldrige National Quality Award or the MBNQA emphasizes the roles of performance measurement, information analysis, and learning from performance analysis to ensure the ability avoid repeated mistakes and to consistently repeat excellent performance[3]. Its category is specifically named as Measurement, Analysis, and Knowledge Management. The European Foundation for Quality Management Excellent Model or the EFQM focuses on an organization's ability to identify and utilize key performance results on the areas of processes, people, customers,

[1] See www.apqc.org/pcf (as of 10/18/2009)
[2] See www.iso.org/iso/management_standards.htm (as of 10/14/ 2009)
[3] See www.baldrige.nist.gov/ (as of 10/23/2009)

and society in order to ensure constant improvement, learning, and continuous innovation[4]. Both the MBNQA and the EFQM commonly stress this role as a means to sustain organizational competitiveness and continuous improvement.

Other accepted models such as the Capability and Maturity Model or CMM explicitly show the need for an organization to quantitatively measure and analyze performance information for sustaining improvement and strengthening its long-term competitiveness[5]. The CMM has been extensively applied for systems and software development and has recently been adapted for contractor risk management—contractor/ supplier audits. According to Blanchard (2008), the CMM was developed by Carnegie Mellon University in 1986. This effort was initiated in response to the request of the U.S. Government to provide a method for assessing the potential risk of its major contractors. The CMM describes an evolutionary improvement path from an ad hoc, immature process to a mature, disciplined process. There are five levels of progressive process maturity— initial, repeatable, defined, managed, and optimizing respectively. The use of quantitative information for monitoring and evaluation represents the managed level or level 4 while the continuous performance improvement reflects the optimizing level or level 5. The lower capability and maturity reflect the inability to achieve and repeat the specific levels of performance required by customers.

The effectiveness of a benchmarking model depends on performance measurement (Sink and Tuttle, 1989; and Dixon *et al*., 1990). Benchmarking generally involves several key steps such as planning, partner selection, process identification, measuring process performance, information and gap analysis, adaptation of better practices, and process redesign and improvement. APQC has strongly advocated benchmarking as a mechanism for continuous performance improvement in an organization[6]. Benchmarking helps build knowledge on improvement. Benchmarking represents an effort to become a learning or a knowledge-based organization. It enhances innovation within an organization since the changes in key processes such as new product development, customer complaint handlings, and supplier development are inevitable. In other words, benchmarking can be applied in conjunction with ISO 9001: 2008, the MBNQA, and the EFQM. Even in the public sector, benchmarking has been encouraged. For the U.K., the Public Sector Benchmarking Service, launched in November 2000, aims to promote effective benchmarking and to help share good practices across the public sector [7]. It enables organizations to share knowledge and learn from the best.

Recently, a management process has been the focus of the public sector's reform. An improvement in a management process should positively affect a public agency's operations (Rantanen *et al*., 2007). Good governance, transparency, accountability highlight the need to have an effective performance measurement which focuses on the outputs and outcomes of an organization in addition to budget disbursement and project/ program management[8].

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[4] See www.efqm.org (as of 10/25/ 2009)
[5] See www.sei.cmu.edu/cmmi/ (as of 10/17/2009)
[6] See www.apqc.org/portal/apqc/site?path=/research/bmm/osbc/index.html (as of 10/22/2009)
[7] See www.archive.cabinetoffice.gov.uk/servicefirst/.../benchmarkingservice.htm (as of 10/25/2009)
[8] See www.whitehouse.gov/omb (as of 10/29/2009)

This effectiveness also implies openness and public accessibility into an agency's performance information. Reporting performance results to a general public and representatives in the Parliament and Congress should be mandatory. Key public sector reforms such as Government Performance Results Act of 1993, Government Management Reform Act of 1994, and Program Assessment Rating Tool or PART of 2001 in the U.S. require public agencies to measure, report, and analyze their performance, especially in the areas of impacts, expectations, and fulfillment of citizens' needs [9].

To specifically ensure that all public agencies are accountable with good governance practices with a great deal of congressional oversights, the Office of Management and Budget of the U.S. government developed a performance measurement- related tool in the early 2000s, known as PART. Information from performance measurement helps complete most of the checklists contained in PART. Moreover, performance measurement also plays a crucial role in implementing value-for-money or performance audits. There are several regions and countries that have performed value-for-money audits such as European Court of Auditors for European countries, Hong Kong, and Singapore. The aim is to ensure the public's confidence and trust in governmental spending. Furthermore, the practices of audits in the public sector have gradually changed from internal (i.e., control, financial and compliance) to performance (sometimes known as value-for-money) audits. For examples, in Finland, Ministry of Finance's Financial Controller advocates the need to demonstrate performance of a public agency in terms of its quality on service delivery, efficiency in cost management, and effectiveness relating to the ability to solve or address citizens' needs[10]. Simply put, the trends in the public sector's reforms and performance audits highlight the importance of a management process within an agency. Eggers (2005) clearly stated that a key success factor for a public agency to become more responsive, accountable, transparent, and efficient depends on its management process as this process drives organizational missions, policies, and objectives.

3. Management process

The awareness of a management process' significance in an organization was steadily created by Deming (1986). He unambiguously summarized an entrenched problem that needed to be tackled by American firms into three succinct sentences. "You cannot manage what you cannot measure". This was subsequently followed by "You cannot measure what you cannot define" and "You cannot define what you do not understand." Deming (1986) visualized performance measurement as a key mechanism (decisions should be rational in accordance with information) for a management process. In general, performance measurement plays a critical role in linking an organization with its database and information technology systems. In addition, many firms have used performance measurement as a supporting tool for communicating directions and policies, establishing accountability, monitoring and evaluating activities, establishing goals and benchmarks, and initiating changes to ensure continuous improvement (Hodgetts, 1998). See Figure 1.

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[9] See (1) www.whitehouse.gov/omb/mgmt-gpra_gplaw2m,
(2) www. govinfo.library.unt.edu/npr/library/misc/s2170.html, and
(3) www.whitehouse.gov/omb/part (as of 10/26/2009)

[10] See www.vm.fi/vm/en/02_ministry/02_organisation_and_functions/12_controller/index.jsp (as of 10/31/2009)

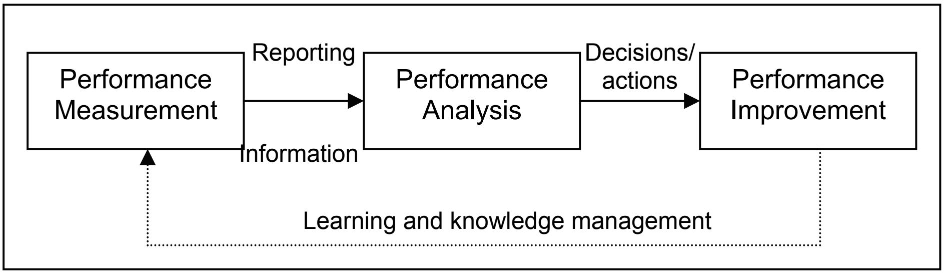

Fig. 1. Management Process Adapted from Deming (1986) and Kursteadt (1992)

Specifically, performance measurement has been increasingly recognized by researchers and practitioners alike over the last two decades (Try & Radnor, 2007; and Hoque, 2008). Information from performance measurement has evolved from merely accounting-based to more comprehensive financial and non-financial information (Neely, 1998; and Wilson, *et al.*, 2003). Performance measurement addresses the following three issues of concerns (Kurstedt, 1992 and Neely, 1998). How well an organization is performing? Is the organization achieving its objectives? How much has the organization improved from a last period—a trend exists? Simply put, it is critical to become aware of the effectiveness on improvement interventions. Performance measurement represents a system that consists of mechanisms, processes, and criteria or areas of performance (Sink & Tuttle, 1989; Dixon *et al.*, 1990; Kaplan & Norton, 1996; and Neely, 2002). Performance measurement needs to be aligned with organizational missions, policies, and objectives (Kaplan & Norton, 2004). The targets, standards, and benchmarks are typically identified and set through performance measurement (Talluri & Sarkis, 2002). Information from performance measurement needs to be visible throughout an organization. This helps organizational communication (Vokurka, 2004). See Figure 2 for the roles of and the implications from performance measurement.

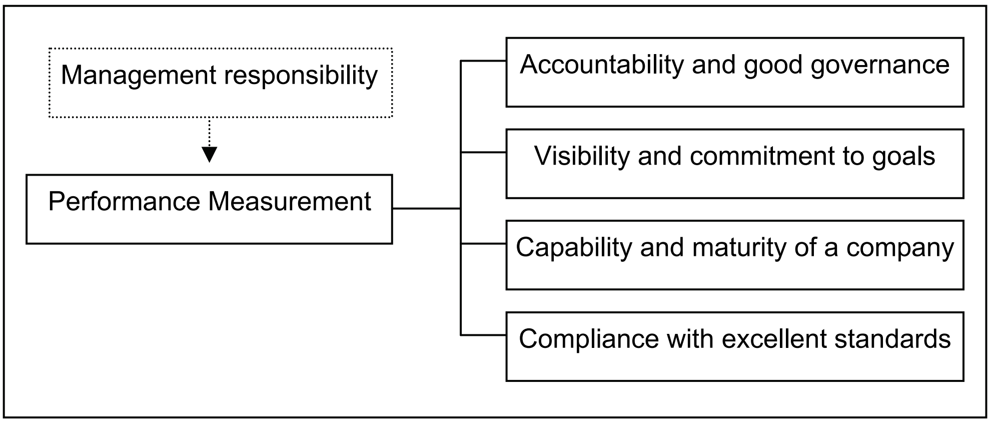

Fig. 2. Roles of Performance Measurement in an Organization

Specifically for measuring at the organizational and functional levels, there are several popular concepts. The Balanced Scorecard concept (Kaplan & Norton, 2004) has been used to measure organizational performance levels. At the same time, the approach developed by

Sink (1985), and Sink and Tuttle (1989) has been cited and adapted by several sources in both public and private sectors when measuring their functional and organizational performance. According to Sink and Tuttle (1989), the term performance is a function of profitability, productivity, quality, quality of work life (QWL), innovation, effectiveness, and efficiency. On the other hand, Harper (1984), suggested that there were seven areas when measuring performance. Included are, for examples, productivity, unit cost, price, and so on. There are also other concepts that are more practical and business oriented such as the Balanced Scorecard where performance needs to have information from the four viewpoints; i.e., financial, customer, internal business processes, and innovation and learning areas (Kaplan & Norton, 1996). Neely (2002) also suggested that the concept of performance prism with different facets for required information. See Table 1 for the summary of performance measurement.

Concepts	Measurement Areas	Application
Harper (1984)	Productivity, unit cost, price, factor proportion, cost proportion, product mix, and input allocation	Functional and operational levels
Sink (1985) and Sink and Tuttle (1989)	Profitability, productivity, quality, effectiveness, efficiency, quality of work life, and innovation	Organizational, functional, and operational levels
Neely (2002)	Stakeholders (i.e., customer and intermediaries, employees, suppliers, regulators and communities, and investors), strategies, capabilities, processes	Organizational, functional, and operational levels
Kaplan and Norton (2004)	Shareholders, finance, internal business, and innovation and learning	Organizational level

Table 1. Summary of Performance Measurement Concepts

To bring to light the comprehensiveness of performance measurement, the productivity perspective is used for this revelation. Specifically, when focusing on the industrial, national, and international levels, many approaches have been designed by economists such as the Total Factor Productivity (TFP), or Bureau of Labor Statistics (BLS) multifactor productivity techniques (Duke & Torres, 2005; Meyer & Harper, 2005). At the organizational, functional, program, and project levels, there have been several concepts and ideas involving in the measurement/ assessment work. Harper (1984) also developed a performance measurement framework at the organizational/ functional levels. Other frameworks and methods at the organizational/ functional level include Multi-factor Productivity Measurement Model and value-added productivity (Sink, 1985). Sumanth (1998) also advocated the importance of total productivity measurement. At the group and individual levels, there were many concepts such as motivational methods based on industrial psychologists and performance appraisals for salary structure/ workload analysis extended by human resource specialists, and piece-rate/ standard times determined by industrial engineers (Barnes, 1980). Recent developments for productivity measurement for white-collar workforce have included the integration of immediate customers and key stakeholders into this effort. See Table 2.

Applications	Productivity Measurement	Sources
Industrial and national levels	(1) Total Factor Productivity (2) Bureau of Labor Statistics' Multifactor Productivity	Duke and Torres (2005) Meyer and Harper (2005)
Organizational level	(1) Multi-factor Productivity Measurement Model by APQC (2) Use of surrogate (e.g., profitability, etc.)	Sink and Tuttle (1989)
Functional and operational levels (for projects and processes)	(1) Productivity network (2) Multi-criteria Productivity Measurement Technique (including an integration of metrics or ratios) (3) Use of surrogate (e.g., quality of work life, profitability, quality, efficiency, etc.) (4) Total productivity management (5) Value-added Productivity	Harper (1984) Sink and Tuttle (1989) Dixon *et al.* (1990) Sumanth (1998) Hoehn (2003)
Groups or teams	(1) Use of surrogate (e.g., stakeholder satisfaction— high satisfaction of stakeholders reflecting productiveness of staffs) (2) Zigon's approach	Hodgetts (1998) Zigon (1998)
Individual (e.g., white-collar or knowledge work, and blue-collar workforces)	(1) Motion and Time study (2) Use of surrogate (e.g., stakeholder satisfaction— high satisfaction of stakeholders reflecting productiveness of staffs) (3) Zigon's approach	Barnes(1980) Hodgetts (1998) Zigon (1998)

Table 2. Summary of Productivity Measurement (Source: Phusavat *et al.*, 2009)

Information analysis is critical for continuous performance improvement. It generally involves the use of statistical techniques as well as other quality-related tools such as the Fishbone and Pareto Diagrams[11]. When applying statistics for performance analysis, the underlying question is whether a trend exists that merits the attention from management. In addition, basic quality control tools should be adapted to help strengthen statistical analysis. They are altogether 14 tools for quality and performance analysis (in accordance to Institute for Small and Medium Enterprise Development at www.ismed.or.th/SME/src/bin/controller). The trend analysis is important due to the need to further understand whether a trend can be attributed to special or common causes. Common causes require strong attention and circumstance awareness from management. On the other hand,

[11] See www. en.wikipedia.org/wiki/Seven_Tools_of_Quality (as of 10/24/2009)

benchmarking can help performance analysis as it is important for an organization realizes whether its performance exceeds benchmarking partners. If not, adapting better practices from benchmarking partners for process improvement is necessary. Analyzing performance results with a set of targets is also common. It is important to note that Deming (1986) warned against using the targets that were not reasonably developed. This could lead to the decisions from performance analysis to be irrational and might cause the conflicts between management and organizational workforce. If this problem can be overcome, the quality of performance analysis can be greatly enhanced. Kaplan and Norton (2004) provided a strategy map that could be adapted for performance analysis and evaluation. Performance information when comparing with a strategy map indicates whether actual results meet with the expectation or anticipation earlier designed (in this map).

Performance improvement deals with decisions and actions when tackling current problems or preventing potentially undesirable circumstances for an organization or a function. Recent improvement interventions in both private and public sectors have involved human capital development, knowledge management, outsourcing and supply-chain management, customer relation management, investment in information and communication technology, machinery investment, quality management, production and resource planning, layout improvement, public-private partnership, contestability, and so on (Neely, 2002; and Nisar, 2007). These interventions can focus on the inputs (e.g., labor, capital, machines/ equipment, materials, facility and layout, etc.), organizational and functional operations (e.g., work simplification, elimination of unnecessary tasks, and process combination and reengineering), and outputs (e.g., products and services). Planning for a possible change has to be carefully made as it deals with people and their feeling (Neely, 1998). Managing expectation on the impacts of improvement is also important during this stage in a management process. Despite the various ways to improve the performance levels, repeatedly measuring their impacts on key areas (mentioned earlier in Table 1) is necessary in order to reflect how effective and how well an improvement intervention is carried out.

4. How to measure performance

Sink and Tuttle (1989) clearly outlined, described, and demonstrated how to measure performance. Measuring performance requires the following tasks. The first task is the use of Input and Output (I/O) Analysis to ensure that a total or a system viewpoint is integrated. The I/O Analysis is used to understand an organization's upstream- inputs- processes- outputs- downstream chain. Without this analysis, an effort to identify key performance indicators might not succeed. See Figure 3. The second task deals with identifying key performance indicators in a ratio format. The reason for this format is due to the need to normalize information for performance analysis. The third task is the unambiguous definition of key performance criteria. Finally, the fourth task deals with the activities relating to the management of an organization's database, including data collection, storage, and information report.

According to Sink and Tuttle (1989), with an organizational analysis from the system's viewpoint, it is possible to have several ratio-format key performance indicators. On the other hand, clear definitions are needed. From Phusavat (2007), based on Sink (1985) and Sink and Tuttle (1989), for a case company, profitability examines the interrelationships between revenues and total costs, and the company's profit margin. Quality focuses on assuring compliance of inputs and outputs as specified by an organization and its clients.

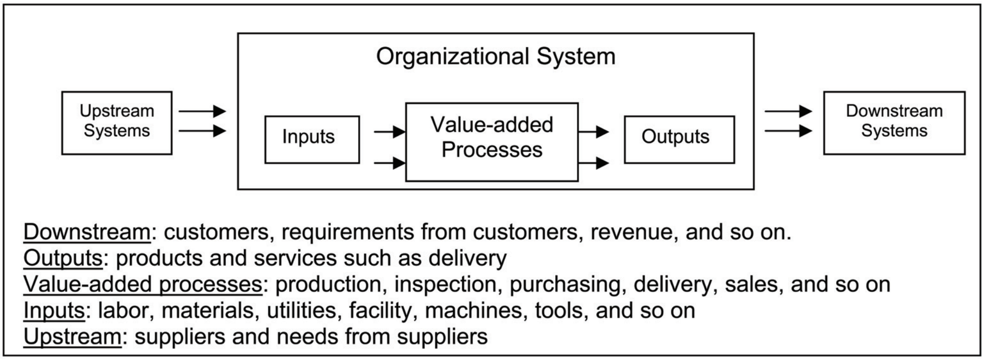

Fig. 3. I/O Analysis (Source: Phusavat, 2007)

Quality of Work Life scrutinizes how people feel about such things as their job, and working conditions. In this case company, absenteeism and work stoppages (likely due to injuries and safety problems) reflect the main concern from top management. Finally, for innovation, it concentrates on an organization's ability to respond to changes in customer preferences such as identifying and obtaining contracts from new customers or from new tools (representing new products for either new or existing customers). Some of the ratio-format key performance indicators can be demonstrated as follows.

1. Profitability Criterion
   (1.1) Revenue ÷ Total cost
   (1.2) Rate of change in revenue ÷ Rate of change in cost
   (1.3) Profit ÷ Revenue
   (1.4) % of sale revenue from rework
2. Quality Criterion:
   (2.1) % Delay in delivery
   (2.2) % Delivery error
   (2.3) % Rework (relatively to output value)
   (2.4) % Return (relative to output value)
   (2.5) % of rejects on incoming materials
3. QWL Criterion
   (3.1) % Injury cost at the workplace (relative to operating cost)
   (3.2) Unplanned absent period ÷ Working period
   (3.3) Work stoppage period ÷ Working period
4. Innovation Criterion:
   (4.1) % Revenue from new design
   (4.2) % Revenue from new customers
   (4.3) Cycle time for new work-design completion (after receiving a drawing order from a customer)

The next step in measuring performance involves data collection and generates information or performance reports for management reviews. It is important to note that clear definition of performance criteria and understandable definitions of terms for each key performance indicators, including unit dimension (e.g., \$, hours, pieces, m^2, and m^3) and frequency (e.g., hourly, daily, weekly, monthly, and quarterly), are important. Furthermore, the preference on either a graphical or a tabular format should be stated. See both Table 3 and Figure 4.

Period	Unplanned absent period ÷ Working period in % (from hours to hours)	Work stoppage period ÷ Working period in % (from hours to hours)
July 02	1.96	0.75
August 02	2.55	0.96
September 02	1.02	0.60
October 02	2.04	0.63
November 02	1.59	1.61
December 02	0.70	0.86
January 03	1.01	0.78
February 03	1.79	0.98
March 03	1.22	1.31
April 03	0.92	0.82
May 03	0.90	1.90
June 03	1.18	2.18

Table 3. Tabular Format for Quality of Work Life Performance Results
(Source: Phusavat, 2007)

Note:

- Unplanned absent period: number of hours that workers are absent without prior notice.
- Work stoppage period: number of hours that production line stops due to safety and health of workers

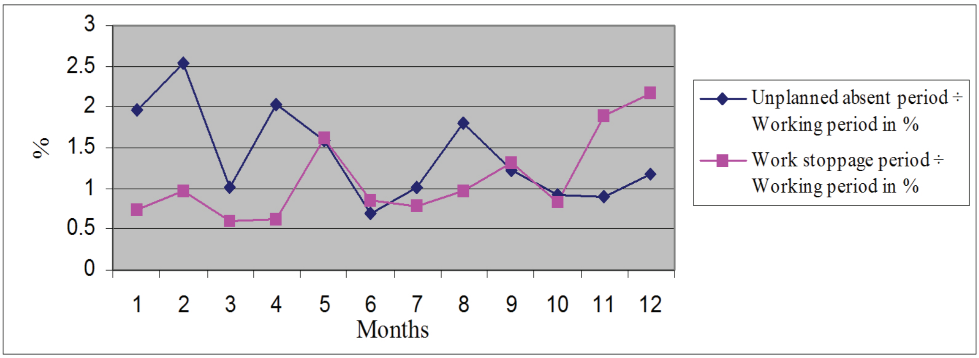

Fig. 4. Graphical Format of Quality of Work Life Performance Results
(Source: Phusavat, 2007)

5. Viewpoints on performance measurement and analysis

The interviews with six organizations aim to help learn more about their current practices on a management process, especially in the areas of performance measurement and analysis. All six firms have completed the applications of the Thailand Quality Award (TQA). The TQA represents one of the most recognized awards for all industries in Thailand[12]. It is part of the overall joint efforts by the public and private sectors to promote the long-term competitiveness and continuous performance improvement. The TQA is essentially identical to the MBNQA. It is important at this point to recognize that the MBNQA has been adapted by many countries such as India (Rajive Gandhi National Quality Award), Malaysia (Prime Minister Quality Award), Singapore (i.e., Singapore Quality Award), Taiwan (Taiwan National Quality Award), United Arab Emirates (Dubai International Award for Best Practices), and Vietnam (Vietnam Quality Award).

Two of the six organizations received the TQA while the remaining four firms were recognized for their Thailand Quality Class (i.e., the first step towards the TQA). The Thailand Quality Class was created for an organization that its score, after two rounds of an independent review, is given between 350 to 550 points[13]. Only an organization that receives a score more than 550 points is nominated for the TQA. The interviews take place with both Chief Executive Officers (CEOs) and Chief Quality Officers (CQOs). Four firms are classified as a manufacturer while two companies were considered as a service provider. For manufacturing firms, they operate in the food, petro-chemical, and textile businesses. For service providers, both organizations are in the healthcare businesses.

CEOs and CQOs have indicated that performance measurement is a necessary tool for successful management. It has improved the quality of information analysis and decision-making processes. Since all six companies are ISO 9001 certified, they view Requirement 8 to be directly under their responsibilities. From their perspective, performance measurement underlines the change towards management by objectives, information, and knowledge. It has resulted in less reliance on experiences and judgment which could lead to wrong problem solutions and the opposition or resistance by staffs. Recent investment in their respective organizations on information and communication technology has been worthwhile as more timely and accurate information become available to management, staffs, suppliers, and even customers. As indicated in the TQA, if performance measurement properly used, it can tremendously help knowledge management as organizational-related information should constantly be shared and communicated. Learning from past mistakes such as errors and customer complaints is necessary for long-term competitiveness. See Table 3 for more details of their feedback.

Given the opinions expressed by both CEOs and CQOs, it is interesting to note that a relatively consistent perspective has emerged on performance measurement. They have indicated that performance has gradually moved from merely an afterthought management tool to become an integral part of a quality management system. More vigorous use of performance measurement highlights the change in management styles within an organization. Performance measurement-related tasks such as identifying an appropriate set

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[12] www.tqa.or.th/th/tqa-history (as of 8/15/2009)

[13] www.tqa.or.th/th/node/690 (as of 8/30/2009)

of key performance indicators and communicating the target levels to staffs within an organization essentially represents fundamental responsibilities of top management. Performance measurement also is regarded as an important management tool to help direct an organization and/or an operation. Performance measurement is viewed as a prerequisite for attaining a learning behavior (Putu *et al.*, 2007). This behavior is nowadays critical in the era of globalization in which a company has to operate with the limited resources but face competitors around the globe (Sheng & Trimi, 2008).

Comments on Performance Measurement	General Viewpoints
It highlights the requirements and responsibility of management.	Reflecting management responsibility
Management without performance information is risky and irresponsible.	
It represents a milestone of effective management—when there is no performance measurement, it implies a serious failure on management.	
It can be considered as an information provider.	Representing a management tool (e.g., a decision-making process that is based on performance information)
It represents a more systematic mechanism for feedback and information.	
It reflects a more systematic decision-making process.	
It can be utilized with accounting information for better insights into a company's operations.	
It provides feedback for planning and strategic decisions.	
It helps link database with managerial decisions.	
It helps realize benchmarking efforts in an organization.	
It increases more acceptances from staffs when making policy initiatives and decisions.	Indicating a strength of a quality management system
It improves communications between management and workforce with greater visibility.	
It provides visibility to all staffs so that possible changes in operations and processes can take place quite easily.	
It represents groundwork for making operations in an organization more repeatable and predictable (as the focus is on variations— root causes of a problem instead of random attributes).	Attaining desirable characteristics from external parties— competency and capability

<table>
<tr><th>Comments on Performance Measurement</th><th>General Viewpoints</th></tr>
<tr><td>It strengthens working environment that focuses improvement such as a use of benchmarking practices.</td><td rowspan="2"></td></tr>
<tr><td>It symbolizes competency of top management and capability of an organization due to the commitment towards accountability.</td></tr>
<tr><td>It represents a foundation of knowledge management as required by the TQA.</td><td rowspan="4">Supporting an effort on becoming a Learning or knowledge-based organization</td></tr>
<tr><td>It provides positive atmosphere for all staffs where performance information is visible as it indicates transparent and good corporate governance.</td></tr>
<tr><td>It can enhance a learning capability of an organization as there is more visibility for everyone.</td></tr>
<tr><td>Information should be made available and accessible to staffs in regard to organizational and functional performance, and possible improvement interventions.</td></tr>
</table>

Table 3. Perspectives on Performance Measurement (Adapted from Phusavat *et al.*, 2009)

5. Management process in the future

For private firms, the continued acceptance and applications of ISO 9001: 2008, the CMM, the MBNQA, the EFQM, and benchmarking highlight a need to strengthen a management process. Recent studies have advocated a better linkage between a management process, and information and communication technology design, especially in the areas of database robustness, cognitive styles of managers, quality of a management report, etc (Eggers, 2005; and Sheng & Trimi, 2008). For examples, the Control Objectives for Information and related Technology (COBIT) is a set of best practices (framework) for IT management[14]. COBIT was earlier developed by the Information Systems Audit and Control Association and the IT Governance Institute in 1996. COBIT helps address several critical issues relating to a management process, including the accuracy of data on the performance levels and the integration of performance information and reports into decision-making processes at all levels within an organization.

The Information Technology Infrastructure Library (ITIL) is a set of recommended practices for managing the Information and communication technology services during design, planning, deployment, operations, and upkeep. ITIL is a registered trademark of the United Kingdom's Office of Government Commerce. ITIL can benefit a management process in several ways. First of all, ITIL addresses the risk involving data security and verification on

[14] See www.isaca.org/cobit (as of 10/17/ 2009)

authentic accessibility[15]. Business disaster recovery plan represents key ITIL consideration as an organization needs to maintain its capability to recover important data and information when needed. This is critical for timely responses and crisis or emergency management. Secondly, ITIL focuses on how a database is managed, ranging from data collection, data storage, data release and retrieval, and information report. As indicated earlier, quality of information (e.g., accuracy, reliability, timeliness) influences the quality of decisions and actions by top management.

Finally, a management process at the present time symbolizes and reflects the transparency in an organization. From the wisdom of Deming (1986) to ISO 9001: 2008, the MBNQA, and the EFQM; the roles and importance of a management process has been increasingly recognized. In fact, it is singled out by the APQC's PCF. It is even nowadays embedded in popular frameworks such as the CMM and is an integral part of ongoing public sector reforms around the world. A management process helps describe foremost responsibility for all managers. It illustrates that a manager should be accountable for his/her decisions and actions as their impacts are continuously measured. More importantly, a management process helps drive organizational missions, policies, and objectives. In addition, a management process strengthens organizational capability to overcome current competition and to better prepare for future endeavors in the globalization era. Therefore, an effective management process should benefit any organization operating under financial limitations, demographic changes, changing expectations of customers and/or citizens.

6. References

Barnes, R. (1980) *Motion and time study: design and measurement of work*, John Wiley & Sons: New York.

Blanchard, B., (2008), *System Engineering and Management,* John Wiley, Singapore

Deming, W. (1986), *Out of Crisis,* MIT Center for Advanced Engineering Study: MA

Dixon, J., Nanni, A., and Vollman, T. (1990) *The New Performance Challenge: Measuring Operations for World Class Competition*, Business One Irwin, Homewood, IL

Duke, J. and Torres V. (2005) "Multifactor productivity change in the air transportation industry", *Monthly Labor Review* (sponsored by Bureau of Labor Statistics, Department of Labor, USA), March

Eggers, W. (2005) Government 2.0: using technology to improve education, cut red tape, reduce gridlock, and enhance democracy, Rowman & Littlefield Publishers, NY

Harper, J. (1984) *Measuring Business Performance*, Institute of Manpower Studies, Gower Publishing, the U.K

Hodgetts, R., (1998), *Measures of Quality and High Performance,* AMACOM: New York

Hoque, Z. (2008) "Measuring and reporting public sector outputs/outcomes: exploratory evidence from Australia", *International Journal of Public Sector Management*, Vol. 21, No. 5, pp. 468- 493

[15] See www.itil-officialsite.com/home/home.asp (as of 10/19/2009)

Kaplan, R. and Norton, D. (1996) *The Balanced Scorecard: Translating Strategy into Action*, Harvard Business School Press

Kaplan, R. and Norton, D. (2004) *The Strategy Maps*, Harvard Business School Press

Kurstedt, H., (1992), Management System Theory and Practices, Course Lectures for ISE 4015, 4016, and 5004, Department of Industrial and Systems Engineering at Virginia Tech

Meyer, P. and Harper M. (2005) "Preliminary estimates of multifactor productivity growth", *Monthly Labor Review* (sponsored by Bureau of Labor Statistics, Department of Labor, USA), June

Neely, A. (1998), *Measuring Business Performance*, Economist Books, London

Neely, A. (2002) *Business Performance Management Theory and Practice*, Cambridge University Press

Nisar, T. (2007) "Value for money drivers in public-private partnership schemes", *International Journal of Public Sector Management*, Vol. 20, No. 2, pp. 147- 156

Phusavat, K. (2007) "Roles of performance measurement in SMEs' management processes," *International Journal of Management and Enterprise Development,* Vol. 4, No.4, pp. 441 - 458

Phusavat, K., Anussornnitisarn, P., Helo, P., and Dwight, R. (2009) "Performance measurement: roles and challenges," *Industrial Management & Data Systems*, Vol. 109, No. 5, pp. 646-664

Putu, N., Mimba, S., van Helden, G., and Tillema, S. (2007) "Public sector performance measurement in developing countries: a literature review and research agenda", *Journal of Accounting & Organizational Change*, Vol. 3, No. 3, pp. 192- 208

Rantanen, H., Kulmala, H., Lonnnqvist, A., and Kujansivu, P. (2007) "Performance measurement systems in the Finnish public sector", *International Journal of Public Sector Management*, Vol. 20, No. 5, pp. 415- 433

Sheng, H. and Trimi, S. (2008) "M-government: technologies, applications, and challenges", *Electronic Government, An International Journal*, Vol. 5, No. 1, pp. 1- 18

Sink, D. (1985) *Productivity Management Planning Measurement and Evaluation Control and Improvement*, John Wiley & Sons, NY

Sink, D. and Tuttle, T. (1989) *Planning and Measurement in Your Organization of the Future*, IE Press, GA

Sumanth, D. (1998) *Total productivity management*, St. Lucie Press, FL

Talluri, S. and Sarkis, J. (2002) "A model for performance monitoring suppliers", *International Journal of Production Research*, Vol. 40, No. 16, pp. 4257-4269

Try, D. and Radnor, Z. (2007) "Developing an understanding of result-based management through public value theory", *International Journal of Public Sector Management*, Vol. 20, No. 7, pp. 655- 673

Wilson, C., Hagarty, D., and Gauthier, J. (2003) "Results using the balanced scorecard in the public sector", *Journal of Corporate Real Estate*, Vol. 6, No. 1, pp. 53- 64

Vokurka, R. (2004) "Operationalising the balanced scorecard using the Malcolm Baldrige Criteria for Performance Excellence (MBCPE)", *International Journal of Management and Enterprise Development*, Vol. 1 No. 3, pp. 208- 217

Zigon, J. (1998) “Measuring the hard stuff: teams and other hard-to-measure work”, from the Zigon Performance Group Web Site (available at: www.zigonperf.com as of October 15th 2005)

2

Process Performance Measurement as Part of Business Process Management in Manufacturing Area

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1. Introduction

Process performance measurement tools and techniques applied to enterprise environments are essential for enterprise continuous improvement. It is the reason why the next generation of process management leads to Process Performance Management or Corporate Performance Management. The phrase Corporate Performance Management (CPM) was coined by Gartner Group to describe the combination of process, methodologies, metrics and technologies to measure, monitor and manage the performance of the business. The oft-citied phrase: " *If I can not measure it, I cannot manage it*" can be motivation of this chapter.

This chapter deals with presentation way leads to establishment of efficiency system for process measurement and controlling in the manufacturing area. The process measurement can be defined as the application of the management cycle with a focus on organizational process. Muehlen present process management as the collection of planning, organizing and controlling activities for the goal-oriented management of the organization's value chain regarding the factors quality, time, cost and customer satisfaction (Muehlen, 2004). The main goals of process management are the achievement of transparency with regard to process structure and process contribution.

The description and practical application of process performance management system will be presented in case study. The case study also presents exploitation of data from an enterprises information system for decision–making is next point of this chapter.

2. Related work and literature review

The process controlling has been discussed in the published books and papers in scientific journal (Shen, 2007) and (Aalst, 2007). A. Kronz presents principal tasks of process controlling in book (Scheer, 2006). He mentioned these points:

1. Evaluation, analysis and continues monitoring of business workflows (automatically or manually),
2. Map the process reality in a task-oriented manner according to the issue and task.
3. Result of process controlling is transparency of the process, in structural terms and for purpose of evaluation,

4. Results can also be used as the basepoint for process optimization.

Next author Michael zur Muehlen discusses in his book (Muhlen, 2004) of the workflow audit trail data with existing data warehouse structures and develops a reference architecture for process-oriented information system.

The term of process controlling has been often discussed in relation to process management, because implementation of business process management is a way how to achieve of process performance management system establishment. The "Process Management and "Business Process" are contemporary terms used in the many companies. Many successful companies applied this management approach based on Hammer's Business Process Reengineering Concept (Hammer, 1993). The authors develop the Hammer's and Champy ideas in related works nowadays.

Many articles in journals and international conferences proceedings deal with BPM issue. High number of citations on business process management (BPM) seems to prove that BPM is a significant field of the recent research (Harmon, 2008). For example a Google.com search on „Business Process Management" returns more than fourteen thousand pages where this phrase appears. The BPM issue is the subject of research focused on methodological or technological solution of BPM problems (Weske, 2007). The main problems are described by Wasana Bandara in article (Bandara, 2007), where fourteen global experts were interviewed for example. The problems examples show the lack of governance, lack of standards, lack of methodology, lack of tool support for process visualisation etc.

The main principles of process measurement system are described by the authors and many authors discuss about phrase Corporate Performance Management. The phrase Corporate Performance Management (CPM) was coined by Gartner Group to describe the combination of process, methodologies, metrics and technologies to measure, monitor and manage the performance of the business. Prof A. W. Scheer discusses this issue and trends of CPM in his book (Scheer, 2006).

CPM is thus directed at continues monitoring of the effectiveness of the results of all company processes and the constant optimization thereof, i.e. its objective is a monitoring system that monitors the business performance of all pertinent business processes all the time, detects and reports weaknesses and problem situations, ideally even suggests optimization option and evaluates the success of improvement measures. Substantive recommendations for actions, including their chances of success, are needed so that the better decisions can be made more quickly. Process Performance Management may be regarded as the heart of CPM. (Scheer, 2006)

The present trends in Corporate Performance Management are:

- Process mining for automated weak point analysis
- Right time monitoring
- Dynamic organizational analysis

These trends describe the purpose of application of process controlling in the manufacturing area. The application of process controlling based on process management principles for technological and diagnostics process control is one objective of our research. The main objectives of our research are design and verification of a control system based on business process management approach for control of process in the diagnostics and the electrical engineering and electronics manufacturing. In the following case study, I shall describe the practical demonstration of process controlling application.

3. Research methodology and methodology framework

3.1 Design of generic methodology

Designed methodology concept helps to implement the process performance measurement system based on process controlling. The concept has been developed into two steps:

1. Analysis of processes and current needs of responsible managers, staffs, researchers and technicians. The designed questionnaires can be used in this step. We have obtained process attributes of key processes.
2. Study, selection and modification of suitable methods and tools for business process management and performance measurement.

The application of designed methodology is demonstrated on case study. Data collection for this case study was conducted these different techniques:

1. Questionnaire – This method was used for process analyses and mapping of process attributes. The main problems were done via structured question to management and workers.
2. Participation/Observation – The researches were able to observe and processes in operation and validate recorded data.
3. Interview – This method enabled the collection information of management vision and requirements.

3.2 Generic methodology framework

Methodology framework is presented by Table 1. As we can see the table presents key steps and activities in defined order. The methodology concept is based on business process and process performance management theory. It means application of Business Process

Step	Activities	Output
Business strategy definition	Analysis of current situation Definition of mission, vision and strategic goals.	Strategy are defined
Process design	Implementation of process modeling methodology Process models making Definition of main optimization criteria Process optimization	Processes are designated.
Process Controlling Implementation and Indicators Setup	Design of process measurement and execution system Determination of periodicity of process measurement Implementation of tools for process measurement, execution and evaluation Design of system for correction proposal and improvement	System for process evaluation and execution of processes is implemented. Improvement system is defined.

Table 1. Designed methodology framework

Management in first step. This step leads to:
- process analysis and key process indicators setup
- process description, modeling and optimization,
- system of evaluation and process execution.

The information infrastructure can be applied for the methodology support. The information structure should be built on Service Oriented Architecture (SOA) which provides methods for systems development and integration where systems group functionality around business processes and package these as interoperable services. SOA also describes IT infrastructure which allows different applications to exchange data with one another as they participate in business processes. Service-orientation aims at a loose coupling of services with operating systems, programming languages and other technologies which underlie applications.

3.3 Methods for process performance management

The current management literature presents different methods for process performance management. Firstly, they are methods based on financial analysis of basic enterprise economic indicators (for example Economic Added Value measurement, DuPont analysis). Secondly, they are management methods used the financial and non financial indicators (typically represented by Balanced Scorecard method (BSC), EFQM model, Six Sigma, Value Based Management). The Balanced Scorecard method sophisticated presents how to define and implement the key process indicators and metrics for performance evaluation. Many companies have adopted Balanced Scorecard as a way of evaluating managerial performance.

This methods supplements traditional financial measures with three additional perspectives: the customers, the internal business process and the learning and growth perspective. It is supposed to be a tool describing an organization’s overall performance across a number of measures on a regular basis.

The basic idea is very straight forward. Kaplan and Norton began by arguing that "What you measure is what you get" and that "an organization's measurement system strongly affects the behaviour of managers and employees." They went on to say that "traditional financial accounting measures, like return-on-investment and earning-per-share, can give misleading signals for continuous improvement and innovation..." To counter the tendency to rely too heavily on financial accounting measures, Kaplan and Norton argued that senior executives should establish a scorecard that takes multiple measures into account. They proposed a Balanced Scorecard that considered four types of measures:

1. Financial Measures: How Do We Look to Shareholders?
2. Internal Business Measures: What Must We Excel At?
3. Innovation and Learning Measures: Can We Continue to Improve and Create Value?
4. Customer Measures: How Do Customers See Us?

The BSC method gives a definition of strategy as hypothesis summary about causes and results. It can be declared as a sequence of “if – then”. The BSC, proposed by Kaplan and Norton, is the strategic management instrument:
- to clarify and translate vision and strategy,
- to communicate and link strategic objectives and measures,
- to plan, set goals and align strategic initiatives,
- to enhance strategic feedback and learning.

4. Case study

The case study is focused on printed circuit board production. This production is one part of our department and its customers are other universities departments and small companies from the Pilsen region. The objective was to establish the performance measurement system focused on process time measurement and real processes current status analysis. This case study also presents application of designed methodology.

4.1 Business strategy definition

Definition of core problem and strategy of company was first task. The core problem of visualization was effectively solved by the Current Reality Tree (CRT). This chart shows causality of relevant undesirable effects of the analyzed situation. The practical example is shown in Fig. 1. The main problem is fall of profit related to production time, capacity and quality of process. On the other hand this situation might be described by a conflict diagram (Fig. 2). The diagram describes decision and optimizing problem of manufacturing - determination of optimum batch size.
The conflict exists between increasing and decreasing of the batch size. The increasing of production run (D) makes to cost reduction (B) and decreasing (D) of the batch size makes to high quality of products (C). Both described situations have negative effect on the

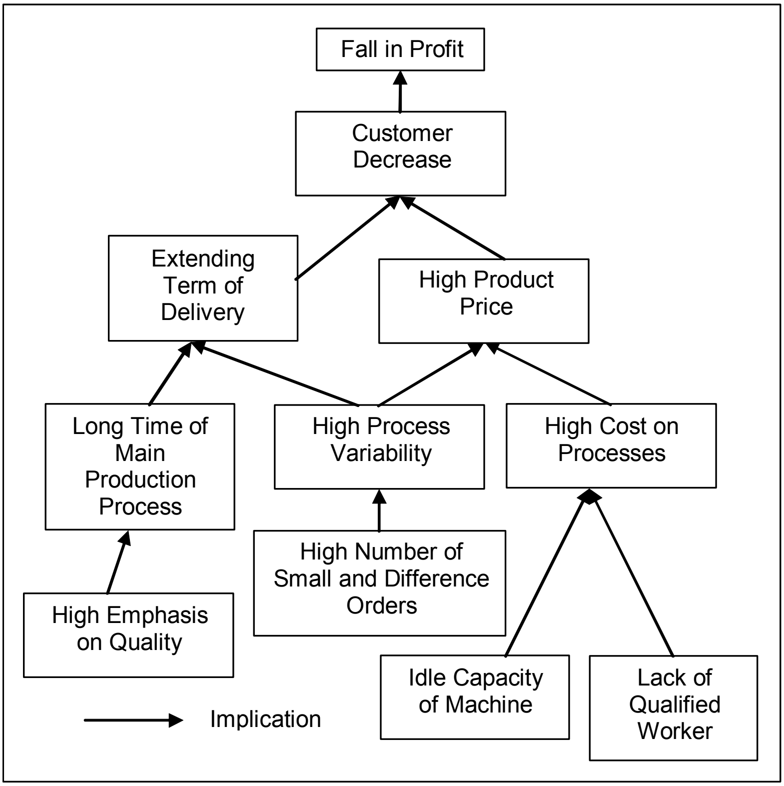

Fig. 1. Current problem of causality

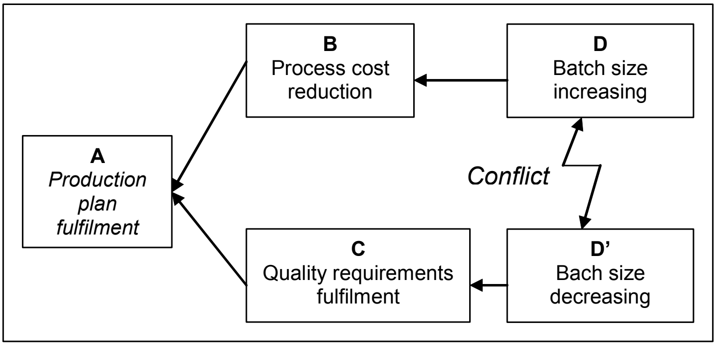

Fig. 2. Conflict diagram of company

production plan and profit. These problems and conflict were solved by designing methodology effectively. So cost reduction, quality improvement and time reduction were the main optimizing criteria according to methodology.

Secondly, the business strategy and main key process indicators were developed according to Balanced Scorecard. The Table 2 shows process indicators and the strategy is describes in ARIS model (Fig. 3). From this model we can make performance dynamic execution (it is part of last step methodology implementation).

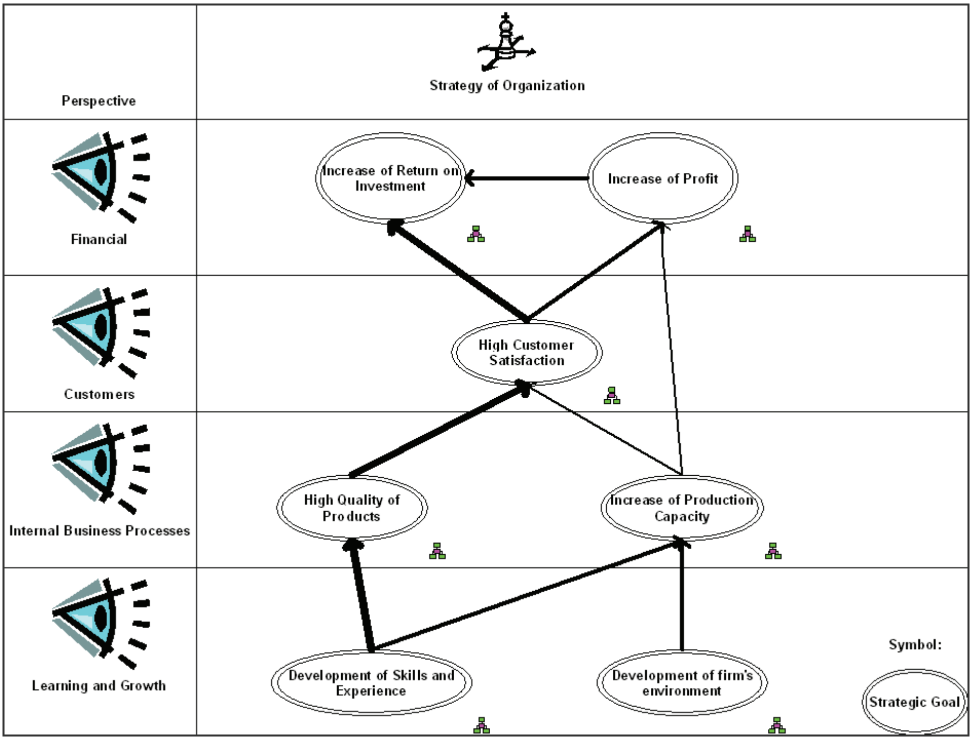

Fig. 3. ARIS model of Balanced Scorecard business strategy

Process indicators	Staffs Satisfaction	Internal Productivity	Customer Satisfaction	Training Course	Fail-ures	ROI	Process Time	Process Costs
Unit	[%]	[-]	[%]	[number]	[number]	[-]	[min]	[EUR]
Minimal Value	75	2	80	1	95	4	24	40
Maximal Value	100	4	100	3	100	8	72	60
Tolerance	5	5	5	5	5	5	5	5
Period	Q	Q	Q	Q	Q	Q	Q	Q
Planned Value	95	3	90	2	99	5	48	50
Current Value	95	1,5	85	2	98	5,3	75	75

Table 2. Strategic indicators

4.2 Process design

The process analysis and process modelling was the first important steps lead to process design. It contained following activities:

- definition of the process model and attributes. It means determination of targets, key processes fragments, key performance indicators (KPI) and their dimensions,
- processes fragment modelling (Fig. 5).

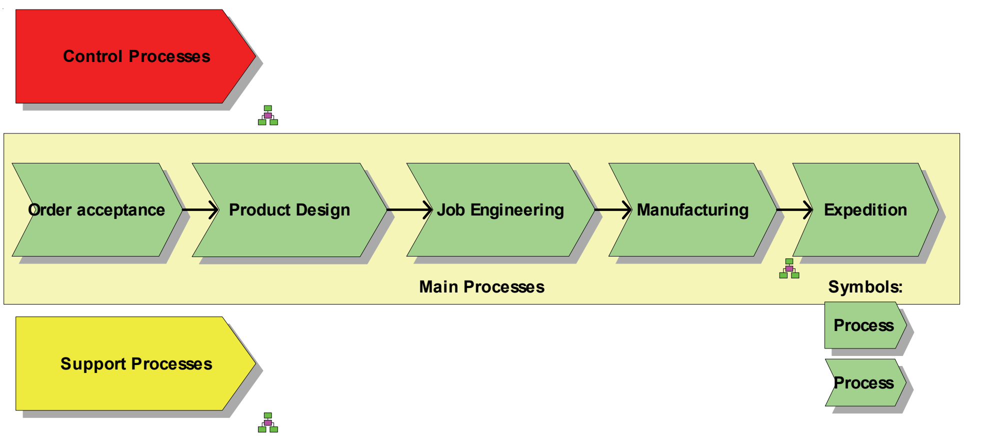

Fig. 4. Core process model of PCB production

The ARIS (Architecture of Integrated Information System) tools and process analyses were used in this part. The main problem was fall of profit related to production time, capacity and quality of the process. Due to this fact, the process controlling application based on CPM leads to this core problem minimization.

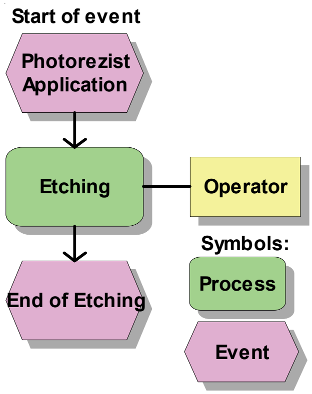

Fig. 5. Model of process fragment

4.3 Process controlling implementation and indicators setup

We decided use the ARIS Process Performance Manager (ARIS PPM) software tool for process controlling in this case, because this tool can be implemented to any information system and structure. The information technologies make the important support for business process management nowadays. Owing to the fact that we are using tools ARIS for process modeling and optimization of processes, we decided to use the software ARIS PPM.

With ARIS Process Performance Manager, IDS Scheer company offers a software solution that is a purpose-built for controlling and analyzing business processes. As a part of this solution, a patented procedure is used to collect process relevant data from the operational IT systems available for reconstructs process automatically and calculates key performance indicators online and particularly for presenting the actual process measurement in the form of event-driven process chains (eEPC).

ARIS PPM imports all business transactions to be reviewed into the repository from one or more source systems via application-specific adapters. To begin with, depending on the source system, the process-relevant runtime information about the activities performed is highly disparate in nature (e.g. log files, vouchers, records). These are imported one after the other in chronological order by ARIS PPM and compiled into a process. A graphical illustration – the "event-driven process chain" (EPC) - containing all the individual activities (functions) are then generated automatically for each operation (process instance) – see Figure 8. As a result, even a process that extends beyond the boundaries of a single system can be represented cohesively and uniformly.

The ARIS Process Performance Manager tool has these important functions for Process Performance Management:

- Visualizing Real Process Structure
- Key Performance Indicators and Analyses
- Process documents
- Weak Point Analysis
- Process Mining: Automated Weak Point Analysis
- Management Views
- Offline Reports

Key process indicator	Type	Category	Description
Interval of order processing	Process	Time	Process duration from an order acceptance till issue of an invoice.
Interval of acceptance of an order	Process	Time	Sub process duration: "Receipt of order".
Interval of PCB design	Process	Time	Sub process duration: "Design of PCB".
Interval of manufacturing preparation	Process	Time	Sub process duration: "Manufacturing data preparation".
Interval of PCB manufacturing	Process	Time	Sub process duration "Manufacturing of PCB.
Interval of PCB expedition	Process	Time	Sub process duration: "PCB expedition".
Interval of invoice issue	Process	Time	Sub process duration: "Issue invoice".
Activity process time	Function	Time	Difference between the end of current activity (process) and the end of previous activity.
Processing time of an activity	Function	Time	Difference between the end of activity and the start of a particular activity.
Idle time of activity	Function	Time	Difference between the start of an activity and the end of previous activity.
Keeping the order term	Function	Time	Difference between planned and real order completion date.

Table 3. Key process indicators definitions

The basis for all processes controlling is a process-oriented key performance indicator system that links the process perspective to the essential controlling aspects for business. The key performance indicators must enable conclusions to be drawn regarding the effectiveness of the processes (e.g. customer satisfaction) and their efficiency (e.g. processing time, delivery reliability, process quality and costs). In addition, the process-oriented key performance indicator system is configured so that it would be possible to make statements about the actual course of the process.

Pre-configured process key performance indicators are calculated and aggregated for each imported process stage. The ARIS PPM base system already includes a core set of key performance indicators, and these are set as default ones regardless to a connected source system. The key performance indicator types can be divided into 3 groups:

- time-related key performance indicators (e.g. throughput times, processing times, frequencies),
- cost-related key performance indicators (e.g. process costs/rates on the basis of the performance standard) and
- quality-related key performance indicators (e.g. number of processors, error rates, deadline reliability)

The process owner can use ARIS PPM to achieve the optimum balance in the "Time-Quality-Cost" magic triangle by taking a number of key performance indicators from each of the three ranges with added weighting and thus to yield a new key performance indicator. These user-defined key performance indicators can be set in the front-end at any time during runtime. Besides the preset key performance indicators, other specific key performance indicators are configured in the ARIS PPM base system as a part of the adaptation to the customer individual environment.

These are defined, for instance, by the process types to be reviewed. The key performance indicators in ARIS PPM are endowed with process-relevant decision variables - "dimensions". These dimensions are also imported from the source systems as features of the individual process instances. The user evaluates the efficiency of his business processes with reference to the interplay between key performance indicators and dimensions in the process analysis.

The set of key performance indicators must be calculated and defined flexibly, and in such a way that it can be expanded to the need of changing requirements of the company specific processes. Besides calculating key performance indicators, it is also necessary to be able to visualize the structure of actual processes since, it is the only way to how obtain generalized explanations for their performance behaviour.

The implementation of ARIS PPM tool has been formulated in project. The project main phases were:

1. Implementation for printed circuit board manufacturing.
2. Verification and validation of results from implementation for PCB manufacturing.
3. Implementation for diagnostic process control.
4. Verification results and examination implementation proposal.

The first two phases were realized in following steps:

1. Conceptual and technical workshop
2. Determination of process instance, fragments, KPI and process attributes. The results of process mapping and analysis from previous part were used in this step. The Table 3 presents used KPI.

The SW tool implementation means installation, customizing and connectivity settings. The manufacture section does not use information system now and data must be recorded on operation record cards. Due to this fact, we had to prepare the special software for CSV files generation and rewrite the data into SW ARIS PPM database using PC. Validation of results and their definition is last step of implementation.

4.4 Result of process controlling implementation

First experience of PPM implementation, based on CPM idea, has shown benefits of this solution in the manufacturing area for technological process control, in this case for printed circuit board manufacturing. The SW tool ARIS PPM helps us to make analysis and processes monitoring, particularly:

- real process course,
- processes time,
- comparing of the real and planned key indicators value,
- type and kind of order.

The results of process mining and analysis have been used for process models correction and KPI planning. In short, the responsible management obtains quick management and performance view (see Fig. 7, 8).

The solution mentioned above doesn't use sophisticated information system. In this phase the data about process has been collected in excel files. The records from the paper sheet in manufacture section had to be rewritten to ARIS PPM database. In consequence of this we had to realize software for data converting from excel database to ARIS PPM database (CSV data format was used for this converting operation). It is obvious that this way isn't suitable for big data volume. From this reason, the suitable information system has to be implemented in the next project phase. The structure and components of used information system presents Fig. 9.

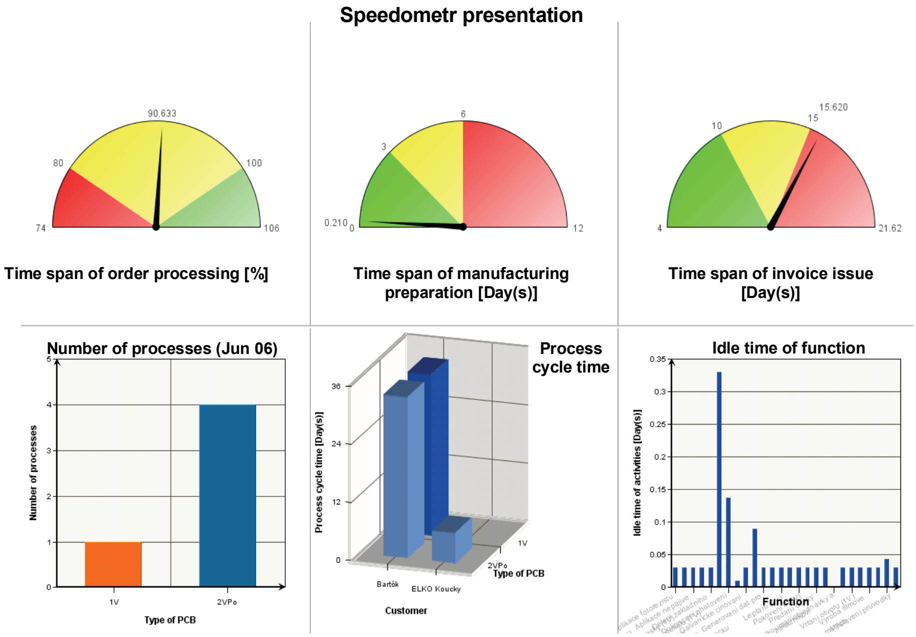

Fig. 7. Management view

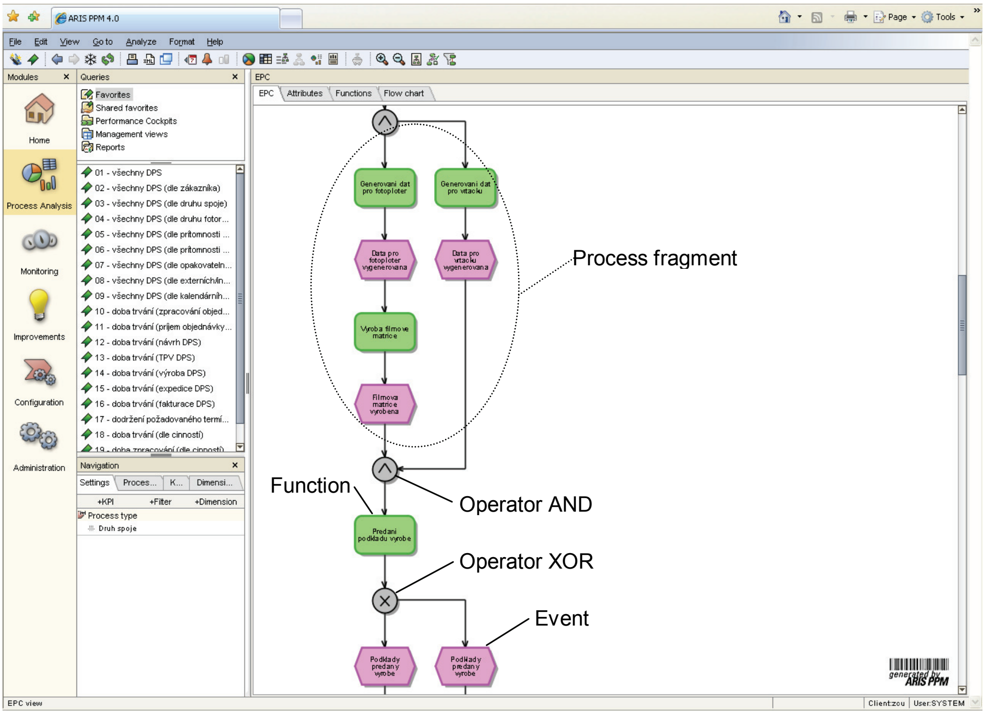

Fig. 8. Visualization of a process instance generated in ARIS PPM

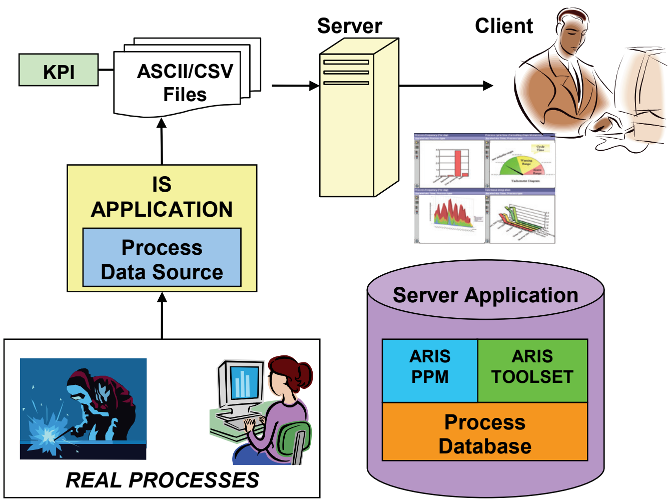

Fig. 9. Information system structure

5. Conclusion

This chapter presents an example of process controlling application. Process controlling described in this paper, comprises the following components:
- Evaluation of the efficiency of business processes based on key performance indicators
- Transparent representation of procedures actually performed for cause analysis.
- Deduction of optimization measures.
- Continuous monitoring of success developments.
- Organizational analysis.

The process controlling is very important tool for process improvement in manufacturing area. The real application in manufacturing area was described in the practical case study focus on the small printed circuit board production. The case study describes way how to analyze the processes and introduces software tools, which have been applied. The benefits and results are documented in the Figures 7-8 as well.

This solution corresponds with the new trend in process management area. Companies that are able to align their business processes to the requirements of their environment and surroundings will not only gain a competitive advantage, but they will also be able to manipulate this alignment better and faster than their competitors. The prerequisites for this solution are the supply of decision-relevant information and an ability to transform this information quickly and effectively into sustained measures for targeted alignment of business processes.

6. Acknowledgments

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7. References

Muhlen, M. (2004). *Workflow – based Process Management*, Logos, Verlag Berlin, ISBN 3-8325-0388-9, Berlin.

Scheer, A. W. et al., (2006). *Corporate Performance Management, ARIS in Practice*, Springer Verlag, ISBN 3-540-30703-6, Berlin.

Shen, W.; Tan, W.; Zhao, J. (2007). A methodology for Dynamic Enterprise Process Performance Evaluation. *Computers in Industry*, Vol. 58, Issue 5 (June, 2007), pp. 474-485, ISSN 0166-3615.

Aalst V., et al. (2007). Business Process Mining: An Industrial Application. *Information System*, Vol. 32, No. 5 (July, 2007), pp. 713-732, ISSN 0306-4379.

Harmon, P.; Wolf, C. (2008), *The State of Business Process Management*. *A BPT Report*, <http://www.bptrends.com/members_surveys/deliver.cfm?report_id=1003&target=BPTrends 2008 Survey Report 2-11-08 Final, V_2_.pdf&return=surveys_landing.cfm>, (accessed September 5, 2009).

Hammer, M.; Champy, J. (1993). *Reengineering the Corporation: Manifesto for Business Revolution*, Harper Clins Publisher. New York.

Weske, M. (2007). *Business Process Management*, Springer Verlag, ISBN 978-3-540-73521-2, Berlin.

Bandara, W. et al. (2007). *Major Issues in Business Process management: an Expert Perspective*, <http://www.bptrends.com/publicationfiles/09-07-ART-MajorIssuesinBPM-Chong%20et%20al.pdf>, (accessed September 5, 2009).

3

A Design for Quality Management Information System in Short Delivery Time Processes

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1. Introduction

Recently, by the advance of IT (information technology), the IT control charts have been paid attention and been used in quality management information system, for not only putting quality into products at the production stage but also improving communication between management and manufacturing [1], [2]. Because the high quality, low cost and short delivery time are demand from customer, delivery to the multi-item small-sized production, the reduction of delivery time is emphasized. For those needs, developing the methods and designs of control chart suitable for today's work situations (For example, short delivery time process.) become a new problem for manager, which is also one research theme of control chart practical applications study group of JSQC [3].

The classical definitions of the control chart's PDCA (Plan, Do, Check and Act) procedures are known. Recently, the evaluation of the economy of this control chart's PDCA procedures is connected with "daily management".

By investigating literature cases in the activities of control chart practical applications study group, it is recognized that the act procedure is the most important in the procedures of PDCA of control chart [4]. Because the systematic investigations of control chart's PDCA design was not done in the works before, Sun, Tsubaki and Matsui defined and considered the PDCA designs based on the $\bar{x}$ control chart [5] and P control chart [6], respectively. In addition, the PDCA design of the $\bar{x}$ control chart with tardiness penalty is investigated [7]. However, the ACT time was not considered in above researches.

In this research, first a design of the $\bar{x}$ control chart is presented and its mathematical formulations are shown. Then, the presented design based on the judgment rules of JIS Z 9021 [8], [9] is studied, finally, by numerically consideration using the data from real situation, the relations of key parameters and delivery time and the total expectation cost are discussed.

2. The design

When the control chart is used in short delivery time processes, the penalties for delay of the delivery time should be imposed. In this research, the PDCA design is set up based on the

case which starts from deciding the control lines of the $\bar{x}$ control chart, in which the penalties for delay of the delivery time (T) have been considered.
The evaluation function of this research is the expected total cost per unit time as follows:

$$C_{t(CAPD)} = \frac{E[cost\ per\ cycle]}{E[cycle\,(PDCA)]} = \frac{E[cost\ per\ cycle]}{E[\min(T_p + I_1 + O_1 + a, T)]} \\ = C_p + C_d + C_c + C_a. \tag{1}$$

The definition of the procedures of the PDCA design and the cost elements of equation (1) are explained in Table 1.
The time variables used in the design of this research are defined by Figure 1.

Procedure	Difinition	Element of cost (per unit time)
PLAN	Constructs control lines of control chart.	*Cp=Cp(p)+Cp(pe)* *Cp(p)* cost of PLAN *Cp(pe)* cost of the penalty for delaying the PLAN
DO	Samples and plots on control chart for monitoring the process.	*Cd=Cd(d)+Cd(pe)* *Cd(d)* cost of DO *Cd(pe)* cost of the penalty for delaying the DO
CHECK	Examines whether the points plotted on control chart are beyond the upper and lower control limits.	*Cc=Cc(c)+Cc(e)+Cc(pe)* *Cc(c)* cost of CHECK *Cp(p)* cost of type I error *Cp(pe)* cost of the penalty for delaying the CHECK
ACT	Investigate the assignable cause and correct it.	*Ca=Ca(a)+Ca(pe)* *Ca(a)* cost of ACT *Ca(pe)* cost of the penalty for delaying the ACT

Table 1. The definition and the cost elements of the design

Figure 1 shows some of the time variables used in the design of this research. At the start of the PDCA design, PLAN for deciding the control lines is made in *Tp* time. Therefore, it is thought that the PDCA model starts from the in-control state,
because the process is managed by these control lines. Let the process start at the point of *Q*, and let *S* be the point in time at which the quality characteristic shifts to an out-of-control state as shown in Figure 1. An assignable cause is detected at the point of *C*, and then corrected at the point of *D*. Here, the random variables I_1 and O_1 represent the interval from *Q* to *S* and the interval from *S* to *C*.
The assumptions of the design in this research are as follows:
1. The delivery time is short, and the process is repetitive.
2. The quality shift occurs in the middle of an interval between samples [10]

In this research, both the random variables I_1 and O_1 are assumed to be independently and exponentially distributed with mean λ_1^{-1}, μ_1^{-1}, then (1) is

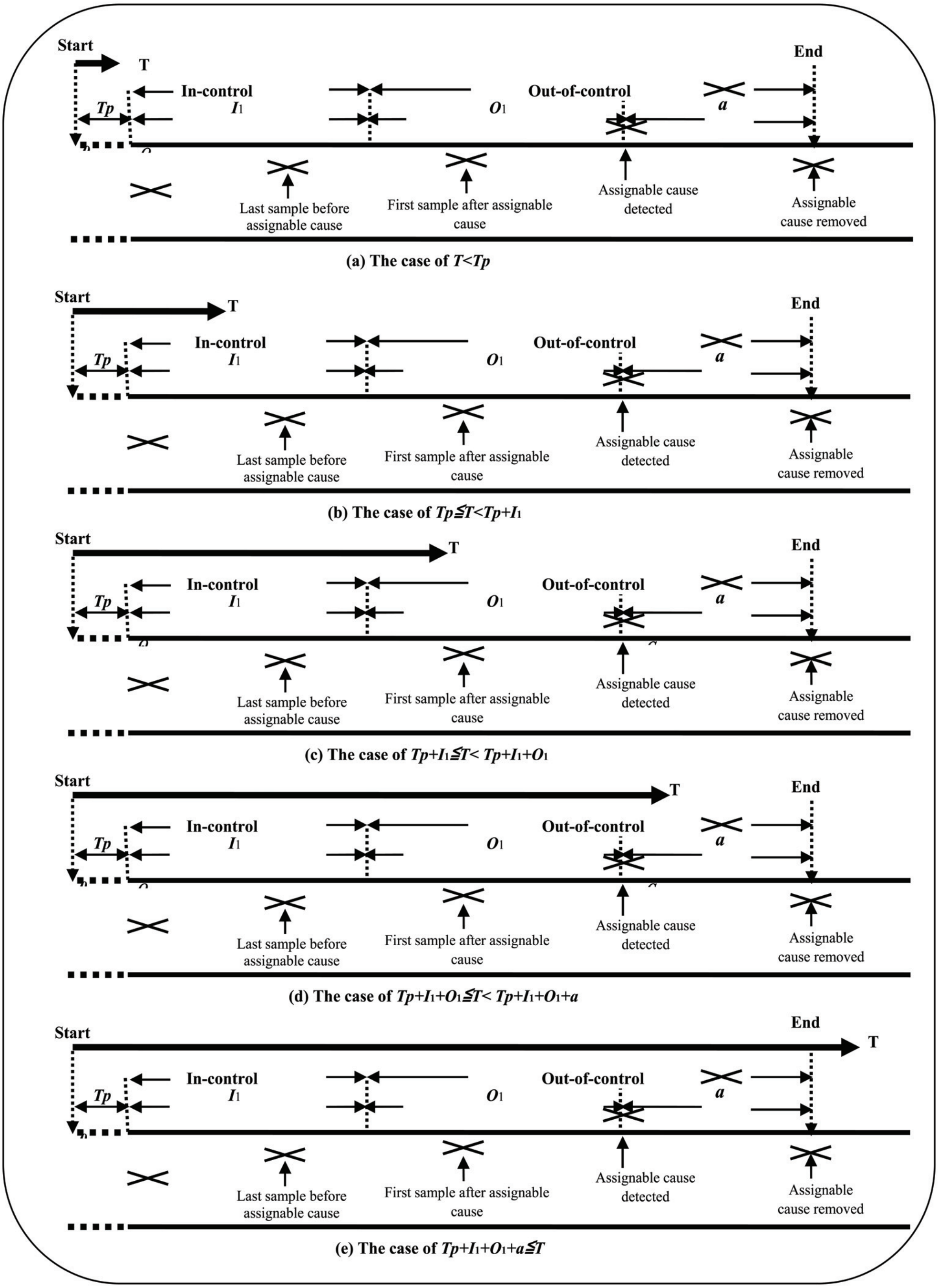

Fig. 1. Some of time variables used in the design

$$
\begin{aligned}
Ct = \{ & ((c_0 + c_1 n)/v)[T\phi_1 + T_p(1-\phi_1)] + c_{\beta p}\phi_1 + [(c_0 + c_1 n)/v] \\
& [\frac{1}{\lambda_1 - \mu_1}\{\frac{\mu_1}{\lambda_1}(e^{-\lambda_1(T-T_p-a)} - 1) - \frac{\lambda_1}{\mu_1}(e^{-\mu_1(T-T_p-a)} - 1)\} + T_p + a - \\
& (T\varphi_1 + T_p(1-\phi_1))] + c_{\beta d}\phi_2 + (c_2/v)[\frac{1}{\lambda_1 - \mu_1}\{\frac{\mu_1}{\lambda_1}(e^{-\lambda_1(T-T_p-a)} - 1) - \\
& \frac{\lambda_1}{\mu_1}(e^{-\mu_1(T-T_p-a)} - 1)\} + T_p + a - (T\phi_1 + T_p(1-\phi_1))] + \\
& (c_3/v_1)\alpha\frac{1}{\lambda_1}(1 - e^{-\lambda_1(T-T_p)}) + c_{\beta c}[\frac{1}{\mu_1} + \frac{1}{\lambda_1 - \mu_1}(e^{-\lambda_1(T-T_p)} - \\
& \frac{\lambda_1}{\mu_1}e^{-\mu_1(T-T_p)})] + c_4[a + \frac{1}{\lambda_1 - \mu_1}(\frac{\lambda_1}{\mu_1}e^{-\mu_1(T-T_p)}(1 - e^{\mu_1 a}) - \\
& \frac{\mu_1}{\lambda_1}e^{-\lambda_1(T-T_p)}(1 - e^{\lambda_1 a}))] + c_{\beta a}[\frac{\lambda_1\mu_1}{\lambda_1 - \mu_1}(-\frac{1}{\mu_1}e^{-\mu_1(T-T_p)}(1 - e^{\mu_1 a}) + \\
& \frac{1}{\lambda_1}e^{-\lambda_1(T-T_p)}(1 - e^{\lambda_1 a}))]\} / [\frac{1}{\lambda_1 - \mu_1}\{\frac{\mu_1}{\lambda_1}(e^{-\lambda_1(T-T_p-a)} - 1) - \\
& \frac{\lambda_1}{\mu_1}(e^{-\mu_1(T-T_p-a)} - 1)\} + T_p + a]
\end{aligned}
\tag{2}
$$

Where

$$\mu_1^{-1} = v(1/P_a - 1) + v/2 = v(1/P_a - 1/2). \tag{3}$$

3. Numerical experiments

A. Explanation of parameters from a real situation

The parameters used in this research are from A company, which is based on a real situation. Where $c0$=50，$c1$=40，$c2$=100, $c3$=2000, $c4$=8000, $c_{\beta a} = c_{\beta p} = c_{\beta d}$ =1000000, $c_{\beta c}$ =1000000, v=1day, f'=20, ϕ_1 =0.01, ϕ_2 =0.001, $1/\lambda_1$=10days, δ=1, k=3.0, a=0.083 day. The notation used is as follows:

n the sample size per each sampling
v the sampling interval
T delivery time
Tp the interval of PLAN
c_0 fixed sampling cost
c_1 variable sampling cost
c_2 cost of per unit time for checking the point plotted
c_3 cost of a false alarm
c_4 cost of restoring an in-control state
$c_{\beta p}$ cost of per unit time for penalties delay of PLAN
$c_{\beta d}$ cost of per unit time for penalties delay of DO
$c_{\beta c}$ cost of per unit time for penalties delay of CHECK (penalties for sending the mistake information)

$c_{\beta a}$ cost of per unit time for penalties delay of ACT
f' number of samples taken during T-Tp
δ size of the quality shift in the mean
a the ACT time
k control limits width

In this research, the outside dimension of molding plate is a key quality characteristic. The difference between the outside dimension and set value is plotted on the $\bar{x}$ control chart.

B. Investigations based on the judgment rules of JIS Z 9021

In the production process, the power (Pa) is different depending on the kind of the judgment rule. In this section, the presented design is considered based on the rule 1 (3σ rule) and rule 2 (9 ARL rule) of JIS Z 9021. Because sample size n is not only an influence element to test but also an important parameter of cost, at first, the two judgment rules are studied by the change of n.

From Figure 2, it can be noted that the Pa by the two rules increases with the increase of sample size n, and the speed of increase of 9 ARL rule is faster.

Next, the design based on the two judgment rules is studied by the change of n. From Figure 3, it can be note that when n is small, the expected total cost Ct of 9 ARL rule is cheaper.

From Figure 3, it also can be note that the expected total cost Ct of 3σ rule is the cheapest when n is five. This result is corresponding to the sampling size actually used in A company. Therefore, it could be said that the presented design is applicability.

C. Investigations of the relations between the power and delivery time and the total expectation cost

From Figure 4, it can be understand that the expected total cost per unit time *(Ct)* decreases with the increase of the power (Pa). This is because that the cost of defective goods decreases by the increase of the power (Pa).

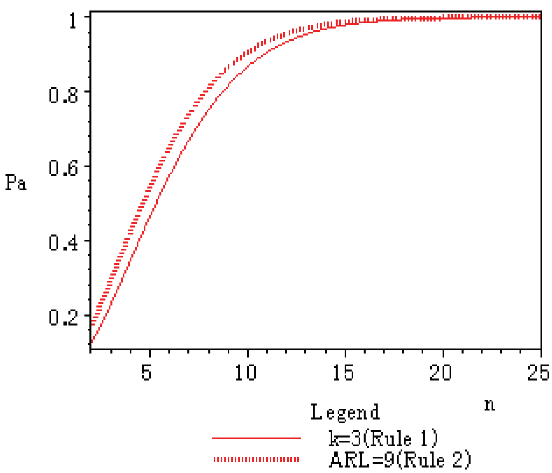

Fig. 2. Power by the two rules

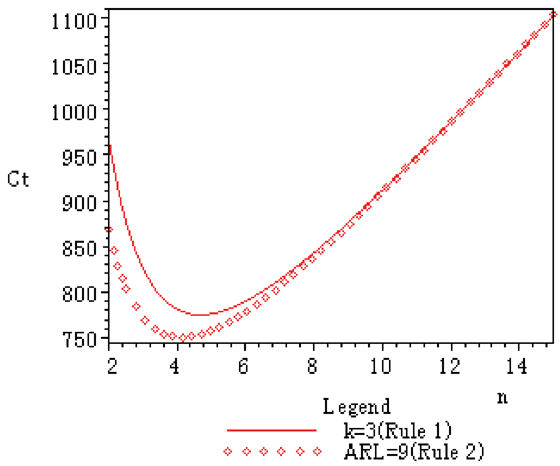

Fig. 3. Investigating the design by the two rules

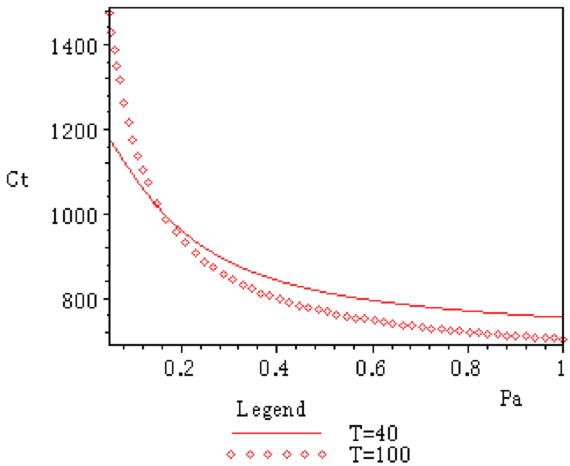

Fig. 4. The relation between *Pa*, *T* and *Ct*

From Figure 4, it also can be understand that a longer delivery time should be set when the higher power for higher quality is demanded; while a shorter delivery time should be set when the low power for not higher quality is demanded.

In addition, to understand a more detailed setting, Table 2 is shown, which is based on the case of A company. The axis of ordinate and abscissas are *Pa* and *T*.

From Tables 2, it can be understood that this tables are divided into two areas: in the colourlessness area, a longer delivery time should be set for the higher power (higher quality) being demanded; in the Blue area, a shorter delivery time should be set for the low power (not higher quality) being demanded.

Pa	*T*								
	40	*50*	*60*	*70*	*80*	*90*	*100*	*110*	*120*
0.05	1176.9	1302.2	1377.4	1422.1	1448.7	1464.6	1474.0	1479.5	1482.7
0.10	1090.8	1135.5	1155.3	1163.8	1167.3	1168.6	1169.05	1169.06	1168.9
0.15	1017.8	1023.5	1024.6	1024.8	1024.6	1024.4	1024.15	1023.88	1023.6
0.20	961.3	949.7	944.8	942.8	941.9	941.4	941.03	940.71	940.4
0.30	890.0	863.6	855.2	852.0	850.6	849.9	849.47	849.11	848.8
0.35	860.0	836.8	827.7	824.2	822.8	822.0	821.58	821.21	820.9
0.40	840.0	816.2	806.6	802.9	801.4	800.6	800.12	799.74	799.4
0.46	824.1	796.0	786.0	782.1	780.5	779.7	779.25	778.87	778.5
0.50	810.0	786.4	776.1	772.2	770.5	769.7	769.25	768.87	768.5
0.55	800.0	775.2	764.8	760.8	759.1	758.3	757.79	757.40	757.1
0.60	799.0	765.9	755.2	751.1	749.5	748.6	748.13	747.74	747.4
0.65	791.0	757.9	747.1	742.9	741.2	740.4	739.88	739.49	739.1
0.70	781.4	751.0	740.0	735.8	734.1	733.3	732.76	732.37	732.0
0.75	775.7	744.9	733.9	729.7	727.9	727.1	726.55	726.15	725.8
0.80	770.6	739.6	728.5	724.2	722.4	721.6	721.08	720.68	720.3
0.85	766.2	734.9	723.7	719.4	717.6	716.7	716.23	715.83	715.5
0.90	762.1	730.7	719.4	715.1	713.3	712.4	711.90	711.50	711.1
0.95	758.5	726.9	715.5	711.2	709.4	708.5	708.01	707.61	707.3
1.00	755.3	723.5	712.0	707.7	705.9	705.0	704.50	704.10	703.7

Table 2. The balance of *Pa*, *T* and *Ct*

From Tables 2, it also can be understood that how much total expectation cost should be paid by the different power, when the delivery time is strictly demanded; how much total expectation cost should be paid by different delivery time, when the power of process is strictly demanded. Because Table 2 shows the relation (concrete value) of power, the delivery date and the total expectation cost, it would become a reference for business plan.

D. The balance of k, T and Ct

In this section, we study the relations between the delivery time and ACT time and the total expectation cost, then we investigate the balance of control limits width (*k)* and delivery time *(T)* and the total expectation cost *(Ct)* by numerically analyzing the above design. Where, c_0=1，c_1=0.1，c_2=10, c_3=50, c_4=25, $c_{\beta a}=c_{\beta p}=c_{\beta d}$ =200, $c_{\beta c}$ =2400, n_1=4, v_1=0.0316, Tp=1, ϕ_1 =0.01, ϕ_2 =0.001, λ_1=1.

Table 3 show the balance of the quality (control limits width) and delivery time and the total expectation cost of the above case, which is useful for setting the optimal delivery time and control limits width to the supplier.

T	k: 2.75	3.00	3.25	3.50	3.75	4.00	4.25	4.50	4.75	5.00	5.25	5.50	5.75	6.00
2.50	284.941	285.070	286.939	290.475	295.984	304.187	316.349	334.550	362.096	403.805	465.203	548.437	645.798	740.137
2.75	283.866	283.992	285.869	289.420	294.957	303.206	315.447	333.810	361.788	404.863	470.364	563.733	679.704	798.529
3.00	283.039	283.164	285.046	288.609	294.166	302.448	314.745	333.210	361.406	405.115	472.825	572.936	703.662	844.432
3.25	282.376	282.500	284.385	287.957	293.529	301.836	314.174	332.713	361.056	405.130	474.100	578.676	720.880	880.838
3.50	281.825	281.947	283.836	287.414	292.998	301.322	313.691	332.286	360.737	405.055	474.801	582.367	733.437	909.961
3.75	281.351	281.473	283.364	286.947	292.539	300.878	313.270	331.907	360.438	404.934	475.194	584.798	742.705	933.441
4.00	280.933	281.054	282.947	286.534	292.133	300.483	312.893	331.562	360.155	404.784	475.404	586.425	749.612	952.502
4.25	280.554	280.676	282.570	286.161	291.765	300.123	312.548	331.241	359.882	404.612	475.495	587.523	754.794	968.065
4.50	280.206	280.327	282.223	285.816	291.424	299.789	312.225	330.938	359.616	404.424	475.505	588.260	758.701	980.833
4.75	279.879	280.001	281.897	285.492	291.103	299.474	311.918	330.647	359.354	404.224	475.456	588.746	761.652	991.350
5.00	279.568	279.690	281.587	285.184	290.798	299.173	311.624	330.366	359.096	404.014	475.363	589.053	763.881	1000.038
5.50	278.980	279.102	281.000	284.600	290.218	298.599	311.062	329.821	358.585	403.572	475.085	589.309	766.817	1013.199
6.00	278.420	278.542	280.441	284.042	289.664	298.050	310.520	329.292	358.078	403.111	474.728	589.271	768.430	1022.266
6.50	277.875	277.998	279.898	283.500	289.124	297.513	309.989	328.770	357.573	402.636	474.322	589.064	769.250	1028.517
7.00	277.340	277.462	279.363	282.967	288.592	296.985	309.465	328.253	357.068	402.154	473.887	588.757	769.588	1032.807
7.50	276.809	276.932	278.834	282.438	288.065	296.460	308.944	327.738	356.563	401.666	473.434	588.391	769.632	1035.723
8.00	276.281	276.405	278.307	281.913	287.541	295.938	308.425	327.224	356.058	401.175	472.970	587.989	769.497	1037.673

Table 3. The balance of *k*, *T* and *Ct*

From Table 3, it can be understood that this tables are divided into two areas by the changed control limits width: in the colorlessness area, the expected total cost per unit time *(Ct)* increases with the increase of delivery time *(T)*; in the blue area, the expected total cost per unit time *(Ct)* decreases with the increase of delivery time *(T)*.
From Table 3 and Figure 5, it can be noted that the expected total cost per unit time *(Ct)* increases with the increase of control limits width *(k)*. This is because that the cost of defective goods increases by the increase of control limits width.

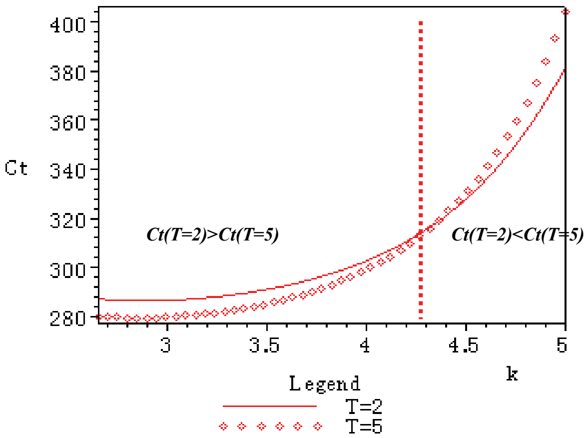

Fig. 5. The relation between *k* and *Ct* (*T*=2, *T*=5).

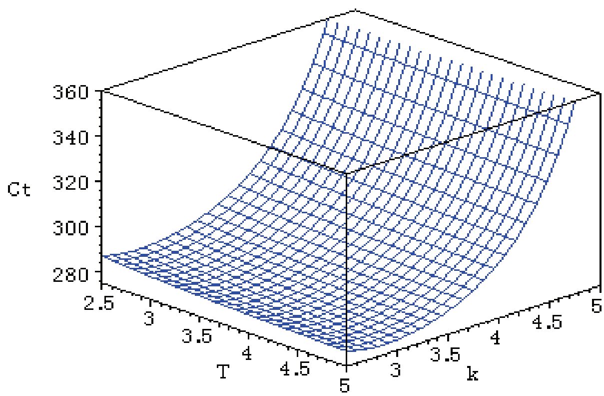

Fig. 6. The relation between *T*, *k* and *Ct*.

From Table 3, it also can be understand that a longer delivery time should be set when the high quality (when *k* is small) is demanded, while a shorter delivery time should be set when the low quality is demanded from an economic aspect.
In addition, to clarify it more, we also show the Figure 6 which is the same as the case of Table 3.

T	a													
	0.15	0.25	0.35	0.45	0.55	0.60	0.65	0.70	0.75	0.80	0.85	0.90	0.95	1.00
2.50	221.694	230.491	238.745	246.552	253.999	257.612	261.164	264.665	268.122	271.545	274.942	278.323	281.696	285.070
2.75	226.160	234.398	242.090	249.321	256.171	259.474	261.164	265.877	268.993	272.060	275.087	278.080	281.046	283.992
3.00	229.371	237.191	244.462	251.266	257.674	260.750	263.750	266.680	269.549	272.360	275.122	277.839	280.518	283.164
3.25	231.686	239.192	246.148	252.632	258.712	261.619	264.447	267.201	269.887	272.512	275.081	277.598	280.070	282.500
3.50	233.351	240.619	247.338	253.583	259.417	262.198	264.897	267.520	270.072	272.559	274.985	277.355	279.675	281.947
3.75	234.533	241.623	248.164	254.228	259.878	262.565	265.168	267.693	270.145	272.528	274.849	277.110	279.317	281.473
4.00	235.354	242.311	248.718	254.647	260.159	262.775	265.306	267.757	270.134	272.440	274.682	276.862	278.985	281.054
4.25	235.902	242.759	249.067	254.895	260.304	262.867	265.344	267.740	270.061	272.310	274.492	276.611	278.671	280.676
4.50	236.242	243.026	249.260	255.013	260.345	262.869	265.306	267.662	269.940	272.146	274.284	276.357	278.371	280.327
4.75	236.424	243.154	249.334	255.033	260.308	262.803	265.211	267.535	269.782	271.956	274.061	276.101	278.080	280.001
5.00	236.482	243.175	249.317	254.976	260.211	262.685	265.070	267.373	269.597	271.748	273.828	275.843	277.796	279.690
5.50	236.338	242.989	249.087	254.700	259.886	262.335	264.694	266.970	269.166	271.287	273.338	275.322	277.242	279.102
6.00	235.963	242.602	248.685	254.281	259.448	261.886	264.234	266.497	268.681	270.789	272.825	274.794	276.698	278.542
6.50	235.450	242.093	248.179	253.776	258.940	261.376	263.722	265.983	268.163	270.267	272.299	274.262	276.161	277.998
7.00	234.852	241.511	247.610	253.217	258.391	260.831	263.179	265.443	267.625	269.730	271.763	273.727	275.626	277.462
7.50	234.203	240.884	247.003	252.627	257.816	260.262	262.618	264.887	267.074	269.185	271.222	273.190	275.092	276.932
8.00	233.522	240.230	246.372	252.018	257.225	259.681	262.044	264.321	266.516	268.633	270.677	272.651	274.559	276.405

Table 4. The balance of a, T and Ct

E. The relation between T, a and Ct

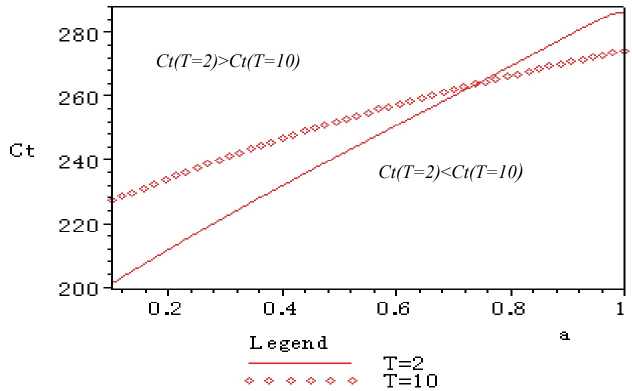

Fig. 7. The relation between *a* and *Ct* (*T*=2, *T*=10)

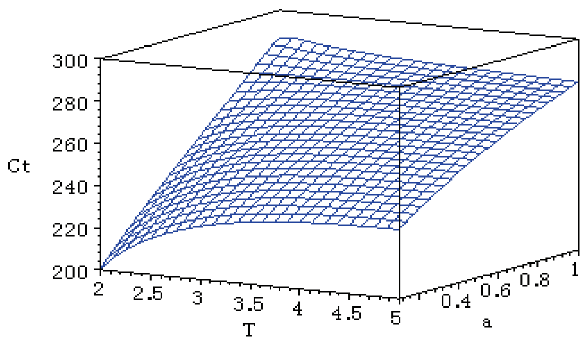

Fig. 8. The relation between *T*, *a* and *Ct*

Figure 7 show the relation between the delivery time and ACT time and the total expectation cost, which is useful for setting the optimal delivery time and ACT time to the supplier.

From Figure 7, it can be understood that this tables are divided into two areas by the changed ACT time: in the colorlessness area, the expected total cost per unit time *(Ct)* increases with the increase of delivery time *(T)*; in the blue area, the expected total cost per unit time *(Ct)* decreases with the increase of delivery time *(T)*.

From Figure 7 and Table 5, it can be noted that the expected total cost per unit time *(Ct)* increases with the increase of Act time *(a)*. This is because that the cost of defective goods increases by the increase of ACT time. Also it can be understand that a longer delivery time should be set when the ACT time is long, while a shorter delivery time should be set when the ACT time is short from an economic aspect.

In addition, to clarify it more, we also show the Figure 8 which is the same as the case of Figure 7.

4. Conclusions

In this research, from an economic viewpoint, a design of the $\bar{x}$ control chart is analyzed for quality management information system used in short delivery time processes.

Because of competition in markets, studying the balance of quality and the delivery time and cost has become a new problem to manager. To resolve this problem, the mathematical formulations which correspond to this design were shown, and then by numerically consideration using the data from real situation, the relations of the power of process and delivery time and the total expectation cost, the balance of quality (control limits width) and delivery time and the total expectation cost, the relations between the delivery time, ACT time and the total expectation cost are discussed, respectively. Moreover, the presented design based on the judgment rules of JIS Z 9021 was studied.

Some comments are drawn as follows, which would become useful references for setting the optimal delivery time, ACT time and the power of process to manager.

1. The expected total cost per unit time decreases with the increase of the power of process.
2. The power by the two rules (3σ rule and 9 ARL rule) increases with the increase of sample size n, and the speed of increase of 9 ARL rule is faster.
3. A longer delivery time should be set when the higher power for higher quality is demanded from an economic aspect.
4. A longer delivery time should be set when the ACT time is long, from an economic aspect.

5. References

[1] K. Amasaka, ed., "*Manufacturing Fundamentals: The Application of Intelligence Control Chart- Digital Engineering for Superior Quality Assurance*", Japanese Standards Association , 2003 (in Japanese).

[2] Y. Kanuma, and Y. Suzuki, and T. Kamagata, "Application and Efficiency of FDAS for Strengthening Real Working Front Ability", *Proceedings on the 37st Research Conference of Japanese Society for Quality Control*, pp.161-164, 2007 (in Japanese).

[3] Y. Ando, "An activity report of 'control chart practical applications study group' in JSQC", *Proceedings on the 5th ANQ Quality Congress*, 2007.

[4] S. Yasui, "On key factors for effective process control based on control charts through investigating literature cases", *Proceedings on the 37st Research Conference of Japanese Society for Quality Control*, pp.169-172, 2007 (in Japanese).

[5] J. Sun, M. Tsubaki and M. Matsui, "The comparisons between two quality control cycles-when the time of in-control and time of out-of-control is independent", *Proceedings on the 31st Research Conference of Japanese Society for Quality Control*, pp.227-230, 2003 (in Japanese).

[6] J. Sun, M. Tsubaki and M. Matsui, "Economic considerations in CAPD Model of P Control Chart for Quality Improvement", *International Conference on Quality '05-Tokyo Proceedings*, pp.VI-10, 2005.

[7] J. Sun, M. Tsubaki and M. Matsui, "Economic Models of $\bar{x}$ Chart with Tardiness Penalty in Finite Due Time Processes," *Journal of Japan Industrial management Association*, (in Japanese), vol. 57, no.5, pp.374-387, 2006.

[8] Japanese Industrial Standards Committee (1998): "*JIS Z 9021: The Shewhart Control Chart*", Japanese Standards Association (in Japanese).

[9] Y. Katou, "Verification of judgment rules of Shewhart control chart (JIS Z 9021)", *Proceedings on the 37st Research Conference of Japanese Society for Quality Control*, pp.165-168, 2007 (in Japanese).

[10] S. P. Ladany and D. N.Bedi, "Selection of the Optimal Setup Policy," *Naval research Logistics Quarterly*, vol. 23, pp.219-233, 1976.

4

Design Cycle Period Management

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1. Introduction

As competition increases and new technologies emerge, the civil aerospace industries need relatively better appropriate frameworks to guarantee their success. Efficient and close interactions among all disciplines involved in the aircraft design process from manufacturing, to the flight testing, are essential for improving the quality of the product. However, such necessities generally lead to a lengthy design cycle. Because of this, a strategy for cycle time reduction (CTR) must always be available. This process is called Integrated Airframe Design (IAD), (AGARD Report 814). A proper CTR leads to lessened costs which is essential in surviving a competition since time, cost and quality are three parameters that are normally used to evaluate the efficiency of a design process (Ullman, 2003).

Researches on CTR could be categorized into four branches: 1- reducing engineering man hours; 2- reducing tooling hours; 3- reducing testing activities 4- implementing process and information technologies(NASA/CR-2001-210658).

In the design process of complex systems, similar to that of an airplane, engineering tasks are either: coupled, sequential, parallel or compound ones. The design process of such a product is naturally in an iterative form (Eppinger & Whitney, 1994). In the scientific modeling of a design process, iterations are considered as specific features to be addressed (NSF, 1996). Iterations of a design process could be divided into two types (Browning, 1998):

1. Intentional iterations, performed between any two disciplines which help converging toward a satisfying solution.
2. Unintentional iterations that occur due to arrival of new information into the design process.

In this chapter we concentrate on the first type.

The very existence of iterations in the design process is the primary source of the increase in the development cycle time and its associated cost. Several studies have documented iteration effects as the driver of the overall development cycle time (Clark, 1993, Eisenhardt, 1995). Therefore, one expects that managing iterations and keeping them to a minimum leads to a more efficient design process. In this chapter, we investigate reducing man-hours by improving iteration characteristics. According to Smith and Eppinger there are two main strategies in increasing the speed of the design process: 1- faster execution of iterations; 2- reducing the number of necessary iterations in the design process (Smith & Eppinger, 1997). Extensive studies have been carried out by different researchers for either strategy. For example, the information flow model in designing tasks and distinguishing their cyclic

loops has been investigated by Steward in the form of a design structure matrix (DSM) (Steward, 1981). Eppinger continued this work and the information cycle in a design process was modeled in a clearer fashion while different strategies for the process management were investigated (Eppinger and Whitney, 1994). Browning developed a new methodology to understand product development cost, schedule, and performance (Browning, 1998). These works could be assessed from different points of views such as; presenting a systematic method for "Cycle Time Reduction" that allows each design topic to be analyzed according to its specific features. This approach allows managers to involve contractors in designing a big system in an efficient manner. One might also consider the approach in the broader subject of "Subcontracting". The fact that the WTM Concept could suggest what part of the project would be a good candidate for subcontracting, does not necessarily means that such implementation is an economic solution as well. That is WTM deals only with controlling the duration of the project and not the financial aspect of it. This chapter however, focuses on controlling iterations by means of iteration dynamic order reduction or tear-out "Controlling Features" (C.F.s) of a design process. To show how the new approach could be implemented, we use the WTM of a GENERAL AVAITION(G.A.) AIRPLANE.
Following an introduction, we briefly discuss the application of Design Structure Matrix (DSM) to describe the so called Work Transformation Matrix (WTM). Then, we describe the main idea of the current chapter and how it is used to reduce the dynamic order of the iterations in a typical design process. Finally, we present a case study together with discussions on a G. A. airplane design process, and discuss the results.

2. Design process modeling by means of (DSM)

Most designers believe that the first step in design process management is creating a comprehensive model which contains all the design tasks and their relationship. According to Yassine and Falkenburg, and Chelst; one of the main problems in the design process is the existence of the information cycles in tasks (Yassine et al., 1999). Any information cycle means the information interchanges among different disciplines in the design process. According to Pahl and Bietz the reason for the very existence of information cycles is related to the complexity in disciplines of the coupled design parameters (Pahl& Bietz, 1996);. Using a comprehensive model one could break the information cycles in suitable points, thus the complexity of the design process will be reduced. A comprehensive model should contain two characteristics:

1. Ability to identify information cycles
2. Ability to identify effective dynamic elements or suitable points to break information cycles

The DSM method decomposes a more general design problem into separate tasks and while representing the relation among tasks as X; it provides a systematic way to analyze the design process structure. Each of the tasks is placed in rows and columns of a square matrix and the relationship among the tasks shown by the **X** marks. The **X** marks along each row show the input data which is needed for carrying out the tasks of that row. The **X** marks along each column show the output data which is supplied by that column task for other tasks. As a result the **X** marks above the diagonal show the feedback information and the **X** marks under the diagonal show the feed forward information; thus, the coupled part of the design process is then readily available (Figure – 1).

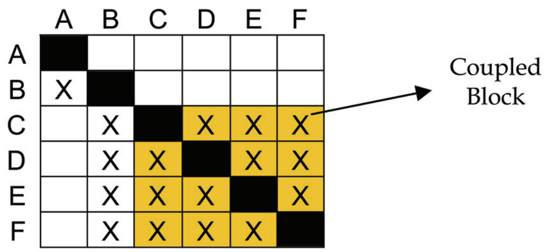

Fig. 1. Sample DSM Representing Coupled Tasks

Thus DSM provides the aforementioned characteristics in a systematic way. In order to study of the behavior of iterations, a numerical DSM, called the Work Transformation Matrix (WTM), can be used (Smith&Eppinger 1997). Works done by the mentioned researchers suggest that three assumptions enable us to use linear algebra to analyze a WTM; as follows:

1. All iterations are done parallel.
2. The rework done is a linear function of the work done in the previous step.
3. The relationships among the tasks do not change in time.

In this Chapter, we accept the aforementioned assumptions as the basis of the work; however, from a theoretical point of view, assumption number (1) applies to a big design organization where all engineering disciplines are available. This assumption basically means that members of engineering teams are fixed and that they work simultaneously on the same design problem. Also, this assumption gets closer to the reality wherever "Concurrent Engineering" is exercised.

Assuming "time of conducting an iteration" to be a linear function of previous ones, is generally not a precise assumption. However, due to an engineer's cognitive learning, it is believed that as the design process proceeds, performing iterations become both simpler and faster. Considering this, a linear decrease in conducting iterations would be somehow meaningful; as we would expect with a linear decrease in work associated with iterations. It is worth noting however, that at the moment there is no other approach to quantitatively model the nature of iterations. Besides linear approximation, one might think of a bi-linear model or tri-linear one. Nevertheless, different case studies by the authors show that such models would not effectively change the behavior of iterations (Soltanmohammad, PhD Thesis, 2007). One of the factors that influence the validity of the linear model is the very existence of some technological jumps that might occur during the execution of the project. In such cases, one might use a new approach based on "Time Dependent Complexity" (TDC) of coupled design parameters (Suh, 2003). In general, the second and third assumptions will be correct if we are not dealing with too many iterations. Moreover, since assumption number (3) does not support the effect of the so called "Learning Curve" in an organization it must be used very carefully.

Based on what was described earlier, one can describe any iteration as a vector $\mathbf{u}_t$ with dimension "n" where "n" is the number of coupled design tasks, relation (1). Each entries of the iteration vector shows the iteration job done after the t^{th} stage of iteration. If matrix A is a part of WTM, which contains the data about the dependency intensity of tasks to one another, then according to Smith and Eppinger the work vector and total work vector U are (Smith and Eppinger, 1997):

$$u_{t+1} = A \cdot u_t \tag{1}$$

$$U = \sum_{t=0}^{M} u_t = \left(\sum_{t=0}^{M} A^t \right) u_0 \tag{2}$$

That t is the iteration stage, u is the work vector, and M is the total number of iterations and u_0 is the initial work vector, that, all entries of u_0 are equal to 1.0. After decomposing matrix A, one might derive a relationship between U and eigenstructure of A as follows:

$$U = S \cdot (I - \Lambda)^{-1} \cdot S^{-1} u_0 \tag{3}$$

Where S and Λ are eigenvectors and diagonal eigenvalues of matrix A respectively. According to (3), the dynamics (structure) of a design process is related to the time needed for conducting that design and from there to the nature of the eigenvalues and eigenvectors of the WTM. According to (3) the eigenvalues which are real and positive values close to unity, have a major role in the work vector U and in contrary role of the negative eigenvalues which are close to -1.0 are not important. The effect of complex eigenvalues is established by their real parts. If the real part is positive and near 1, then the eigenvalue plays an important role; otherwise it does not. Based on Perron-Frobenius theory, the biggest eigenvalue of a matrix like WTM, where all entries are non-negative, is always a real and positive number (Minc, 1988). In this way, the design mode associated with the largest eigenvalue can be selected as the most dominant design mode. This design mode has an eigenvector which is strictly positive and relatively larger elements of the eigenvector determine the contribution of the corresponding tasks to the dominant design mode. From a mathematical point of view, one might interpret the entries of this eigenvector to be more effective in the dominant design mode. In this way the C.F.s of the design process are identified as the tasks inside the most dominant design mode which have relatively greater contribution in convergence/divergence of iterations.

By thoroughly examining the eigenvector entries, one can understands the C.F.s of the design process (Smith& Eppinger 1997). It can be stated that the number and characteristics of iterations are function of the C.F.s of a design process. Unlike what we interpret from Smith and Eppinger's work, we might say that the contribution of each task and the number of effective tasks are different in generating iterations. The differences are related to the nature of the WTM.

Based on the mentioned reasoning, C.F.s can be selected by following the simple relation:

$$\frac{V_i}{V_{\max}} > K_d \tag{4}$$

V_i : i^{th} Entry of dominant mode eigenvector

$V_{\max}$: Maximum entry of dominant mode eigenvector

K_d : A decision parameter based on the designers experience (usually 0.5)

If (4) holds, then V_i is a C.F. Obviously, C.F.s each design processes differs, of course, this adapt with designers experiences and observations.

To optimize a DSM, one might take advantage of four mathematical operations as follows:

1. Partitioning: Partitioning is the process of manipulating (i.e. reordering) the DSM rows and columns such that the new DSM arrangement does not contain any feedback marks, that is, in a lower triangular form. In engineering systems, it is highly unlikely that a simple row and column manipulation will result in a lower triangular form. Therefore, the objective changes from eliminating the feedback marks to moving them as close as possible to the diagonal.
2. Clustering: The goal of clustering is to find subsets of DSM elements (clusters or modules) that are mutually exclusive or minimally interacting subsets. Clusters absorb most of the interactions while links between separating clusters are eliminated or minimized.
3. Banding: Banding is the addition of alternating light and dark bands to a DSM to show independent, parallel or concurrent activities.
4. Tearing: Tearing is the process of choosing a group of (X) (feedback marks) inside the information cycles in such a way that eliminating them from the matrix, changes that matrix into a lower triangular one. The X signs which are eliminated from the matrix are called "tear tasks".

In this chapter, we use tearing to reduce cycle time in a systematic manner. Therefore, we can further explain the tearing operation.

The procedure to eliminate some tasks from iteration, known as tearing, is explained by different authors. Based on works published by; (Austin et al.,1999); tearing is the process of choosing a group of feedback marks inside the information cycles in such a way that eliminates them from a DSM to render a lower triangular one. The tasks which are eliminated from the existing DSM are called "tear tasks". Knowing that tear tasks are equivalent to the assumptions needed to start a design process, no further estimation is needed for conducting the design process (Yassine, 1999). According to Austin and Yassine, although there is no optimum method available, there are two main criteria for the tearing process (Austin & Yassine, 1999):

1. Confine tears to the smallest blocks along the diagonal.
2. Minimize number of tear tasks.

Steward suggests tearing on the basis of breaking the effective information cycles. He uses shunt Diagrams for this purpose (Steward 1981). However, since analyzing the diagram of the tear tasks becomes too complicated, the method proves to be unsuitable for big design organizations. Roger, suggests a heuristic process for selecting the tasks in order to minimize the information cycles (Roger 1989). Kusiak and Wang explored all tasks involved in producing iterations and their occurrence frequency (Kusiak & Wang, 1993). They suggested tear those with a relatively greater occurrence frequency. Yassine presents the so called "Quality criteria" for tearing via a degree of sensitivity, uncertainty, and a dependency of tasks (Yassine, 1999).

All tearing criteria suggested so far have been proven inefficient; as they are either too complex to implement, or highly dependent on previous experiments and individual innovations taken from managers who need to have some type of international participation. In this chapter we reduce dynamic order of the design process, to minimize the design cycle period. To do this, in first step, the C.F.s of a given design process, must be identified. This tends to be a systematic approach that relies basically on the understanding of the design process itself; rather than previous experiences or personal skills. It is necessary to mentioned, reduce dynamic order of the design process also known as

"Tearing". This new approach tends to help less-experiencing designers control the whole design as well as its associated factors of time and cost.
Next section of this chapter, further explained about the suggested approach to reduce dynamic order of the design process.

3. Controlling of iterations by reducing DSM dynamic order

In the design process of multi-disciplinary systems, such as aircrafts, the design task can be decomposed into sub-tasks based on the nature of the subsystem and the engineering discipline involved. Naturally, all disciplines tend to solve their own problems in an optimum manner. However, due to the coupled nature of the design parameters (Figure-2), optimizing individual sub-tasks would not necessarily lead to an optimized overall design.

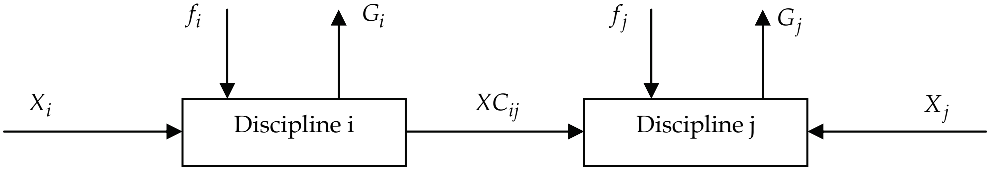

Fig. 2. Schematic Representation of Coupled Design Problem

Based on Hacker with DSPi, any design problem could be mathematically expressed as a systematic procedure to find a set of design parameters while optimizing function fi, where (Hacker, 1996):
Goals: Optimize f i; fi =F(Xnc_i, Xc_i)

Constraints: G i; G i =G(Xnc_i, Xc_i)

fi : Objective function in discipline i
G i : Constraint function in discipline i
Xi : Design parameters of discipline i
Xnc i : Non – Coupled Design parameters of discipline i
Xci : Coupled Design parameters of discipline i
DSPi : Decision Support Problem of discipline i

Obviously, changing any of the coupled design parameters between either two disciplines will change the objective and other constrictive functions accordingly. That is, as soon as a change is applied to any coupled design parameters by one of the disciplines, other disciplines must re-iterate their process as a response to the imposed change. This, in turn, has effect on other coupled parameters. This process continues until all disciplines reach to a satisfactory solution based on their individual objectives. The satisfactory solution described based on Figure -3. This Figure illustrates the difference between the range of selecting a coupled design parameter in two disciplines i and j. At the beginning of the iteration process, both disciplines designated by i and j might select $XC_{ij_{i0}}$ as a coupled design parameter. Once iterations proceed each discipline receives information from others that might lead to changing the coupled design parameter. These changes should establish a pattern moving toward a common area (Figure -3). Once each discipline selects the coupled design parameter at the common area iteration will terminate, meaning that cost function and constraint of each discipline DSP is satisfied. It must be note that work done on DSP change as all disciplines cost functions and constraints change, at each stage of iteration. According to Shearer, Murphy and Richradson in dynamic systems at least one variable varies in time (Shearer, Murphy and Richradson, 1971). Then, one might treat iteration process as a dynamic system as work done at each stage varies in time. According to Figure–3, any iteration while dealing with WTM could be treated as a time dependent complexity between two disciplines; where complexity is defined as a function of common range between task i and task j (Suh 2003). It is necessary to mention that probability density on Figure-3 follows a uniform distribution.

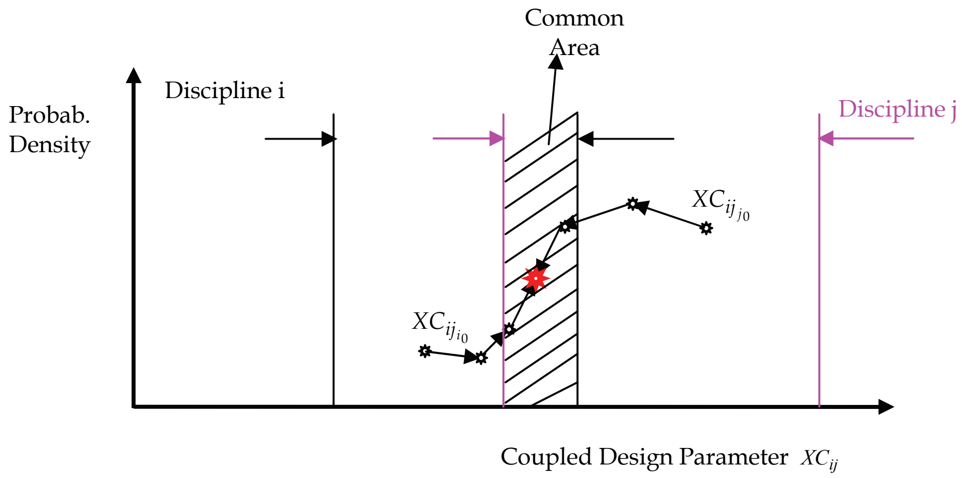

Fig. 3. Complexity between two coupled tasks

Considering a work vector modeled by WTM as:

$$u_{t+1} = Au_t$$

With t, as the iteration stage, above relation could rewrite as:
U(t+1)=Au(t) (a)
The equation describing the so called discrete- linear- time invariant dynamic system becomes:
X(k+1)=G • X(k) (b);
Where G represents the State Transition Matrix that shows the nature of the dynamic system. Here, we present a systematic approach to improving the dynamic behavior of the iterations process through modifications in the state transition matrix. There are two general approaches for such improvement (Soltanmohammad, PhD Thesis, 2007):

1. Improving [A], by improving its entries through injecting information to some tasks
2. Improving [A] by reducing its dynamic order (eliminating rows &columns).

In this chapter, we use the second approach, knowing that entries of [A] are greater or equal to zero:

$$A=\left[a_{ij}\right] \qquad a_{ij} \geq 0$$

Assuming $\rho(A)$ is the spectral radius or the largest eigenvalue of [A]; where [A] is a non-negative matrix, then according to Minc, spectral radius of any sub-matrix of [A] are smaller than spectral radius of [A] itself (Minc, 1988). That is, if any associated row and column of [A] is eliminated (tearing), then the remaining matrix has a spectral radius which is smaller than [A] itself. This is interpreted as increasing iteration speed or iteration convergence rate.
In order to minimize the spectral radius of [A], element(s) that have the highest influence on the dynamics must first be identified. These are in fact C.F.s with relatively greater values. Thus, we perform tearing (system dynamic reduction) based on the order of magniuted of the C.F.s This mathematical process requires a successive conversion of work vector u together with the state transition matrix [A] to u′ and A′, with the following equations:

$$U = \left(\sum_{t=0}^{M} A^{t} \right) u_0$$

$$U' = \left(\sum_{t=0}^{M'} A'^{t} \right) u'_0$$

Since A' is in fact a principle sub matrix of [A], then, according to (Minc, 1988):

$$\begin{aligned} &\rho(A) > \rho(A') \\ &\rho(A) \equiv \max|\lambda| \quad \lambda \in \sigma(A) \end{aligned} \tag{5}$$

In which, σ(A) is a set representing all the distinct eigenvalues of [A] (spectrum of [A]). Regardless of what mathematical proof offers, we present a real case scenario for a typical General Aviation airplane design process to demonstrate the effectiveness of the new approach. Of course, it must be note that tearing some tasks would not lead to ignoring them. In reality it simply means converting a coupled block to a smaller block or smaller blocks and a block containing tear-out tasks (Figure-4)

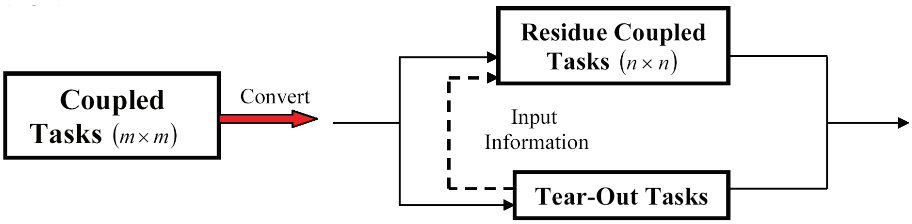

Fig. 4. Architecture of coupled part of design process after iteration dynamic reduction (m > n)

The generic blocks of Figure-4 could be performing in a semi-parallel way. That is, the tear-out C.F.s block provides necessary input information for residue coupled tasks block(s), in this way, the blocks can run parallel. Tear-out C.F.s block can provide necessary input information for other blocks by Rational Reaction Set (RRS); (a-Kurt Hacker & Kemper Lewis, 1998; b-Wei Chen & Kemper Lewis, 1999).

4. Case studies and results

To show the merits of the new approach, we describe how it is applied to an actual G.A. airplane design process. In this study, dynamic order of the G.A. airplane design process is reduced using five different scenarios. The selected scenarios allow us to investigate the influence of tearing C.F.s on iteration convergence speed. Since G.A. airplane is in fact an actual aircraft going through the certification and enhancement process, case studies might help validate the proposed approach. The execution algorithm starts by establishing G.A. airplane DSM. We demonstrate a simplified version of such DSM (Table 1). Applying partitioning to identify the design cycles (Table 2). Next, we establish WTM and identify its coupled part through interviewing engineers participating in the project (Table 3). Dominant modes and therefore candidate C.F.s, to implement "tearing" are identified by the eigenstructure analysis of the WTM (Table 4). Table-5 provides the selected scenarios to reduce the dynamic order of the design iteration of G.A. airplane.
For having the ability to compare the results both with and without the application of new methods and for undergoing different scenarios while applying it, authors use the following set of criteria:

Task Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Decide on General Design Requirements	1																
Performance Sizing	2	1															
Select Preliminary Configuration Alternative	3	1	1					1		1		1					
Mathematical Surface Models	4			1		1		1									
Aerodynamics Calculation	5	1			1												
Preliminary Structural Arrangement	6	1			1						1				1	1	
Prepare for cabin & Fuselage Design	7	1		1													
Develop Structural Design Conditions	8	1					1										
Integration Propulsion	9	1	1					1									
Perform Preliminary Weight & Balance	10							1		1					1		
Stability & Control Analysis	11	1				1				1	1						
V-n Diagram	12					1			1		1			1			
Internal Load Distributions	13								1		1		1				
Structural Analysis	14	1							1	1			1	1			
Preliminary Production Program	15	1					1	1		1					1		
Concept Selection	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	

Table 1. G.A. airplane DSM

1. **Convergence Improvement:** The degree of increase in Convergence Speed (CS) is defined as:

$$CS = \frac{\lambda_{1_{BT}} - \lambda_{1_{AT}}}{\lambda_{1_{BT}}}$$

Where $\lambda_{1_{AT}}$, $\lambda_{1_{BT}}$ are respectively the most dominant mode eigenvalues before and after tearing.

Task Name		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Decide on General Design Requirements	1																
Performance Sizing	2	1															
Select Preliminary Configuration Alternative	3	1	1					1		1		1					
Mathematical Surface Models	4			1		1		1									
Aerodynamics Calculation	5	1			1												
Preliminary Structural Arrangement	6	1			1						1				1	1	
Prepare for cabin & Fuselage Design	7	1		1													
Develop Structural Design Conditions	8	1					1										
Integration Propulsion	9	1	1					1									
Perform Preliminary Weight & Balance	10							1		1					1		
Stability & Control Analysis	11	1				1				1	1						
V-n Diagram	12					1			1		1			1			
Internal Load Distributions	13								1		1		1				
Structural Analysis	14	1							1	1			1	1			
Preliminary Production Program	15	1					1	1		1					1		
Concept Selection	16	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	

Table 2. Partitioned G.A. airplane DSM

Tasks	No.	3	4	5	6	7	8	9	10	11	12	13	14	15
Select Preliminary Configuration Alternative	3	0	0	0	0	0.3	0	0.3	0	0.2	0	0	0	0
Mathematical Surface Models	4	1	0	0.4	0	0.2	0	0	0	0	0	0	0	0
Aerodynamics Calculation	5	0	0.5	0	0	0	0	0	0	0	0	0	0	0
Preliminary Structural Arrangement	6	0	0.5	0	0	0	0	0	0.1	0	0	0	0.3	0.1
Prepare for cabin & Fuselage Design	7	0.2	0	0	0	0	0	0	0	0	0	0	0	0
Develop Structural Design Conditions	8	0	0	0	0.2	0	0	0	0	0	0	0	0	0
Integration Propulsion	9	0	0	0	0	0.4	0	0	0	0	0	0	0	0
Perform Preliminary Weight & Balance	10	0	0	0	0	0.3	0	0.4	0	0	0	0	0.5	0
Stability & Control Analysis	11	0	0	0.7	0	0	0	0.5	0.7	0	0	0	0	0
V-n Diagram	12	0	0	0.1	0	0	0.2	0	0.1	0	0	0.4	0	0
Internal Load Distributions	13	0	0	0	0	0	0.5	0	0.5	0	0.3	0	0	0
Structural Analysis	14	0	0	0	0	0	0.5	0.2	0	0	0.1	0.1	0	0
Preliminary Production Program	15	0	0	0	0.2	0.1	0	0.1	0	0	0	0	0.1	0

Table 3. WTM of the G.A. airplane Project Showing Coupled part

2. **Coupled part Reduction:** This criterion presents the effect of tearing most important C.F.s on work volume of design process coupled part and is calculated as follows:

$$CW \equiv S^{-1}U_0 \cdot \left(\sum All\ Coupled\ Tasks\right);\ CW: Couple\ Task\ Weight$$

$$(CPR) = \frac{(CW)_{Before\ Tearing} - (CW)_{After\ Tearing}}{Tear\ Task\ Weight}$$

$$CPR: Couple\ Part\ \mathrm{Re}duction$$

Task Name	Eigenvector Elements	Task No
V-n Diagram	0.283	12
Aerodynamics Calculation	0.302	5
Internal Load Distributions	0.322	13
Preliminary Structural Arrangement	0.424	6
Mathematical Surface Models	0.425	4
Stability & Control Analysis	0.482	11

Table 4. Controlling Feature of the most dominant design mode before tearing

Scenarios	Tear-out Tasks	Tasks No.
Case-1	Preliminary Structural Arrangement Mathematical Surface Models Stability & Control Analysis	6 4 11
Case-2	Mathematical Surface Models Stability & Control Analysis	4 11
Case-3	Stability & Control Analysis	11
Case-4	Mathematical Surface Models	4
Case-5	Preliminary Structural Arrangement	6

Table 5. Design Scenarios under Study for tearing

3. **Number of Controlling Features:** No of C.F.s
4. **Total Work:** Total work is the sum of entries of the work vector and is computed based on (3)
5. **Rank Improvement:** Resulting improvement in the rank of each mode is the fifth criterion and is calculated by:

$$\frac{\left(\left(\frac{1}{1-\lambda_{1_{BT}}}\right)-\left(\frac{1}{1-\lambda_{1_{AT}}}\right)\right)}{\left(\frac{1}{1-\lambda_{1_{BT}}}\right)}$$

6. **Controlling Features Weight:** Controlling Feature weight is computed from multiplying the sum of C.F. vector entries in $S^{-1}U_0$ of the same Mode.

It is interesting to note that there would be no difference in results while applying coefficient of $S^{-1}U_0$ instead of ones associated with $(I-\Lambda)^{-1}S^{-1}U_0$. Since:

$$(I-\Lambda)^{-1}=\begin{bmatrix} \frac{1}{1-\lambda_1} & 0 & \cdots & 0 \\ \vdots & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ 0 & \cdots & \cdots & \frac{1}{1-\lambda_n} \end{bmatrix}$$

Therefore, the first entry of $(I-\Lambda)^{-1}S^{-1}U_0$, that is used as a coefficient associated with the first mode, is:

$$\left[(I-\Lambda)^{-1}S^{-1}U_0\right]_1 = \frac{1}{1-\lambda_1}\left[S^{-1}U_0\right]_1$$

The difference between $\left[(I-\Lambda)^{-1}S^{-1}U_0\right]_1$ and $\left[S^{-1}U_0\right]_1$ is in fact $\dfrac{1}{1-\lambda_1}$ can not influence the results of comparison.

After the eigenstructure analysis of table-3, the eigenvalue of the most dominant mode of G.A. airplane design process is $\lambda = 0.700$ and the C.F.s of the most dominant mode are shown in table (4). Considering all tasks of table (4) which are the C.F.s of the most dominant mode, one can deduce that the most important part of the G.A. airplane design process are Stability & Control analysis (task 11), Mathematical Surface Models (task 4), structural design & analysis (tasks 13,12 and 6) and Aerodynamic Calculation (task 5), in all of which four disciplines are involved. These problems are the main problems of the G.A. airplane design process. The reduction of dynamic order of the design iteration of G.A. airplane design process is now investigated under five different scenarios (Table (5)).

Case-1: In this case, the three most efficient C.F.s, tasks 11, 4, 6, are torn. After tearing and repartitioning, the task table of the G.A. airplane will become as demonstrated in Table-6. This table shows a new design process in which coupled parts are broken into two. The larger block has four coupled tasks while the other has three. We consider the former as the major block and the latter as the minor block. The relationships in the new arrangement of the blocks are shown in Figure-5. The C.F.s of the most dominant design mode resulting from this new arrangement are shown, after tearing, in Table-7.

Tasks	No.	10	12	13	14
Perform Preliminary Weight & Balance	10	0	0	0	0.5
V-n Diagram	12	0.1	0	0.4	0
Internal Load Distributions	13	0.5	0.3	0	0
Structural Analysis	14	0	0.1	0.1	0

Table 6. The WTM after partitioning and tearing (First case major block)

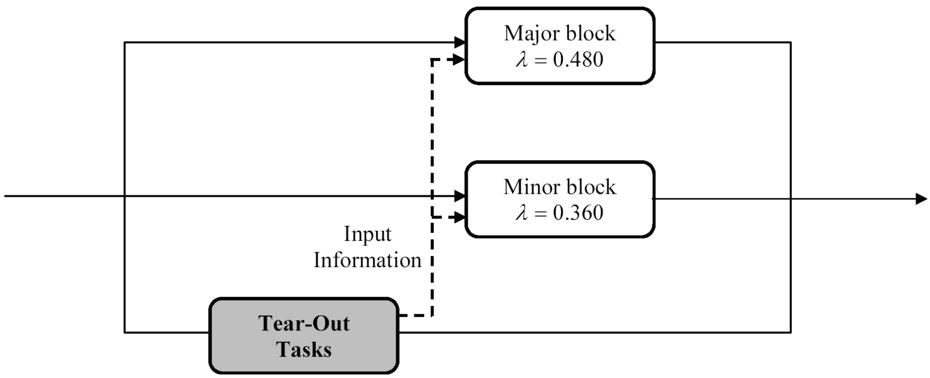

Fig. 5. Architecture of the major and minor blocks with tear-out tasks at (Case-1)

It is necessary to mention that the presented characteristics in Table-20 relating to the major block, because of the eigenvalues of the major block, are greater than the minor block.
Case – 2: In this case the two tasks, 4 and 11, will be considered as tear-outs. Table (9) shows the results of the tearing. Here, we have two coupled blocks: a major block in which there are six coupled tasks and a minor block in which there are three coupled tasks. The C.F.s of the most dominant design mode are shown after tearing in Table-10. Also, Figure-6 demonstrates the arrangement discussed in the preceding case.

Task Name	Eigenvector Elements	Task No
V-n Diagram	0.622	12
Internal Load Distributions	0.679	13

Table 7. C.F.s of the most dominant design mode after tearing (First case)

Tasks	No.	3	7	9
Select Preliminary Configuration Alternative	3		0.3	0.3
Prepare for cabin & Fuselage Design	7	0.2		0
Integration Propulsion	9	0	0.4	

Table 8. The WTM after partitioning and tearing (First case minor block)

Tasks	No.	6	8	10	12	13	14
Preliminary Structural Arrangement	6	0	0	0.1	0	0	0.3
Develop Structural Design Conditions	8	0.2	0	0	0	0	0
Perform Preliminary Weight & Balance	10	0	0	0	0	0	0.5
V-n Diagram	12	0	0.2	0.1	0	0.4	0
Internal Load Distributions	13	0	0.5	0.5	0.3	0	0
Structural Analysis	14	0	0.5	0	0.1	0.1	0

Table 9. The WTM after partitioning and tearing (Case-2 major block)

Task Name	Eigenvector Elements	Task No
V-n Diagram	0.575	12
Internal Load Distributions	0.662	13

Table 10. The C.F.s of the most dominant design mode after tearing (Case-2)

Case – 3: In this case, only the most effective C.F. will be torn. After the tearing and repartitioning, the design process changes into Tables 12, 14 and 15. The major block (Table-12), has seven coupled tasks. There are also two minor blocks: block-a (Table-14) and block-b (Table-15). The new arrangement of the blocks and tear-out task are shown in the following Figure-7. The C.F.s of the most dominant design mode after tearing is also shown in Table (13).

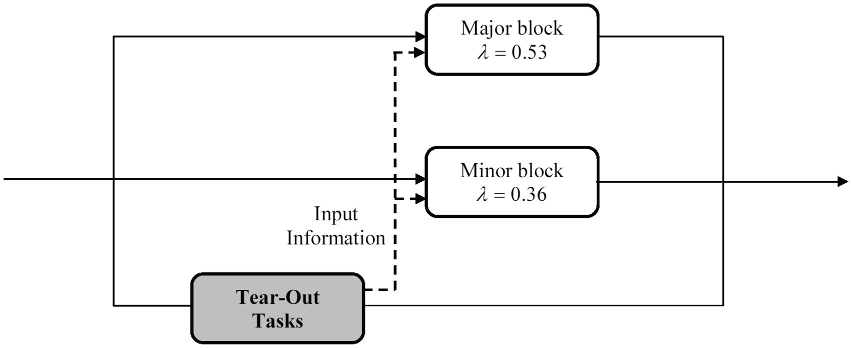

Fig. 6. Architecture of major and minor blocks and tear-out tasks at Case-2

Tasks	No.	3	7	9
Select Preliminary Configuration Alternative	3		0.3	0.3
Prepare for cabin & Fuselage Design	7	0.2		0
Integration Propulsion	9	0	0.4	

Table 11. The WTM after partitioning and tearing (second case minor block)

Tasks	No.	6	8	10	12	13	14	15
Preliminary Structural Arrangement	6	0	0	0.1	0	0	0.3	0.1
Develop Structural Design Conditions	8	0.2	0	0	0	0	0	0
Perform Preliminary Weight & Balance	10	0	0	0	0	0	0.5	0
V-n Diagram	12	0	0.2	0.1	0	0.4	0	0
Internal Load Distributions	13	0	0.5	0.5	0.3	0	0	0
Structural Analysis	14	0	0.5	0	0.1	0.1	0	0
Preliminary Production Program	15	0.2	0	0	0	0	0.1	0

Table 12. The WTM after partitioning and tearing (Third case major block)

Task Name	Eigenvector Elements	Task No
V-n Diagram	0.562	12
Internal Load Distributions	0.650	13

Table 13. C.F.s of the most dominant mode C.F.s after tearing (Third case).

Tasks	No.	3	7	9
Select Preliminary Configuration Alternative	3		0.3	0.3
Prepare for cabin & Fuselage Design	7	0.2		0
Integration Propulsion	9	0	0.4	

Table 14. The WTM after partitioning and tearing (Third case minor block-a)

Tasks	No.	4	5
Mathematical Surface Models	4		0.4
Aerodynamics Calculation	5	0.5	

Table 15. The WTM after partitioning and tearing (Third case minor block-b)

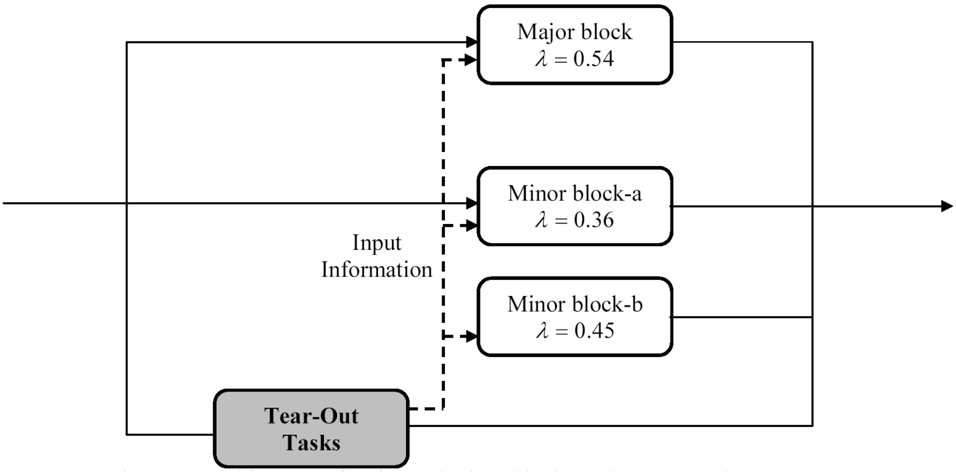

Fig. 7. Architecture of major and minor blocks and tear-out tasks at Case-3

Case – 4: In this case, only Task 4 will be torn. After the tearing and repartitioning of the WTM, the table of the tasks of the G.A. airplane will change into Table (16). This table shows that after tear-out, number of coupled tasks will change to 11 tasks.
The C.F.s of the most dominant design mode are shown in Table (17).

Tasks	No.	3	6	7	8	9	10	11	12	13	14	15
Select Preliminary Configuration Alternative	3	0	0	0.3	0	0.3	0	0.2	0	0	0	0
Preliminary Structural Arrangement	6	0	0	0	0	0	0.1	0	0	0	0.3	0.1
Prepare for cabin & Fuselage Design	7	0.2	0	0	0	0	0	0	0	0	0	0
Develop Structural Design Conditions	8	0	0.2	0	0	0	0	0	0	0	0	0
Integration Propulsion	9	0	0	0.4	0	0	0	0	0	0	0	0
Perform Preliminary Weight & Balance	10	0	0	0.3	0	0.4	0	0	0	0	0.5	0
Stability & Control Analysis	11	0	0	0	0	0.5	0.7	0	0	0	0	0
V-n Diagram	12	0	0	0	0.2	0	0.1	0	0	0.4	0	0
Internal Load Distributions	13	0	0	0	0.5	0	0.5	0	0.3	0	0	0
Structural Analysis	14	0	0	0	0.5	0.2	0	0	0.1	0.1	0	0
Preliminary Production Program	15	0	0.2	0.1	0	0.1	0	0	0	0	0.1	0

Table 16. The WTM after partitioning and tearing (Fourth case)

Task Name	Eigenvector Elements	Task No
Perform Preliminary Weight & Balance	0.300	10
Stability & Control Analysis	0.407	11
V-n Diagram	0.476	12
Internal Load Distributions	0.573	13

Table 17. Controlling feature of the most dominant design mode after tearing in 4th case

Case – 5: Case 5 is very similar to that of Case-4, the only difference being that we will tear-out Task 6 instead of Task 4. Again, after the tearing and repartitioning, we obtain the results shown in Table (18). In this case, the number of coupled tasks changes to 10 and the C.F.s of the most dominant design mode can then be represented as in Table (19).
Table (20), Along with Figures 8 through 13, shown a comparison between results of five scenarios. The comparison is particularly useful for understanding WTM's both before and after tearing.
Table-20 Summer of the important results. The second column of this table indicates a coefficient of $S^{-1}u_0$ for each case. The third column of the table shows the eigenvalues of the most dominant mode of each case. The fourth column of the table presents the main problems of each case.

Tasks	No.	3	4	5	7	9	10	11	12	13	14
Select Preliminary Configuration Alternative	3	0	0	0	0.3	0.3	0	0.2	0	0	0
Mathematical Surface Models	4	1	0	0.4	0.2	0	0	0	0	0	0
Aerodynamics Calculation	5	0	0.5	0	0	0	0	0	0	0	0
Prepare for cabin & Fuselage Design	7	0.2	0	0	0	0	0	0	0	0	0
Integration Propulsion	9	0	0	0	0.4	0	0	0	0	0	0
Perform Preliminary Weight & Balance	10	0	0	0	0.3	0.4	0	0	0	0	0.5
Stability & Control Analysis	11	0	0	0.7	0	0.5	0.7	0	0	0	0
V-n Diagram	12	0	0	0.1	0	0	0.1	0	0	0.4	0
Internal Load Distributions	13	0	0	0	0	0	0.5	0	0.3	0	0
Structural Analysis	14	0	0	0	0	0.2	0	0	0.1	0.1	0

Table 18. The WTM after partitioning and tearing (Case 5)

Task Name	Eigenvector Elements	Task No
Mathematical Surface Models	0.600	4
Aerodynamics Calculation	0.443	5
Stability & Control Analysis	0.580	11

Table 19. Controlling feature of the most dominant design mode after tearing in Case 5

Cases\Results	Dominant Mode $S^{-1}u_0$	Dominant Mode Eigenvalue	Dominant Mode Main Problem
Basic Case	5.730	0.700	1-Structure design &analysis 2-Mathematical surface model 3-Aerodynamic analysis 4-Stability &Control Analysis
Case-1	2.280	0.480	1-Structure analysis
Case-2	3.490	0.530	1-Structure analysis
Case-3	3.510	0.540	1-Structure analysis
Case-4	5.430	0.570	1-Structure analysis 2-Weight & Balance 3-Stability & Control
Case-5	4.980	0.680	1-Mathematical surface model 2-Aerodynamic analysis 3-Stability &Control Analysis

Table 20. Important results after implying mentioned five scenarios

Table (20) and Figures 8 through 13 show:

1. The General Aviation airplane examined here contains four coupled disciplines. However, by using the proposed method, it could effectively reduce the number of coupled disciplines from four to three, two or even one. Thus, implementing tearing based on C.F.s will always lead to a smaller design problem (with less discipline and less coupled parts) (Table -20).
2. The number of C.F.s and the weight of each are minimized in Case-1(Figures-9, 10).
3. FromTable-20 and Figures 8 through 13, we can observe a reduction in the dynamic order of system: that is, the suggested criterion effectively leads to a better convergence speed. Comparing the 1st case to the 5th case one can conclude that Case 1 is more efficient as far as speed of convergence is concerned. In this case, we also observe a

reduction in the coupled part of the design process. This is mainly because Tasks 11, 4, and 6, which have the highest influence on the most dominant mode, are torn. On the contrary, Case 5 offers the least improvement in all the discussed area. In Case 5 only Task 6 is torn, which influences on the most dominant mode 12% less than that of Task 11. (Table-4)

4. It can also be observed that Case-3 offers the best case scenario only if we are restricted to a certain number of tear-out tasks. That is to say that "Coupled Part Reduction" (CPR) is relatively better. We don’t see a big difference as far as other criterion is concerned. Case-3 offers 50% and 44% better CPR than that of Cases 1 and 2 (Fig-11).
5. The total work decreases in all mentioned cases. Case-1 has the most improvement, by 85%, while Case-5 exhibits minimal improvement, by a factor 32% (Fig-12).
6. The rank of the design process dominant mode also decrease after reduction of the dynamic order of the G.A. airplane design process. It can be observed that Case-5 has the minimum ranking improvement (Fig-13). Dynamic order reduction of the design process was performed by the tearing-out of Task 6 only, which influences on the most dominant mode is minimum (relative to Tasks 11 and 4).

This example shows why we need to have a systematic approach, as presented here, in the implementation of "dynamic order reduction" or "tearing".

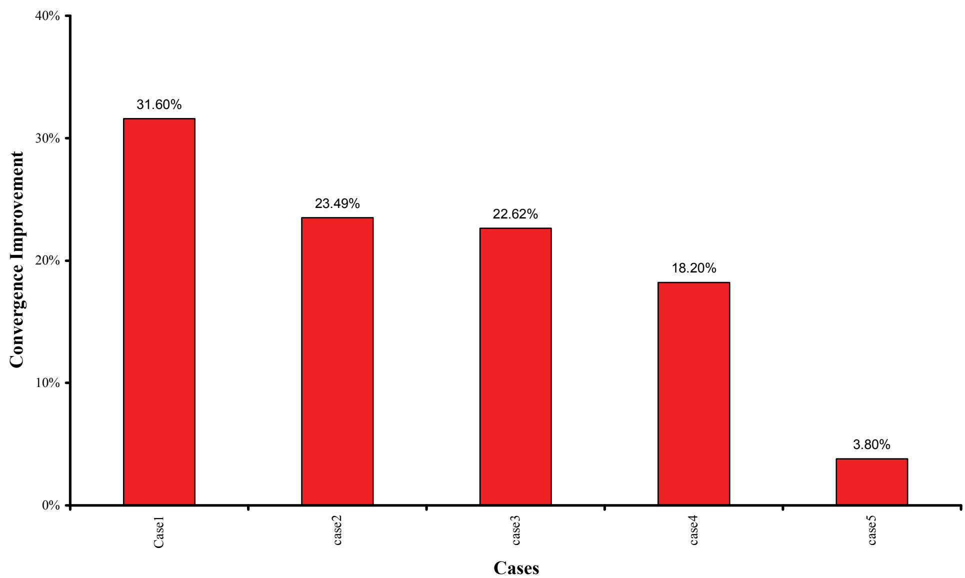

Fig. 8. Convergence Improvement in each scenario

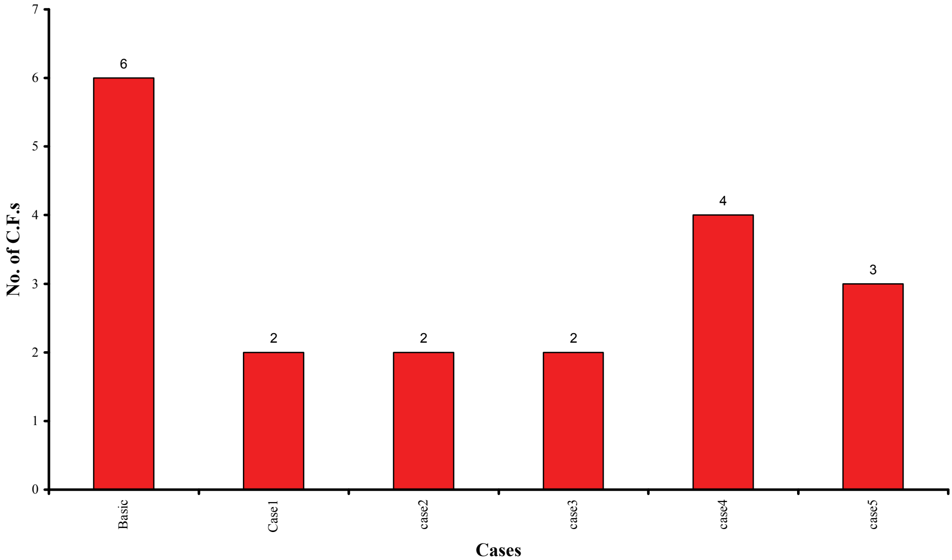

Fig. 9. No. of C.F.s in basic WTM and in each scenario.

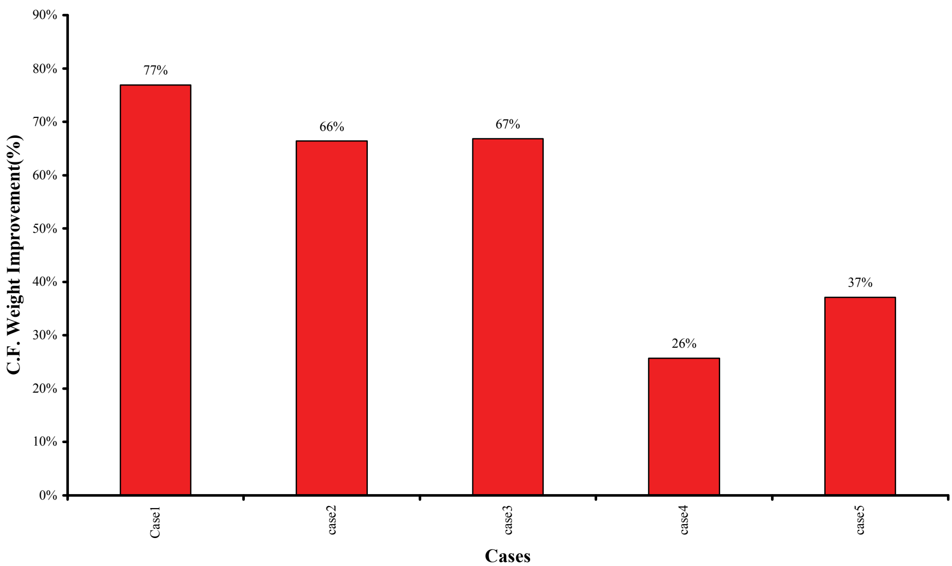

Fig. 10. Improvements in C.F.s Weight in each scenario

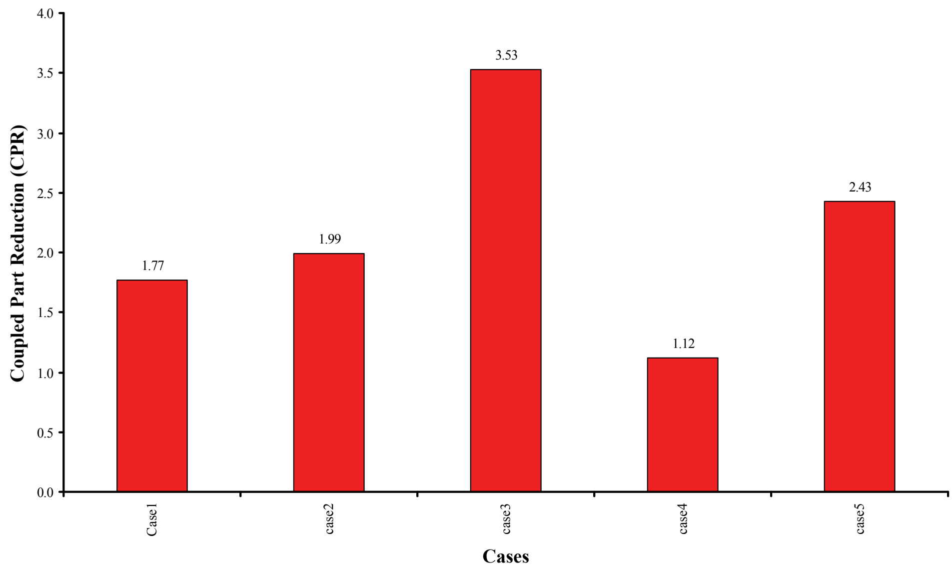

Fig. 11. Coupled Part Reduction (CPR) in each scenario

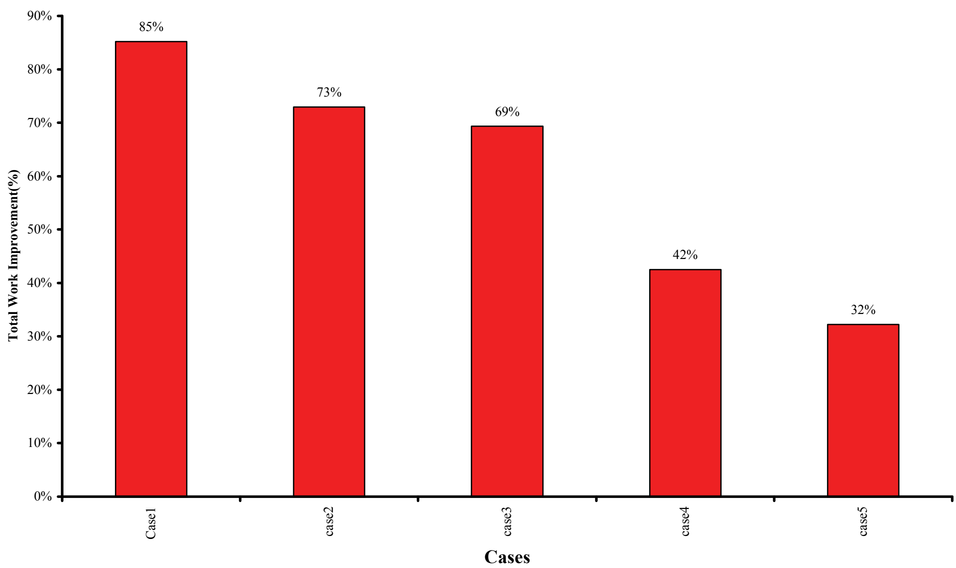

Fig. 12. Total work Improvements in each scenario

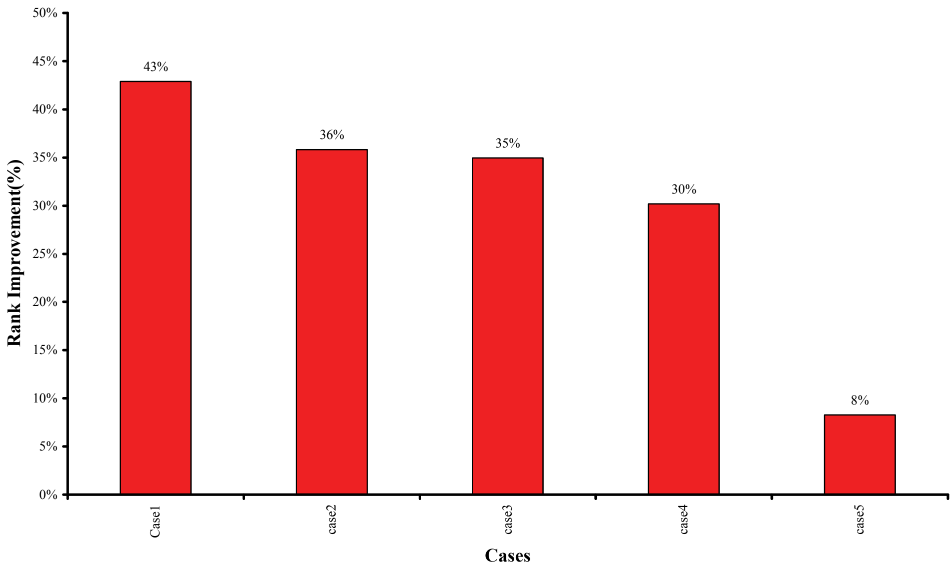

Fig. 13. Rank Improvement in each scenario

5. Discussion

This chapter presents a systematic approach to re-organize a complex design process to a more manageable one based on its analogy to dynamic systems. The proposed method is most useful where there are some limitations on time and budget as well as background experience. This new technique could also serve as a component of the Integrated Airframe Design (IAD) to systematically reduce the design cycle time. The current approach, being simple in nature, can easily be used to prevent additional expenses incurred by employing more elaborate management techniques.

The most interesting feature of this method relates to the fact that it enables engineers to have a management tool of their own to help them better understand the effects of their decisions while dealing with the information cycles.

This approach could also be used as a means of evaluating the possible effects of items, such as: (1) international cooperation and (2) sub-contracting in very big projects. Figures 5, 6 and 7 show how coupled parts of a design process can be converted into modular processes via the proposed technique.

In fact, complex projects such as the International Space Station (ISS) or "Traveling to Mars" are good examples of possible re-evaluations via the current technique. In such projects, proper breaking of information cycles is essential to the success of the project, as the budget constraints are a dominant feature of such projects.

Current chapter could also be used to reorganize engineers to improve the overall organizational behavior in terms of "time of response". Through analyzing the project WTM, proper arrangements for engineers with different levels of skills, knowledge, and experience can also be found. This approach provides a systematic way to increase the responsiveness of an organization by arrangement engineers based on their skills.

Regardless to all the benefits it must be note that there are some legitimate questions regarding the validity of such techniques. In fact, the major concern in applying crisp mathematical procedure in real world applications is the fact that the real world comes with a tremendous amount of details which are not normally modeled. Thus, there is always a concern regarding the influence of "tearing" on the "Quality of the design work".

Fundamentally, by imposing time and budget constraints, one can not expect to have any increase in the quality of the design work. In general, we do not desire to jeopardize the integrity of the design work through imposing such time and budget constraints. Therefore, it would be logical to expect the same while applying the discussed "tearing". Fortunately, using approaches such as "Robust Design" could decrease this sensitivity and, in any case, mathematically guarantee the integrity of the project. The idea, therefore, demands further investigation which has been the subject of the authors separate research. Studies conducted so far show that it needs to somehow correlate and balance the "convergence speed of iterations" and the "quality of the design work".

Another interesting outcome of this method relates to projects, where the entries of the eigenvectors are numerically close to one another. This happens when all experts give the same weight factor to their own work. In such cases, the manager still needs to have a clear understanding of the relative importance of either working groups. One can easily conduct a sensitivity analysis on dependency amount the tasks, and has access to tools such as described in this chapter.

In this study, we consider only the effect of C.F.s on iteration convergence speed. However, it could also be add effect of the number of inputs and outputs of each C.F. those are candidate to the tear-out process.

It is well noted that in some cases, due to the changes in dependency amount the tasks, the assumption of having a time independent work transformation matrix (WTM) will no longer be applicable. In such cases, one could model the complexity amount disciplines to minimize the information cycles inside the organization. Nevertheless, we continually need to exercise caution as to whether the assumptions regarding the linear dependency coefficients is reasonable.

The method described in this chapter aim to open a new window from which chief engineers can improve their management skills. These tools should not be treated as formulas that are expected to deliver crisp results. Rather, they should be seen as strong tools that can provide systematic alternatives to manage a design process.

Although mathematical methods are straightforward and easy to comprehend, there would, however, always be some concern for their suitability in complex socio-economical processes such as cases of multidisciplinary design works. This concern can only be investigated by the proper implementations of the discussed method in real engineering works. Nevertheless, the proposed method stems from solid mathematical background and any possible shortcomings are expected to be dealt with reasonably straightforward.

6. References

AGARD-R-814,"Integrated Airframe Design Technology", 8-9 May, 1996.

Austin S. A, Baldwin A. N., Li B., Waskett P. R.," Analytical Design Planning Technique (ADePT)", Design Studies, Vol. 20, No. 3, April 1999.

Browning Tyson R. “Modeling and Analysis Cost, Schedule, and Performance in complex System Product Development” , Ph.D. Thesis, MIT, December 1998.

B. Soltanmohammad “Design Process Control Based on Dynamic System Characteristics “, Ph.D. Thesis, Sharif University, Tehran - IRAN, Agust 2006.

Clark, Kim B. and Steven C. Wheelwright (1993b) *Managing New Product and Process Development*, New York:Free Press.

David G. Ullman,”The Mechanical Design Process”, McGraw-Hill, 2003.

Eisenhardt, Kathleen M. and Behnam N. Tabrizi (1995) "Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry" *Administrative Science Quarterly* 40(Mar.): 84-110.

Eppinger,S., Whitney, D., Smith, R. and Gebala, D., ”A Model – Based Method for Organizing Tasks in Product Development”, Research in Engineering Design,6,PP. 1-13,1994.

Kurt Hacker. And Kemper Lewis, ”Using Robust Design Techniques To Model The Effects Of Multiple Decision Makers In A Design Process.” ASME Design Engineering Technical Conferences, Atlanta, Georgia,1998.

Kusiak, A. and Wang, J., ”Efficient organizing of design activities”, International Journal of Production Research, 31,735-769, 1993.

Minc Henryk, “Nonnegative Matrices”, John Wiley & Sons, 1988

NASA/CR-2001-210658, William Spitz, Richard Golaszewski, Frank Berardino, ”Development Cycle time simulation for civil aircraft”, Gellman Research Associates, Inc., Jenkintown, Pennsylvania, 2001.

Nam P. Suh,”A Theory of Complexity and Applications”, 2003.

NSF Strategic Planning Workshop Final Report” Research Opportunities in Engineering Design”, April 1996.

Pahl G. and Beitz W.,”Engineering Design: A Systematic Approach”, Springer – Verlag London Limited, 1996.

Robert P. Smith, Steven D. Eppinger.” Identifying Controlling Features of Engineering Design Iteration”, Management Science, Vol. 43, No. 3, March 1997.

Robert P. Smith, ”Development and Verification of Engineering Design Iteration Models,” Ph.D. Thesis, MIT Sloan School of Management, Cambridge, MA, August 1992.

Rogers, J., “A knowledge – based tool for multilevel decomposition of complex design problem”, NASA TP 2903, may 1989.

Shearer, Murphy, Richradson, "Introduction to System Dynamics”, Addison – Wesley, 1971

Soo-Haeng Cho, Eppinger. S., “Product Development Process Modeling Using Advance Simulation”, ASME Design Engineering Technical Conferences and Computer and Information in Engineering Conference, September 2001.

Steward, D., “The Design Structure System: A Method for Managing the Design of Complex Systems”, IEEE Transactions on Engineering Management, EM -28, 1981.

Steward, D.,” System Analysis and Management: Structure, Strategy, and Design”, New York: Petrocelli Books, 1981.

Yassine A., “An Introduction to Modeling and Analyzing Complex Product Development Processes Using the Design Structure Matrix (DSM) Method”, Product Development Research Laboratory.

Yassine, A., Falkenburg, D., Chelst, K. "Engineering Design Management: an Information Structure Approach", International Journal of Production Research, Vol. 37, No. 13, 1999.

Wei Chen and Kemper Lewis, "A Robust Design Approach for Achieving Flexibility in Multidisciplinary Design", AIAA Journal, 1999.

5

Supervisory Control of Industrial Processes

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1. Introduction

Modern production is complex, integrated and is constantly being adapted to the market requirements by means of the reconfiguration of equipment structure and process alteration. The development of such production is performed based on evolutionary strategy by successively engaging (eliminating) stand-alone technological systems.

Evolutionary developed technical systems and facilities presently make up a considerable share of technical systems. It is typical both for high-tech industries, namely: aviation, space exploration, military equipment, machine-building (Sujeet, 2005), and for applications based on large-scale interconnected production complexes (e.g. oil- and gas-producing industry, oil and gas transportation, city economy engineering etc) (Gilard, 1999; Van Brussel et al., 1999; Jo, 1999; Ambartsumyan, Prangishvili, Poletykin, 2003; Ambartsumyan, Kazansky, 2008; Ambartsumyan, Potehin, 2003; Ambartsumyan, Branishtov, 2006).

Evolutionary developed technical systems and facilities are featured by complex control system availability. The latter integrates into a single whole different, as to the purposes, automatic control loops (automatic control and regulation of physical process parameters, automatic shielding and blocking, logical configuration control) as well as the functions of supervisory control mainly aimed at coordination of different processes in a technical system.

Supervisory control (SC) is intrinsically logical and is to provide the required operational sequence and exclude mutual blocking and deadlocks for stand-alone components (operating according to their internal rules time scale). SC is discrete and asynchronous by its nature and most commonly reveals itself as the change of event flow as required by certain application (technical system functionality).

It is important to consider two "event" aspects: first, everything happens as the result of a certain event; second, the change of states is regulated by events – there is no physical time though the system is dynamic.

Though control systems are widely spread in the technical systems of such kind (Sujeet, 2005; Gilard, 1999; Van Brussel et al., 1999; Jo, 1999; Ambartsumyan, Prangishvili, Poletykin, 2003; Ambartsumyan, Kazansky, 2008; Ambartsumyan, Potehin, 2003; Ambartsumyan, Branishtov, 2006), presently there is no appropriate theoretical base to solve such supervisory control tasks as local control loops coordination, configuration of material flows structure and interaction with operations staff.

Most spread concept of practical engineering of such systems is based on the model of interacting ″black boxes″: a ″black box–control object″ and symmetrically connected with it as to inputs and outputs a ″black box–control system (device)″. (Fig. 1).

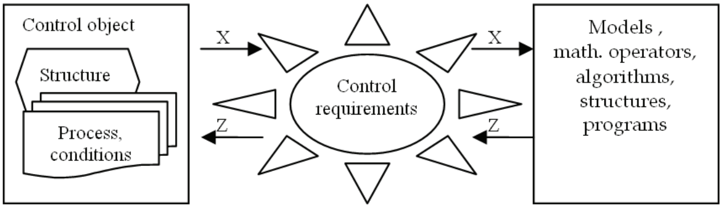

Fig. 1. The scheme of transfer from the object data base and control requirements to the mathematical description of the control

The first ″black box–control object″ is formed as a data base on the control object and technique at the stage of the object examination and includes the requirements of this object appropriate behaviour. The task of the required control search is tackled by the defining of a ″black box–control system″ able to monitor the behaviour – the event flow and, with the control purpose taken into account, to affect the object inputs in such a way that an appropriate behaviour of the object is achieved.

The question is how to search for a ″black box–control system″ with information on the first black box available. Common engineering practice shows that information on control object behaviour is only used indirectly.

What is the problem? We may speak about precise correspondence between a ″black box–control object″ and a ″black box–control system″ only as far as inputs and outputs are concerned, while behaviour is an approximate result of the designer's informal, speculative experiment with the initial data and limitations – the information the designer acquires considering the process physics peculiarities and the object structure properties. At that, there is not any confidence that a ″black box–control system″ can limit the behaviour of a ″black box–control object″ and provide its meeting the requirements since they, as a rule, are specified as models of another (not "event") nature and the extent they are taken into account depends on the designer's skills. The above leads to serious problems: designer's uncertainty in the fact that the designed system complies with the control tasks set; the necessity to make laborious verification of such compliance by computer simulation and the refinement of the designed system at facilities.

For the last 10–15, a sophisticated interaction among computer-driven actuating devices necessitates, when engineering, to analyze the design solutions safety and correctness, to validate technical systems implementation techniques, to take other approaches actually based on testing. It is a common knowledge that such approaches only can reveal a part of errors but cannot guarantee the system as a whole is error-free.

Different engineering approach than that based on two black boxes concept is declared in the theory of discrete event dynamic systems and supervisory control paradigm. The abbreviation is often simplified to DES. The distinctive features of supervisory control theory (all basic concepts and notions of this paper are borrowed from (Cassandras, Lafortune, 2008)) are as follows:

- The controlled object is represented in DES model by three components: generator G of $L(G)$ language – proper control object, specification language K – limitations and G functionality required, supervisor S – control component in DES;
- Setting and solving the task of formal synthesis of S on $L(G)$ and K.

The above, in its turn, creates a theoretical basis for machine control engineering fundamentally different from the deciphering of "black boxes" approximately fitting each other. What does it give as compared with the classic procedure of discrete process control system synthesis according to two-black-boxes model?

First, the description of the object as $L(G)$-language generator G, limited by nothing, is more simple than the object description with all the admissible behaviour limitations taken into account. This work is performed as a separate stage – primary object examination and constructing a model "as it is".

Second, to form the required functionality (K specifications) basing on a generator G model already available is also easier than to consider all limitations and requirements in yet non-existing control system.

Third, control task is solved formally: a supervisor (provided the initial data is correct) is synthesized and does not require verification while the object and its behaviour are specified by object and know-how specialist and he is responsible for the data correctness, its verification and validation.

The present paper formulates the purpose of DES theory development, with the structural properties of technical systems taken into account, thus creating effective methods to synthesize a supervisor as an instrument to solve the task of consistency and co-ordination control of stand-alone components in a technical system.

Here below is given a brief survey of basic concepts and major noted results, as to DES and supervisory control, followed by the description of the present paper tasks and the results obtained.

2. Basic concepts and definitions

DES behaviour is considered generally as behaviour of a certain generator (source) of strings (sequences) of the events from a finite set of events E. The event $e \in E$ is an abstraction for a multitude of facts associated with DES "life". Events are instantaneous, occur spontaneously in unpredictable moments, therefore the only thing that can be observed is their sequences that are represented by strings. Event examples are: the facts of change in position and state of separate object components; commands to which the object reacts by the change of its state (position); characteristics of normal and abnormal states etc.

The main operation of strings forming is concatenation (we would like to remind that concatenation is the appending of separate events or entire strings of events on the right to the string, including ε – a space character). For the string, an integral function $\mu(s) = n$ is defined, where n is the number of characters in string s. If $n = 0$, $s = \varepsilon$. A set of all string of any finite length is designated by E^* (it is endless but countable). Let a string s consist of three parts: r, u, $t \in E^*$ connected by concatenation in such a way that $s = rut$, where r – a prefix, t – a suffix, and u – a substring of string s. Any subset of strings $L \subseteq E^*$ is called a language over E. If L includes ε and, jointly with any string s, contains all its prefixes, L is a prefix–closed language. As usual, conventional language operations are defined, namely: concatenation, prefix-closure and Kleene-closure.

In many constructions of DES theory, a couple of very important operations over languages are used: a projection P and a back projection P^{-1}. Let E_1, $E_2 \subset E$ be such that $E_1 \cup E_2 = E$ (possibly $E_1 \cap E_2 \neq \emptyset$). Projection P_i of any string from E^* on E_i is defined in three steps:

1. $P_i(\varepsilon) = \varepsilon$; 2. $P_i(e) = \varepsilon$ if $e \notin E_i$, otherwise $P_i(e) = e$; 3. $P_i(se) = P_i(s)\ P_i(e)$ for $s \in E^*$ and $e \in E$. Conceptually, a projection of strings from larger alphabet E on smaller one E_i deletes from the string all characters from $E \setminus E_i$ (all characters outside E_i). Inverse function $P_i^{-1}(s) = \{t \in$

E^*: $P_i(t) = s\}$. $P_{i\text{-}1}(s)$ correlates every string $s \in E_i$ with some subset of strings E^* the projects of which on E_i equal s. Both operations are in natural manner extended to the languages $L \subseteq E^*$ and $L_i \subseteq E_i^*$. $P_i(L)=\{t \in L_i: (\exists s \in L) [P_i(s) = t]\}$; $P_{i-1}(L_i) := \{s \in E^*: (\exists t \in L_i) [P_i(s) = t]\}$.

In projection operation definition, instead of set indexes, for the sets, the events of which are excluded from the result of this operation, we shall use the designation of the set itself: P_{E_i} or $P_{E_i}^{-1}$.

Languages are a good instrument to observe DES behaviour but in order to perform analytical study and to set the task of providing the required dynamics (off-line behaviour), it is necessary to present a countable string set as a mathematical operator. There are many ways to present languages in the form of mathematical operators that generate or recognise the language. In DES theory, for these purposes, as a rule, finite state machines are used. A finite state machine is defined as $G = (Q, E, \delta, \Gamma, Q_m, q_0)$, where Q – a set of states; E – a set of events; δ – a transition function $Q \times E \to Q$; $\Gamma : Q \to 2^E$ – a function of admissible events in each state; Q_m – a set of marked states; q_0 – an initial state. We would like to note that in this definition the function of outputs is missing. For every state q_i the function of transitions is specified for the events admissible in this state (e.g. for $q_i \in Q$ and $e \in \Gamma_i$ the function $\delta(q_i, e) := q_j$). This definition can be naturally extended also for the following event strings: $\delta(q_i, \varepsilon) := q_i$, $\delta(q_i, se) := \delta(\delta(q_i, s), e)$ for $s \in E^*$ and $e \in E$. Let's denote by $\delta(q_i, s)!$ the fact that the function $\delta(q_i, s)$ is defined.

The function $\Gamma : Q \to 2^E$ is excessive in a model definition but it simplifies many examination schemes and algorithms development when analysing the languages presented by finite state machines, e.g. consistency definition. $Q_m \subset Q$ is a subset of marked states – the states corresponding to a certain functionality of G, with one of them necessarily being initiated in a specific variant of G use.

The language generated by G machine is designated as $L(G) := \{s \in E^* : \delta(q_0, s)!\}$. This is a set of all strings from E^* admissible in the initial state q_0. It is evident that $L(G) \subseteq E^*$. If the machine is completely defined, $L(G) = E^*$. It G is represented by a weighed graph of transitions, $L(G)$ is presented as a set of strings of the events weighing the edges of all the paths originated from the initial state q_0.

When a sophisticated DES is defined via components, two more operations on machines are often applied: Cartesian product and parallel composition. Product definition

$$G_1 \times G_2 = (Q_1 \times Q_2,\ E_1 \cap E_2,\ \delta_{1,2},\ \Gamma_{1\times 2},\ Q_{m1} \times Q_{m2},\ (q_0 := q_{01,\,02}))$$

is conventional but there is one nuance: a function of transitions is defined on common events for every pair of states. Isolated pairs and those unattainable from the initial state are discarded together with their associated transitions. From the definition it follows that the language $L(G_1 \times G_2)$ of the Cartesian product of two machines is equal to $L(G_1) \cap L(G_2)$ – the intersection of these machines languages.

Parallel composition (or just composition, let it be designated as $\oplus$) is defined on the union of events of both machines $G_1 \oplus G_2 = (Q_1 \times Q_2, E_1 \cup E_2, \delta_{1,2}, \Gamma_1 \oplus_2, Q_{m1} \oplus Q_{m2}, (q_{01}, q_{02}))$. At this, it is possible that $E_1 \cap E_2 \neq \varnothing$, then on common events, transition synchronization takes place in both components. If the event is individual, transition takes place in one component (provided for this pair this event belongs to the value area of the corresponding function Γ).

Formally:

$\delta((q_1, q_2), e) = \{(\delta_1(q_1, e), \delta_2(q_2, e))$ if $e \in \Gamma_1(q_1) \cap \Gamma_2(q_2)$ $|$ $(\delta_1(q_1, e), q_2)$ if $e \in \Gamma_1(q_1) \setminus E_2$ $|$ $(q_1, \delta_2(q_2, e))$ if $e \in \Gamma_2(q_2) \setminus E_1$ $|$ and indeterminate in other cases$\}$.

It is obvious that both operations are associative and, provided parentheses are places accordingly, may be easily generalized for n machines: a product – G $= \times_1^n G_i = G_1 \times \ldots \times G_n$; a composition – G = $\bigoplus_1^n G^i = G^i \oplus \ldots \oplus G^n$.

The initial stage of object study (modelling) is dedicated to prognostication of possible physical behaviour of the entire object or its subsystems, i.e. consideration of possible actions and possible variants of behaviour in the absence of any control and restrictive actions. At this stage, DES is represented by machine G as a language $L(G)$ generator. Thus, G generates event sequences of any kind reflecting control-free DES behaviour. In order to specify and provide control in DES, a set of events E is subdivided into two disjoint subsets: E_c – a subset of controllable events corresponding to the commands and E_{uc} – a subset of uncontrollable events for which the moments they occur are unpredictable.

The present-day view on DES was first worded in (Ramadge, Wonham, 1987) though then the term "discrete event systems" was not used but a new technique of discrete process modelling and control was stated. The term "discrete event systems (DES)" appears already in (Ramadge, Wonham, 1989), where DES is represented by generator G of different sequences of events from E. G is limited by nothing and therefore the sequences reflect the behaviour $L(G) \subseteq E^*$ unbounded by control. Any DES has some functionality to implement which are required not all possible sequences but only those providing this functionality and meeting the limitations specified. In order only to provide the required event sequences, G is term "supplemented" by supervisor S, built-in a "feedback" manner (Fig. 2).

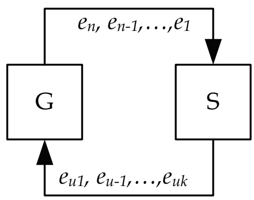

Fig. 2. The scheme of object – supervisor interaction

The scheme in Fig. 2 is no different from the conventional structure "control object – control system" but the behaviour is absolutely different. First, a generator event sequence covers all events in the system; second, a supervisor sequence includes only controlled events and third, controlled event e_k is incorporated into G output sequence conditioned to its presence also in S sequence. This allowed to define S transparently enough as a function of strings from the set $L(G)$: $S : L(G) \to 2^E$.

Supervisor S is equipped with a mechanism of G sequences blocking provided they do not meet limitations. For this purposes, S structure comprises one more component allowing for G "free" behavior restriction – a specification K. For the real object, a certain functionality (depending on G destination) must consider a multitude of all types of requirements and limitations $R = \{r_i \mid i=1,..,n\}$. As a rule, R is formed reasoning from physical, process and design limitations imposed on joint behaviour of separate G components. The allowance for all restrictions R gives rise to $K \subseteq L(G)$ – a language of specifications – a subset of sequences dictated by G functionality. Actual control scheme stated in (Van Brussel et al., 1987) is presented in Fig. 3. It took the name of "Supervisory control theory" or RW approach (named after its authors J. Ramadge J. and W. Wonham W).

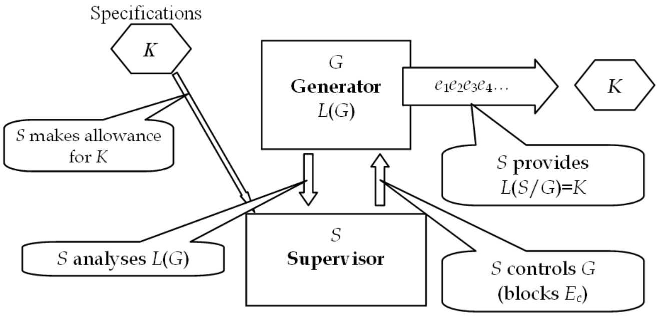

Fig. 3. Interrelationship of supervisory control components in DES

The functioning of G in the presence of S is denoted by S/G and a corresponding language – $L(S/G)$. The scheme symbolically shows that specification K is involved in S forming and in providing blocking. Supervisor is designed, with K taken into account, in such a way that, in accordance with $L(G)$ observation results, S blocking mechanism provide the language $L(S/G) = K$ at DES output. We would like briefly to dwell upon the way $L(S/G)$ generation is realized. G is supposed to have its own controller that generates control events while a supervisor blocks the events the occurrence of which runs counter to the specification (Fig.4).

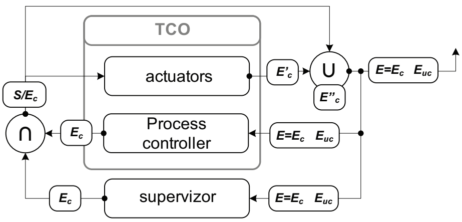

Fig. 4. Control scheme proposed in the paper (Ramadge, Wonham 1987)

Supervisor S monitors G output events and permits all E_{uc} events, while as to E_c events, it is "entitled" to permit or not permit them (to block by imposing limits on transition function $\delta(q_i, e_c) := q_j$). For every string $s \in L(G)$ generated by G under S control, a supervisor only permits a set $\{S(s) \cap \Gamma(\delta(q_0, s))\}$ – a set of events admissible in G current state $\delta(q_0, s)$ and not conflicting with K. Hereinafter, $\delta(q_0, s)$ will mean a state G transfers to from q_0 as affected by s. In other words, G cannot realize the event from its current active event subset $\Gamma(\delta(q_0, s))$ unless this event is contained also in $S(s)$. However, making allowance for the fact that E is subdivided into **controllable** and **uncontrollable** subsets and the appearance of the latter is limited by nothing, supervisor S is called **admissible** if for all $s \in L(G)$, always $E_{uc} \cap \Gamma(\delta(x_0, s)) \subseteq S(s)$, i.e. S is specified in such a way that in all states it is impossible to block an uncontrollable event and vice versa: S blocks the events not meeting limitations (irrelevant to K). Further on, only admissible supervisors will be considered.

For the modelling of DES with passive actuators in paper (Chalmers, Golaszewski, Ramadge, 1987) it is suggested that the model should be expanded with forced controllable events and a new control scheme (Fig. 5), with controllable events generated by supervisor, is developed. For such model, the terms of controllability for specification language are also defined.

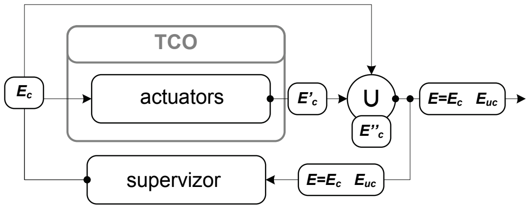

Fig. 5. Control scheme for DES with forced controllable events

For both models were developed the methods of supervisor synthesis as a finite state machine (FSM) with output converters regulating blocking (or generation) of E_c events. However, for the methods proposed the number of supervisor S states is less or equal to the product of the number of states for G and K (Cassandras, Lafortune, 2008).

DES dynamics is interpreted in the sense that the system (a pair of G and S), once set to the initial state, operates off-line, reacting to internal and external events, and provides a resulting flow relevant to G structure and S control.

Since 1987, there have been a lot of publications on DES subject-matter. At three last world IFAC Congresses, three sections on DES theory were working; IFAC Committee on DES theory was established; symposiums on this subject-matter are held. The paper scope limitation does not allow to survey the results on DES theory so we shall confine ourselves to listing the basic research trends. They are as follows:

- Study of DES as a dynamic system with a certain range of states and a structure of event transitions; the study of properties of the languages generating DES from the position of general control theory and the definition, in terms of language properties, of controllability, observability, attainability, safety (avoiding blocking situation) and some others;
- Study of different models of G and K specification (finite state machines, Petry nets etc) and the development of synthesis (engineering) methods for supervisor S on G and K;
- Assessment of supervisor complexity at synthesis with FSM models of G and K involved;
- Study of different modular presentations of supervisor S in the form of parallel generators of sub-languages with their subsequent combining via product operation (conjunctive scheme), via parallel composition operation (disjunctive scheme) and others;
- Development of programming methods for logical controllers in industrial systems with supervisor control theory applied;
- Creation of program verification methods for industrial systems with DES, as simulation instrument, applied;
- Development of the methods of industrial system state diagnostics using DES as a modelling instrument.

A detailed survey of the results obtained on DES can be found in (Cassandras, Lafortune, 2008); herein the major results on controllability from (Ramadge, Wonham, 1987; Ramadge, Wonham, 1989) are set forth:

- Is formulated the condition of controllability for the language: $K \subseteq L(G)$ is controllable if $\overline{K}E_{uc} \cap L(G) \subseteq \overline{K}$
- It is proved that if *K* is controllable, there exists a non-blocked *S* such that *L(S/G) = K*
- Are developed the methods to design supervisor *S* as a function of strings (Ramadge, Wonham, 1987; Cassandras, Lafortune, 2008).

However, the direct practical application of the proposed models and methods is confined to lab examples of dynamic DES engineering and supervisor synthesis. Such constraint is explained by high dimensionality of the object states set. To analyze for controllability, a complete DES specification of generator *G* is required. Even in the simple example given here below (a machine with four mechanisms) the number of states equals 4356. (The number can be considerably reduced with DES structural features taken into account).

Main direction of works focused on overcoming supervisor synthesis complexity is based on different kind of modularity. Methods of modular supervisor synthesis for *G*, as a single entity, are elaborated. At this, different control schemes are explored (disjunctive, conjunctive, hierarchical, generalized). Pioneer work (Ramadge, Wonham, 1989) that initiated the development of modularity, as applied to DES theory, was evolved and generalized in (Yoo, Lafortune, 2002). Later, different authors (De Queiroz, Cury, 2000; Gaudin, Marchand, 2003) developed the methods of modular supervisor synthesis on modular description $G=<G_1, G_2, \ldots, G_n>$ and modular specification $K=<K_1, K_2, \ldots, K_n>$ of modular *S*. However, the complexity of such synthesis and weak correspondence of the initial specification structure to the resulting supervisor make the methods proposed scantily attractive for practical implementation. Besides, controllability properties are verified on language models *K* and *L(G)* defined for the object (Plant) as a whole, which makes it difficult to apply these results to real industrial facilities.

The present paper sets the task to develop a prototype of structured dynamic DES by structuring the object components according to their functionality. To operate the model, the paper proposes the methods that will allow to raise the dimension of supervisor control tasks and form a theoretical basis for a new supervisor control engineering technique. Structured are all three DES components but mainly object model and specification.

3. Structured Discrete Event Systems (SDES)

3.1 Base concept – the structuring of events and specifications

The author considers it promising to develop a supervisory control theory in the direction of structuring the events according to their role in production operations and in the required object behaviour specification. This research is based on two specific machinery features from DES-modelling point of view. The first feature relates to the fact that for discrete machinery a set of events is usually subdivided into three sets. These are sets of controllable and uncontrollable events E_c and E_{uc} (typical for DES theory) and E_w is a set of expected events. The events from E_w simulate states (positions) of actuator(s) or object components. Supervisor cannot block E_w events as those controllable from E_c and thus E_w events are traditionally referred to uncontrollable events as per Wonham's classification (Ramadge and Wonham, 1987). However, E_w events are expected to occur as a response to E_c events – a confirmation of the fact that the commands sent to actuators were executed. So, the foregoing gives the ground to mark out E_w events as a separate set. The second specific feature is as follows: the behaviour of every actuator G^i is simulated by the language $L(G^i)$ of words over $E^i = \{E_w^i \cup E_c^i\}$ and the specification of desired behaviour is formulated as a language K over events $E_d = E_c \cup E_{uc}$, a totality of commands and conditions of their use. Making the allowance for these specifics, makes it possible to get numerous advantages both in defining DES and formulating controllability conditions and supervisor synthesis.

3.2 SDES definition

Definition 1: If the structure of DES is defined by: a collection of components $G=<G^1,G^2,\ldots,G^n>$; sets of E_i events, each being structured on $E^i = \{E_w^i \cup E_c^i\}$, and a set E_{uc} of general uncontrolled events; the behaviour of each DES component being defined by FSM $G^i = \langle Q^i, E^i, \delta_i, \Gamma^i, Q_m^i, q_0^i \rangle$ and $L(G^i)$ language, then the DES with the above structure is called well structured.

A set of common events for $G=<G^1,G^2,\ldots,G^n>$ is defined through the union of subsets $E = \{E_w \cup E_c \cup E_{uc}\}$, where E_w and E_c each are the unions of appropriate component subsets.

Note 1: Sets E_w and E_c for various mechanisms do not intersect, since various mechanisms have their own actuators and their states are individual.

Note 2: Components of G^i define the behaviour of G that is not limited (controllable) by anything, e.g. from the successive operation of $<G^1,G^2,\ldots,G^n>$ in any order up to their independent work in parallel.

According to the theory of supervisory control, a parallel composition of all object components is implemented, and, as the result, a model of uncontrollable object behaviour is created (Ramadge & Wonham, 1987). The narrowing of free behaviour is carried out with the constraints of purposeful joint behaviour considered. This, in essence, is the procedure of adapting the initial unlimited behaviour i.e specifying the behaviour as required by application. We would like to remind that the implementation of all restrictions generates a language $K \subseteq L(G)$ called a language of specifications. Establishing the restrictions is a creative process that requires an experimental approach to achieve a reliable result. Such experiment is quite difficult to carry out as the number of states is increasing in the course of composing. There is a collision.

On the one hand, a system analyst needs to get a general picture of all the transitions to analyze their admissibility.

On the other hand, it is unreal to do it for complete composition, since the number of states in it is too high (for practical applications this number is about $n \cdot 103$). Sequent revealing of restrictions in the process of pair-wise composing, gives a ground to doubt of such restrictions completeness or, on the contrary, of their extreme strictness. At the same time, there is no possibility to consider the joint action of components with those absent in the composition.

At the same time, it is known from the practice of discrete process engineering that the efficient behaviour of discrete systems is achieved by solving two control tasks, namely: operation control and control of operation sequence. Operation control is provided by the execution of a certain command and monitoring the corresponding object response. Commands and their reactions once defined, are iterated in various places of the sequence of operations. In process modelling, it is important to set up the sequence of commands and to evaluate the completeness and correctness of conditions. With the above in view, herein is proposed to create a specification of a well-structured DES with the events $E_d = \{E_c \cup E_{uc}\}$, i.e. combination of commands and conditions for their execution in sequence.

Definition 2: The language $K \subseteq E_d^*$ defined by FSM $\mathrm{H} = (Q^h, E_d, \delta_h, \Gamma^h, Q_m^h, q_0)$ as a set of strings defining the required specifications, is called a directive specification language (a process specification tapes language).

It is assumed that FSM H has no deadlocks (Fig. 6) and livelocks (liveloops, within which H fails to go out of a certain state subset and does not reach Q_m and then q_0), i.e. H is non-blocking.

It is worthy to be noted that if a graph is strongly connected and $q_0 \notin Q_m$, then q_0 transitions only as shown in Fig. 6 are possible.

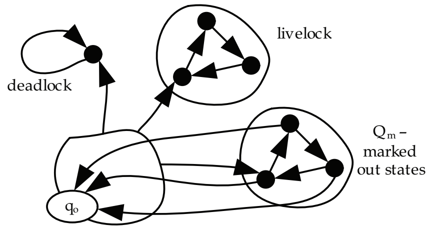

Fig. 6. Types of fragments in the machine H

The fact of non-blocking is easily verified. Contrary to the general DES theory (Cassandras, Lafortune, 2008), where deadlocks and livelocks result from the excessive general description via the product and composition, in SDES, there should be no hurry in cutting down "bad" states and transitions but, vice versa, it is necessary to check if any transition is missed to avoid deadlock or livelock situations.

Let's define a supervisor for G and K. It is conceptually evident, that supervisor is an operator that defins, for every string s, which of possible events, admissible for G, are suitable as the next event not conflicting with K. At this, supervisor remains admissible in terms of (Van Brussel et al., 1998) since it in no way limits E_{uc} occurrence and affects only E_c.

Definition 3. Supervisor S is a converter of strings admissible for the system $G = \langle G^1, G^2, \ldots, G^n \rangle$ initial state to the events $S(s) = \{\varepsilon \cup E_{uc} \cup \{e_c\}\}$ such that: first, these are any of uncontrollable events E_{uc} (i.e. S is admissible for G); second, these are controllable events e_c admissible for the current G state; third, these events do not cause blocking of S and $G = \langle G^1, G^2, \ldots, G^n \rangle$ composition.

Let's denote, as agreed, by $L(S/G)$ the language generating G under S control. It is evident that $L(S/G) \subseteq L(G)$. Let's also give a definition of $L(S/G)$ language generating S/G, that is consistent to the conventional definition of language generating G under S control.

Definition 4. The language $L(G/S)$ generating $G = \langle G^1, G^2, \ldots, G^n \rangle$ under S control contains the following strings:

1. $\varepsilon \in L(S/G)$;
2. $\forall s, e (s \in L(S/G) \wedge e \in S(s)) : se \in L(G) \Leftrightarrow se \in L(S/G)$

In other words, any string se belongs to $L(S/G)$ provided it also belongs to $L(G)$ being at the same time the extension of string s which also enters $L(S/G)$ by event e such that $e \in S(s)$. Possibly, $s = \varepsilon$.

Definition 5. A well-structured DES, for which the uncontrollable part is set up by definition 1, the desired behaviour is set by specification language $K \subseteq E_{d^*}$ $(K \neq \varnothing)$, and which is supplied with a supervisor S such that K is fulfilled, is called a structured dynamic discrete event system (SDES).
K fulfilment means that $P_{E_d}(L(S/G)) = K$, i.e. that K will be equivalent to the projection on E_d of $L(S/G)$ language that is generated by S/G.

3.3 Technical object modelling by structured DES

The events associated with real industrial objects, as a rule, are easily divided into groups (types) as proposed herein. Such event grouping is typical for process systems of many industrial spheres. Here below is the example which refers to the field of mechanical metal-working. We consider this example most interesting since it is close to illustrative examples frequently used in publications on DES (Ramadge, Wonham, 1987; Ramadge, Wonham, 1989; Chalmers, Golaszewski, Ramadge, 1987; Ambartsumyan, 2009).
The structuring of technical object (the first phase of study) includes as follows:

- enumerating actuators;
- defining for each of them the set of events necessary and sufficient for the outer supervisor to identify actuators behaviour;
- defining the classification of marked out events;
- defining the components and object behaviour in the compact-form languages, e.g. finite machine models.

In Fig. 7 a kinematical scheme of a small milling machine is presented. The machine consists of 4 mechanisms: "workpiece clutch" - G^1, "turntable" – G^2, "spindle" – G^3 and "cutter" – G^4

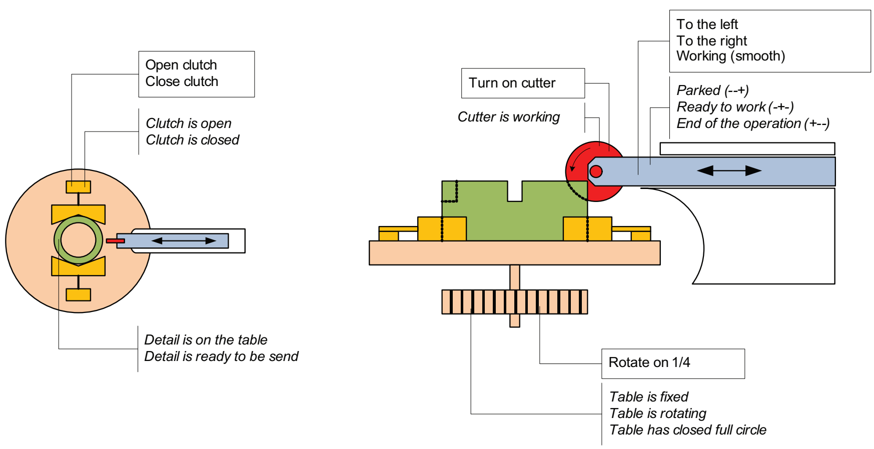

Fig. 7. Kinematical model of the machine

Let's enumerate the events and their semantics in the liveloop (behaviour) of each mechanism.

"Workpiece clutch" mechanism: e_{1-1} – to clamp, e_{1-2} – clutch closed, e_{1-3} – to unclamp, e_{1-4} – clutch closed, e_{1-5} – clutch is moving.
"Turntable" mechanism: e_{2-1} – to lock the table, e_{2-2} – table locked, e_{2-3} – to unlock the table, e_{2-4} – table unlocked, e_{2-5} – locker is moving, e_{2-6} – to make a ¼ turn, e_{2-7} – table is moving, e_{2-8} – table is turned, e_{2-9} – to switch off turning gear, e_{2-10} – table stopped.
"Spindle" mechanism: e_{3-1} – to move spindle fast to the left, e_{3-2} – feed zone, e_{3-3} – working position, e_{3-4} – to move spindle to the left, e_{3-5} – working zone, e_{3-6} – operation finished, e_{3-7} – to move spindle to the right, e_{3-8} – to move spindle fast to the right, e_{3-9} – parked.
"Cutter" mechanism: e_{4-1} – to turn on cutter, e_{4-2} – cutter working, e_{4-3} – to turn off cutter, e_{4-4} – cutter stopped, e_{4-6} – cutter unstable spinning.
Mechanisms behaviour, as agreed here above, will be considered as sequences (strings) of possible events. These sequences will be defined as finite state machines (Fig. 8–11). Hereinafter they are called component finite machines (CFM). It is easily seen that CFM transition graphs and graph edges weighed by events, specify operation of each mechanism quite transparently.

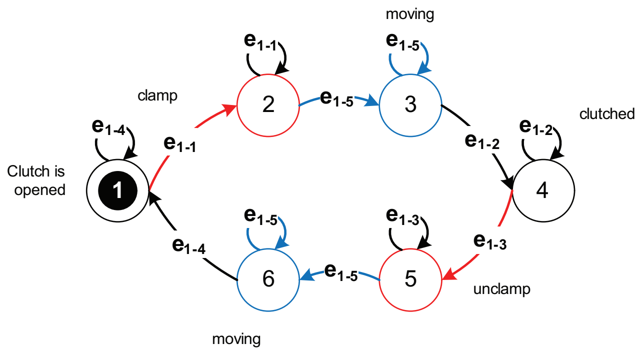

Fig. 8. G^1 CFM – a model of "Workpiece clutch" mechanism

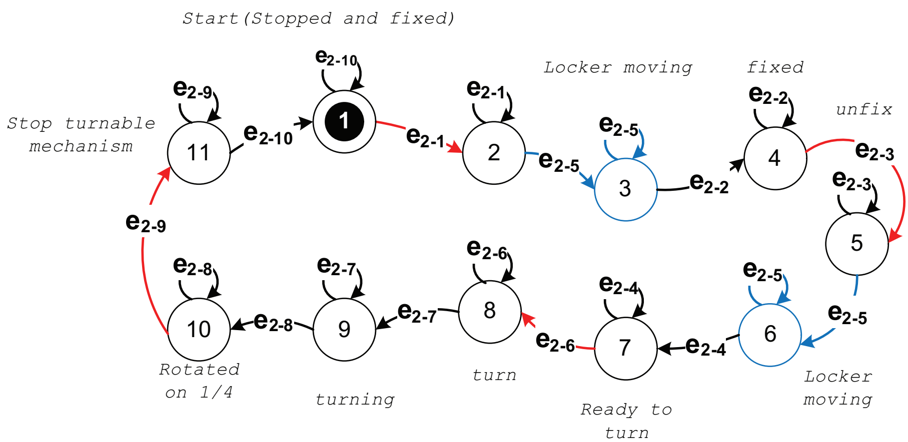

Fig. 9. G^2 CFM – a model of "Turntable" mechanism

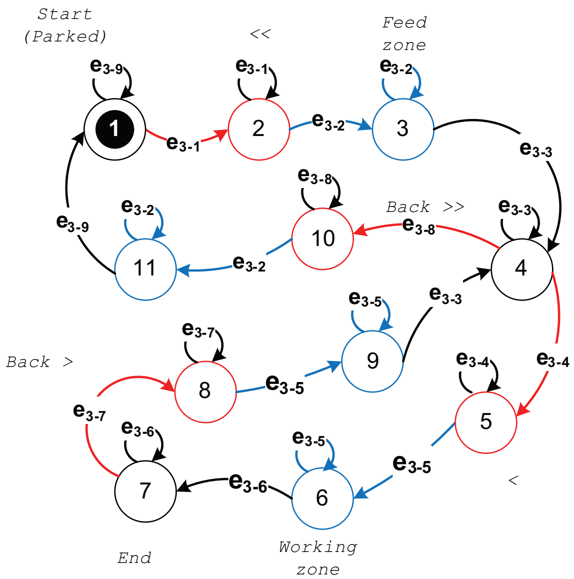

Fig. 10. G^3 CFM – a model of "Spindle" mechanism

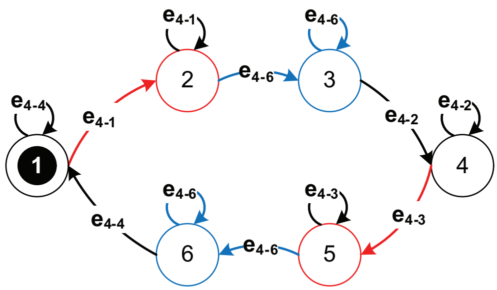

Fig. 11. G^4 CFM – a model of "Cutter" mechanism

It is easy to make natural event grouping in all the CFM, namely:
G^1 – $E_c^1 = \{e_{1-1}, e_{1-3}\}$, $E_w^1 = \{e_{1-2}, e_{1-4}, e_{1-5}\}$; G^2 – $E_c^2 = \{e_{2-1}, e_{2-3}, e_{2-6}, e_{2-9}\}$, $E_w^2 = \{e_{2-2}, e_{2-4}, e_{2-5}, e_{2-7} e_{2-8}, e_{2-10}\}$; G^3 – $E_c^3 = \{e_{3-1}, e_{3-4}, e_{3-7}, e_{3-8}\}$, $E_w^3 = \{e_{3-2}, e_{3-3}, e_{3-5}, e_{3-6}, e_{3-9}\}$; G^4 – $E_c^4 = \{e_{4-1}, e_{4-3}\}$, $E_w^4 = \{e_{4-2}, e_{4-4}, e_{4-6}\}$ and to see the events $E_{uc} = \{e_{ex-1}, e_{ex-2}, e_{ex-3}, e_{ex-4}, e_{\text{ex-s}}, e_{ex-w}\}$ common for all components (respectively: a workpiece is on the table; a workpiece is removed from the table; processing is over, clutch of s type , clutch of w type).

Note 3. Sets E_w and E_c for different mechanisms do not intersect.

It is evident, since different mechanisms have their own drivers and their positions for each mechanism are individual.

The next stage of a technical system SDES-modelling is the defining of the system behaviour specification based on the requirements to the system functionality and limitations. It is

done by forming the behaviour of G as an uncontrollable system, as a whole, followed by putting in limitations, thus "narrowing" G behaviour up to that required.
The traditional approach being applied, uncontrollable G behaviour is defined by component machines combination. Let's use two mechanisms of the above milling machine (Turntable and workpiece Clutch) to illustrate this.

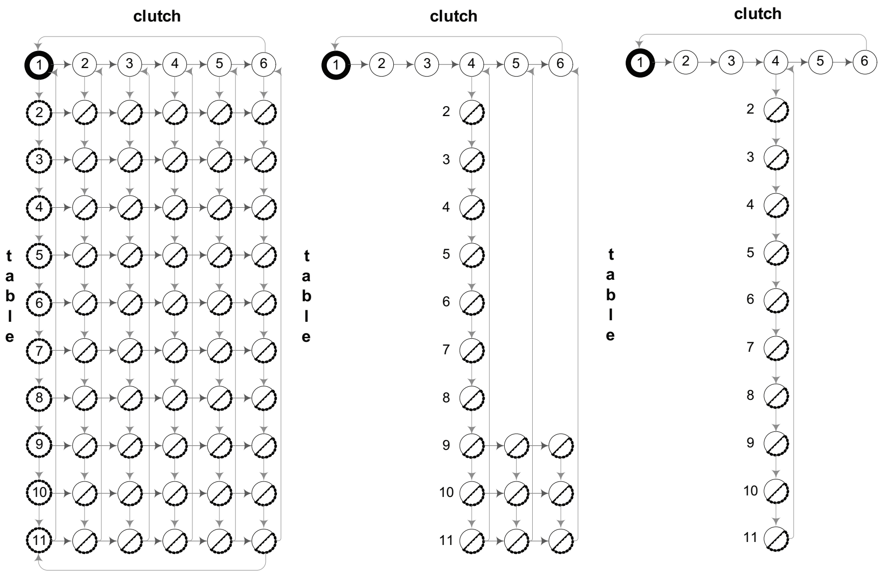

Fig. 12. CFM composition for G^1 and G^2: a) complete; b) with allowance for limitations r_1 and r_2; c) with allowance for limitations r_1, r_2, r_3

Pursuant to SC theory, we should make a composition of all machines to achieve "uncontrollable" G behaviour. DES, modelling "uncontrollable" behaviour of the first two mechanisms, is represented by $G^1 \oplus G^2$ composition, with relevant transition graph structure illustrated in Fig. 12-a. Here a structure of initial components transitions is shown: across - G^1 structure, down - G^2 structure, and relevant pairs are represented by nodes at arrows intersection. Edges weighing corresponds to weighing of transitions in the initial components.
Machine $G^{1\otimes 2}$ represents unlimited by anything, parallel operation of mechanisms G^1 and G^2 originating $L(G^{1\otimes 2})$ language.
In our example, the following restrictions as to joint behaviour of the mechanisms take place: r_1: "turning of G^2 "Turntable" mechanism is possible if a workpiece is clutched"; r_2: "if in the course of the table turning a workpiece unclasping begins , "Turntable" will only terminate turning".
The implementation of these technological restrictions are formally realized by banning the following state compositions: 1, 2, 3 of G_1 CFM and 2-9 of G_2 CFM. With these limitations applied, all pairs of states under verticals 1, 2, 3 and a number of pairs under verticals 5, 6 are excluded (Fig. 12-b). The same refers to their incident transitions. As the result, we get the machine K_1 as shown in Fig. 12-b. More detailed analysis of admissible transitions results in the necessity of one more limitation: r_3 – "at table turning, a workpiece unclasping is inadmissible", which makes specification more strict (K_2) as shown in Fig. 12-c.

Thus, we have DES of $G^{1\otimes 2}$ and it's necessary to provide its operation within the framework of language *K*. In what way is it possible to regulate a path choice in $G^{1\otimes 2}$ graph? In our example, for $G^{1\otimes 2}$ $E_c^{1\otimes 2} = \{e_{1-1}, e_{1\text{-}3}, e_{2-1}, e_{2\text{-}3}, e_{2-6}, e_{2-9}\}$,
$E_w^{1\otimes 2} = \{e_{1-2}, e_{1\text{-}4}, e_{1-5}, e_{2-2}, e_{2\text{-}4}, e_{2-5}, e_{2-7} e_{2-8}, e_{2-10}\}$.
Graph transition trajectory can be regulated by a function of transitions $G_{1\otimes 2}$ by blocking or accepting the events from E_c set with the help of supervisor *S* (outer to *G*) which dynamically interacts with *G* in a feedback manner. The way it can be realized is illustrated by our example. In state, $q_{1,4}$ in cycles 1, 2 and 3 of the table operation, a supervisor each time enables $e_{2\text{-}1}$ and disables $e_{1\text{-}4}$, and, after the table returns to its initial position for the 4-th time, it is $e_{1\text{-}4}$ that is admitted and $e_{2\text{-}1}$ that is banned.
So, CFM sequential merging and the detection of limitations for CFM joint operation are quite a complicated procedure even in our case. We have already noted that the detection of limitations in the course of pairwise component combination, gives the ground to doubt about the completeness of such limitations or vice versa in their excessive strictness. Besides, there is no possibility to predict the consequences of joint operation with the components still absent in the composition. For example, should we start CFM merging with "Spindle" and "Turntable" mechanisms, it will in no way possible to make allowance for the fact that between their "activities" a locker actuation will take place.
At the same time, for technical objects, their required behaviour is always defined by their functionality that is specified, for example, by text description. The required machine behaviour is presented by informal specification in table 1.

1) on arrival, the piece is locked by clutch; 2) after clenching, the spindle moves from park position to work position (to the left); 3) the cutter is switched on; 4) smooth feed to the left utmost position (operation is over); 5) the spindle moves to the right back to work position;	6) positioner makes a ¼ table rotation; 7) after the table is fixed, the next operation is carried; 8) after the table makes a turnover, the spindle is parked, the clutch is unclamped, the signal of the piece readiness is sent; 9) prior to parking, to switch off the cutter and wait for a stop.

Table 1. Text description of initial specification

At SDES-modelling, at this stage, a specification of joint behaviour in *K* language is applied. A specification, compliant with the text specification, is presented by machine $H = (Q^h, E_d, \delta_h, \Gamma^h, Q_m^h, q_0)$ shown in Fig. 13.
Since the verbal behaviour description, as a rule, is inaccurate, the resulting specifications may vary. The example of another interpretation of verbal description is presented in Fig. 14. The specification is described in conformity with verbal description. Basing on the information from table 1, it is possible to assume that at the beginning of operation, the table is fixed, since otherwise is not specified and thus, the operation relevant to the transition graph node 3 is omitted. However, should the order of operations as shown in Fig. 14 be accepted, already the processing of the second workpiece will start with the table unfixed since in the beginning of the large loop locker is not considered. The necessary operation is missing.

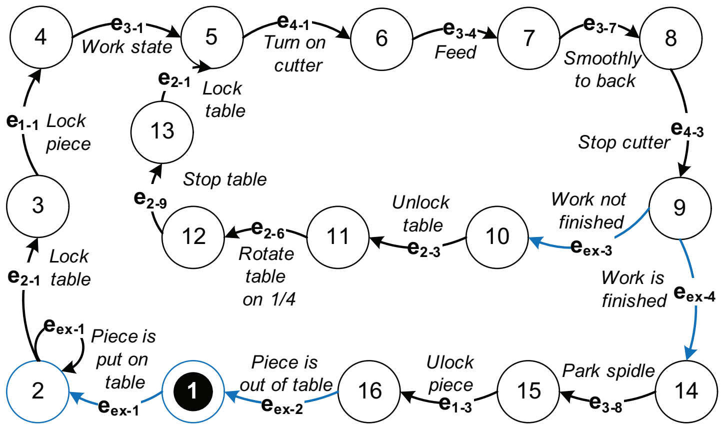

Fig. 13. The required machine behaviour in terms of directive specifications. The semantics is as follows: e_{ex-1} – a workpiece is on the table, e_{ex-2} – a workpiece is removed from the table, e_{ex-3} – processing is not over, e_{ex-4} – processing is over (other events semantics was given here above in the mechanisms description).

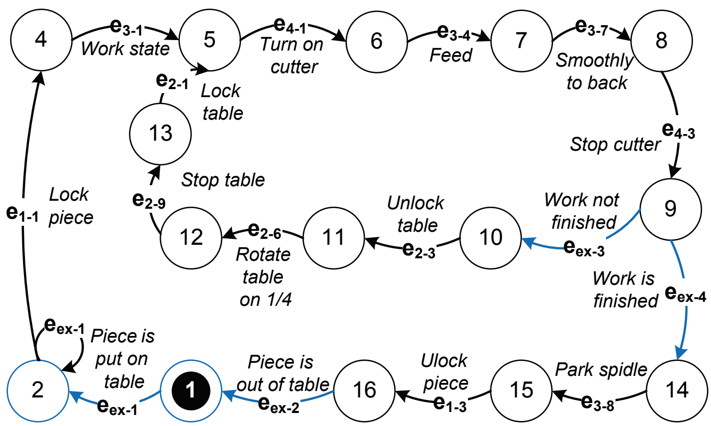

Fig. 14. *H* specification with erroneous missing of "Table locking" operation

Operation omission is far from being the only inconsistency in the required behaviour specification. Here below (Fig. 15) another text description interpretation is given. The specification is elaborated in accordance with the text but a "cutter halt" operation (node 8 of Fig. 15) is performed prior to cutter parking in the "large" loop, which follows from item 9 of the text description from Table 1. Cutter halt is performed in the "large" loop but on the processing termination, therefore, while processing the second piece position, the attempt will be made to switch on a working cutter.

Note3. The composition of modular hierarchic DES description of solely unblocked modules may result in DES blocked operation.

This stage of SDES-modelling reveals a principle difference of discrete control engineering with supervisor *S* on G and *K* given, as compared with a "black box" technique.

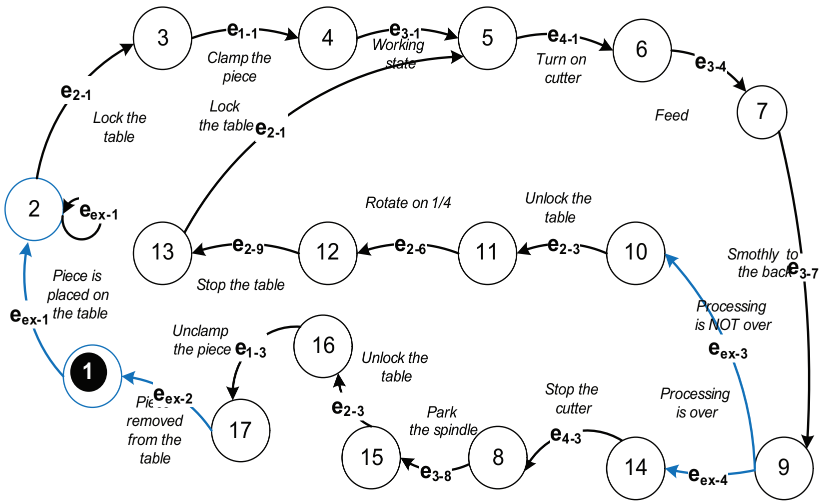

Fig. 15. Machine behaviour as described in the language of directive specifications, with a "Cutter halt" operation moved to the large loop

Indeed, if we make quite a transparent substitution of CFM operations in the transition graph of *H* specification and properly apply the functions of outputs (to be shown here below), we shall get a controlling finite state machine. This machine, provided inputs are independent (this being an indispensable condition for conventional logical control according to the "black box" scheme), will precisely perform the operation sequences specified. Note that substitutions can be made for each of three specifications and, thus, three different controlling machines will be obtained. Later on, it will be possible to carry out arbitrarily profound optimization applying all the methods used in the finite machine theory and logical synthesis. However, at the attempt to unite a control object and $G = \left\langle G^1, G^2, \ldots, G^n \right\rangle$ machines, obtained as per specifications presented in Fig. 15, 16, the errors, mentioned here before, will reveal themselves in blocking (non-fulfilment) of some commands and a "hanging" – an unforeseen cyclic operation interruption will occur. At the same time, with DES theory analytic methods applied, possible blocking situation will be revealed analytically. It is evident that once DES theory methods are applied, a "dimension damnation" will manifest itself: CFM parallel composition of the example in question already gives a machine with the number of states equal to 4356 and its composition with *H* machine results in the machine with dozens of thousands states.
So, we face the following problem: how to predict blocking situation without composition of G_i in *G* followed by general composition with *K*. To tackle this problem, let's continue considering the theory of SDES-modelling.

4. Features of the models of *G* components and H specification

We would like to point out a number of important features of the models of $G = \left\langle G^1, G^2, \ldots, G^n \right\rangle$ components and specifications of industrial objects. Model components, as a rule, simulate the behaviour of different actuators able to "perceive" events-commands, react to them by the change in the position (location, speed, pressure, level, temperature, flow rate etc), with a set of space co-ordinates being split up into a number of intervals and presented by events. Since space, though presented by a set of events remains physical, the events in it may "happen" in a certain order.

Feature of expected events (F1). For the events $e \in E_w^i$ of one component, there exists ordering based on consecution of $e_{i1}, e_{i2}, \ldots, e_{in}$ such that in any chain of these events on graph, the events are arranged in direct or reverse order (this also refers to e_{i1} and e_{in}). Furthermore, this relation is also valid for neighbouring graph chains.

Feature of operations (F2). The events $e \in E_w^i$ weigh on G^i graph the chains of transactions – transitions (edges and states), with one edge and state, weighed by $e \in E_c^i$ (event-command), adjoining to this chain on the left side, and on the right side, either an edge and state, also weighed by another command $e \in E_c^i$, or a fork with events $e \in E_{uc}^i$. This feature allows to unambiguously mark out process operations - the substrings relevant to the command and the reaction expected, on G^i graph (i.e. to "colour" graph). Then, uncoloured will be left only the edges corresponding to $e \in E_{uc}^i$.

Example 1. G^1 operations (Fig. 8) are as follows: To clench piece: states 1→4, chain – $\langle e_{1-1}, e_{1-5}, e_{1-2} \rangle$; to unclench piece: states 4→1, chain – $\langle e_{1-4}, e_{1-5}, e_{1-6} \rangle$.

Example 2. G^3 operations (Fig. 9): Quick feed to the left: states: 1→4, chain - $\langle e_{3-1}, e_{3\text{-}2}, e_{3-3} \rangle$; operational feed to the left: states: 4→7, chain - $\langle e_{3-4}, e_{3\text{-}5}, e_{3-6} \rangle$; slow retraction to the right: states: 7→4, chain - $\langle e_{3-7}, e_{3\text{-}5}, e_{3-3} \rangle$; spindle parking: states: 4→1, chain - $\langle e_{3-8}, e_{3\text{-}2}, e_{3-9} \rangle$.

Feature of forks separability in *G* and *H* (F3**).** Any fork in the transition graph (both for G^i and H) is weighed by the events from $\{E^i_c \cup E^i_{uc}\}$ in a separate way, i.e., branching is always either on $e \in E_{uc}^i$ or on $e \in E_c^i$: $\forall j : [\left|\Gamma_j^i\right| \geq 2] \Rightarrow [\forall e \in \Gamma_j^i : e \in E_{uc}^i \mid e \in E_c^i]$.

Forks in transition graphs are limited, as a rule, to provide one-to-one description and implementation. For example, mixed branching (Fig. 16) is difficult to interpret. Since a transition, particularly in object, has some delay, then, when analysing q_i state (Fig. 16), it is expedient to introduce a new fact – an event $\hat{e}_{uc}$, negating the initial event e_{uc}, and to transform the initial specification in corresponding transitions as shown in Fig. 16.

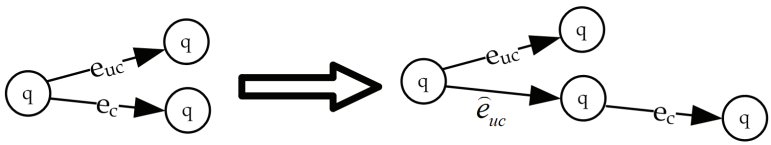

Fig. 16. Transformation of mixed branching

Feature (F4) of marked states $q_j \in Q_m^h$ for H. All edges leading to $q_j \in Q_m^h$ are weighed by $e_l \in E_c$. This is a feature of terminated fragments: specific action is performed last.

Feature of uniqueness in use of operations in *H* (F5). Every edge of H graph can be associated with one chain from G^i graph. Should in the description be any ambiguity, it can be easily eliminated by duplicating the corresponding fragment of H graph. For actuators, all operations of which are associated with different commands, this feature is always valid. If there are still same commands executed at different "path" sections (a fragment of sequence from E_w), they can be always described in different fragments of H graph by duplicating the initial paths.

The features presented are applied to choose the principle of role structuring, as a basis of two-level SDES, and are used in $\Re(s)$ algorithm of carrying out the experiment (refer to i. 5.1), actually, replacing the operation of component machine composition.

5. SDES study

It is natural to inquire, what properties the behaviour specification in language K should possess to provide a supervisor which ensures behaviour $G=\langle G^1,G^2,\ldots,G^n\rangle$ according to the specification, and at the same time is admissible for G. The answer to the question is associated with controllability study (in terms of Ramadge and Wonham, 1987)) of the language K which is a specification of the required behaviour of G defined by a set of components $\langle G^1,G^2,\ldots,G^n\rangle$. As the basic method to study joint G and H behaviour, it is proposed to experiment with $\langle G^1,G^2,\ldots,G^n\rangle$ by strings $s\in K$ (such, that $\delta_h(q_0, s)!$, i.e. admissible for the initial state q_0). The experiment point is to simulate operation of component machines driven by events-commands from strings $s\in K$. The algorithm of such experiment is given here below.

5.1 Algorithm $\Re(s)$ of the experiment with SDES of $G=\left\langle G^1,G^2,...,G^n\right\rangle$ by string *s*

The assignments and functions used in $\Re(s)$ algorithm are as follows: $\mu(s)$ – length of string s; $s(i)$ – current event in string s, with i being the symbol number in string s; $\theta(e)=\{c \mid uc \mid w\}$ – function of event type; $N(e)\in\{0,1,...,n\}$ – number of component G^k in set $G=\langle G^1, G^2,\ldots, G^n\rangle$ such that $e\in E^k$. If $N(e)=0$, then $e\in E_{uc}$ refers to common uncontrollable events of G. $VIS=\left\langle q^1_{r,1},q^2_{r,2},...,q^n_{r,n}\right\rangle$ is called a n-dimension vector of initiated states of each of $G=\langle G^1,G^2,\ldots,G^n\rangle$ components.
As you see, the algorithm executes the experiment on $\langle G^1, G^2,\ldots, G^n\rangle$ collection which is set componentwise to the initial states by strings $s\in K$.
The algorithm has two kind of results:

1. Logical. $\Re(s)=$ *True*$|$*False*. If, under the consecutive influence of symbols s, all components fulfil their transitions successfully, $\Re(s)=$ *True*. If in the course of the experiment for a certain symbol $s(i)$ a component k ($k= v(s(i))$) fails to fulfil its transitions, i.e. $s(i)\notin\Gamma^k_j$, then $\Re(s)=$ *False* (refer to step 2, table 1). The latter means that H is inconsistent with $G=\langle G^1,G^2,\ldots,G^n\rangle$.
2. Constructive. If $\Re(s)=$*True*, $\Re O(s):=v$; $\Re r(s):=r$; $\Re g(s):=k$; $\Re b(s):=j$; $\Re e(s):=l$, where (if $k\neq 0$) k is a component number of G^k, j and l are numbers of its states at which the experiment ends successfully by string s, with j being the beginning and l - the end of a substring v corresponding to the last operation of component G^k as a reaction to string s, and r is a resulting string. If $k=0$, then the experiment is successful, but v, j and l point to the operation of the last component involved in the experiment. In any case, $r\in L(G)$ is a string admissible in G and is one of s prototypes, i.e. $r\in P^{-1}_{E_d}(s)$. (It should be reminded that $r\in P^{-1}_{E_d}(s)$ is a string r, with its projection upon events E_w being equal to s).

The examples of experiments on specifications:

1. For the experiment, let's choose a string s_1 covering the beginning and a small loop: states 1, 2, …, 13, 5 (Fig. 10). Here is the string:

Step	Operation	Comment
1	Set i=1; r:=ε; $VIS=\langle q_0^1,q_0^2,...,q_0^n\rangle$	Initial setting
2	k=$N(s(i))$; If k=0, then r:=$rs(i)$; go to item 5, else choose from VIS the state of component $k - q_j^k$;	steps 2-5: moving along string s
	If $s(i)\notin \Gamma_j^k$, then $\Re(s)$ =False, go to item 6;	Current event of string is not admissible for G^k; the experiment failed
	Let $\delta^k(q_j^k, s(i))=q_l^k$; If $\theta(s(i))=uc$, then r:=$rs(i)$, go to step 4, otherwise $v:=s(i)$;	Uncontrollable event injected into output string. set command from $s(i)$ to operation
3	Choose $e_r\in\Gamma_l^k$ such that { $\delta^k(q_l^k,e_r)=q_p^k$ and $l\neq p$}; If $\theta(e_r)=w$, then v:=ve_r, l:=p go to step 3	Scrolling by e_w – the expected events of operation performed as the reaction to command in G^k
4	place q_l^k in VIS k-position; r:=rv; v:= ε;	Current operation is over
5	i=i+1; if $i\le\mu(s)$, then go to step 2; $\Re(s):=$ True; $\Re O(s):=v;\Re r(s):=r;\Re g(s):=k;$ $\Re b(s):=j;\Re e(s):=l;$	Checking for the string end and assigning of output experiment results
6	The end	

Table 2. Algorithm $\Re(s)$

$s_1=e_{2-1},e_{1-1},e_{3-1},e_{4-1},e_{3-4},e_{3-7},e_{4-3},e_{ex-3},e_{2-3},e_{2-6},e_{2-9},e_{2-1}$. It is easy to trace that all transitions in component models will operate since the commands are given correctly. The experiment result is $\Re$ (s_1) = *True*. We shell not adduce the resulting string but the last string operation is offered in full: $\Re O(s):=e_{2-1},e_{2-5},e_{2-2}$; $\Re g(s_1)=2$; $\Re b(s_1)=1$; $\Re e(s)=4$. String r will include similar extensions for all the events of sting s_1.
For the experiment on erroneous graph (Fig. 13), let's choose string
s_2 = $e_{1-1},e_{3-1},e_{4-1},e_{3-4},e_{3-7},e_{4-3},e_{ex-3},e_{2-3}$. It is easy to notice that G^2 is addressed first at the last event but this attempt fails since the transition from state 1 of G^2 component is not specified for the event e_{2-3} (Fig. 5). Therefore, $\Re$ (s_2)= *False*.

5.2 Main SDES result

It is natural to ask, what properties a specification of behaviour in language K should possess to provide a supervisor making $G=\langle G^1,G^2,..,G^n\rangle$ behave in conformity with specification and not blocking G.
The answer as to the supervisor existence can be obtained using the following theorem.
Theorem of SDES controllability. Let a well-structured G=<G^1,G^2,…,G^n> be given, where $E=\{E_w\cup E_c\cup E_{uc}\}$, E_d= $E_c\cup E_{uc}$, and $K\subseteq E_d^*$ ($K\neq\emptyset$). Non-blocking supervisor S, such that $P_{E_d}(L(S/G))=K$, exists if and only if for any $s\in K$ (such that $\delta_k(q_0, s)!$) $\Re$ (s)=*True* with respect to G=<G^1,G^2,…,G^n>.
In other words, the theorem asserts, that for a well-structured G=<G^1,G^2,…,G^n> and a given specification K, there exists a non-blocking supervisor S such, that the projection on E_d of the

language, generated by G under S control, coincides with K provided that for any line s, specified for the initial state of H, which defines the language of specification K, the experiment on $\Re\,(s)$ algorithm is positive.

Proof The necessity is proved by contradiction: the theorem terms are satisfied, unblocking supervisor S such that $P_{E_d}(L(S/G)) = K$ exists but for a certain string $s \in K$ (such that $\delta_h\,(q_0, s)!$) the experiment $\Re\,(s) = False$ with respect to $G = \langle G^1, G^2, .., G^n \rangle$. There can be a lot of such strings, but let s be the shortest of them. Let $\omega(s) = e$ and $s := ue$. It is evident that for all prefixes of string u and string u itself, the experiment is positive, i.e. $\Re\,(u) = True$, but, in case u is extended, $\Re\,(ue) = False$ and $\theta(e) = c$ (e – control event). It is revealed at 2.2 (Table 1). At this, G^k is in state q_j^k and $e \notin \Gamma_j^k$ (e is inadmissible for G^k in its current state q_j^k).
On the other hand, as u, $ue \in K$ and supervisor S, such that $P_{E_d}(L(S/G)) = K$, exists, let's choose from $L(S/G)$ strings u', $u'e$ for which $P_{E_d}(u') = u$ and $P_{E_d}(u'e) = ue$. Since the sets of CFM events do not intersect (refer to note 1), $N(e) = k$, from u' admissibility for G^k it follows that at u' generation G^k will be transferred to state q_j^k, and then from $u'e$ admissibility for G^k it immediately follows that $e \in \Gamma_j^k$ (i.e. e is admissible for G^k in its current state q_j^k). This comes into conflict with the assumption that $\Re\,(s) = False$. The necessity is proved.
Sufficiency. Let's $K \neq \varnothing$ be a language such that for any $s \in K$ $\Re\,(s) = True$ with respect to $G = \langle G^1, G^2, .., G^n \rangle$. We shall show that in such case there exists a supervisor unblocking for G and providing $P_{E_d}(L(S/G)) = K$.
Let's define language M on K in the following way:

$$M = \left\{ \varepsilon \cup \bigcup_{s \in K} \Re r(s) \right\} \tag{1}$$

For any $u \in M$ let's define:

$$S(u) = \left\{ e : \begin{cases} (\theta(e) = uc \wedge \Re(P_{Ed}(u)e) = True), \\ (\theta(e) = w \wedge e \in \Re O(P_{Ed}(u)e)), \\ (\theta(e) = c \wedge \Re(P_{Ed}(u)e) = True), \\ \text{other } e \text{ not included in codomain } S \text{ for } u \end{cases} \right\} \tag{2}$$

The designed converter admits as follows:

- all E_{uc} possible (as to transition function for G) after u (string 1 from (2));
- all E_w if they fall into the definition area of corresponding transition in a certain G^k component (string 2 from (2));
- all controlled events E_c for which the experiment on $P_{E_d}(u)e$ is positive (string 3 from (2)).

Thus, the converter is a non-blocking supervisor such that $L(S/G) = M$ and $P_{E_d}(L(S/G)) = K$ (this follows from M definition (1) and option 3, step 2 of $\Re\,(s)$ algorithm on which $\Re r(s)$ is formed). Since finite state machine H (generating K) does not contain deadlocks and liveloops, then S by construction also cannot contain deadlocks and liveloops, thus, S is non-blocking. The theorem is proved.
Comments to the theorem. A natural question may arise: how this result is correlated with the controllability condition by Wonham? First of all, it is quite correlated. If for any $s \in K$ $\Re\,(s) = True$ then the language M, built as per the algorithm (refer to (1)), will be controllable, i.e. for it, a controllability condition by Wonham is satisfied.

The controllability condition derived in the paper is formed with respect to specification language K outside $L(S\setminus G)$. Therefore, K is controllable with respect to $<G^1, G^2,\ldots,G^n>$ if it is prefix-closed and $\Re$ experiment is positive on all $s \in K$. This requirement is more strict then Wonham's but it relates to the language K that is more expressive then $L(S\setminus G)$. The example in section 4 illustrates SDES blocking by supervisor (in case the experiment is false). At the same time, this result and, which is most important, the procedure of its verification (algorithm $\Re(s)$) are pragmatic, i.e. the number of checks cannot exceed the number of simple paths to every edge of graph H) and the result is given in terms of conditions and transitions of all the components involved in the experiment.
Our example is illustrated in Table 3, with supervisor S designed as a function of strings as per the algorithm defined above in the theorem proof.

Q^h	Operation	$s = s \bullet u$	$S(s)$
1	e_{ex-1} (Put piece on table)	$s = s \bullet e_{ex-1}$	e_{2-1}
2	$e_{2-1}, e_{2-5}, e_{2-2}$	$s = s \bullet e_{2-1}, e_{2-5}, e_{2-2}$	e_{1-1}
3	$e_{1-1}, e_{1-5}, e_{1-2}$	$s = s \bullet e_{1-1}, e_{1-5}, e_{1-2}$	e_{3-1}
4	$e_{3-1}, e_{3-2}, e_{3-3}$	$s = s \bullet e_{3-1}, e_{3-2}, e_{3-3}$	e_{4-1}
5	$e_{4-1}, e_{4-6}, e_{4-2}$	$s = s \bullet e_{4-1}, e_{4-6}, e_{4-2}$	e_{3-4}
6	$e_{3-4}, e_{3-5}, e_{3-6}$	$s = s \bullet e_{3-4}, e_{3-5}, e_{3-6}$	e_{3-7}
7	$e_{3-7}, e_{3-5}, e_{3-3}$	$s = s \bullet e_{3-7}, e_{3-5}, e_{3-3}$	e_{4-3}
8	$e_{4-3}, e_{4-6}, e_{4-4}$	$s = s \bullet e_{4-3}, e_{4-6}, e_{4-4}$	e_{ex-3} / e_{ex-4}
9	e_{ex-3} (processing is not finished) e_{ex-4} (processing is not finished)	$s = s \bullet e_{ex-3}$ $s = s \bullet e_{ex-4}$	e_{2-3} e_{3-8}
10	$e_{2-3}, e_{2-5}, e_{2-4}$	$s = s \bullet e_{2-3}, e_{2-5}, e_{2-4}$	e_{2-7}
11	$e_{2-7}, e_{2-8}, e_{2-9}$	$s = s \bullet e_{2-7}, e_{2-8}, e_{2-9}$	e_{2-10}
12	e_{2-10}	$s = s \bullet e_{2-1}, e_{2-5}, e_{2-2}$	e_{2-1}
13	$e_{2-1}, e_{2-5}, e_{2-2}$	$s = s \bullet e_{2-1}, e_{2-5}, e_{2-2}$	$\rightarrow 5$
14	$e_{3-8}, e_{3-2}, e_{3-9}$	$s = s \bullet e_{3-8}, e_{3-2}, e_{3-9}$	e_{1-3}
15	$e_{1-3}, e_{1-5}, e_{1-4}$	$s = s \bullet e_{1-3}, e_{1-5}, e_{1-4}$	e_{ex-2}
16	e_{ex-2}	$s = s \bullet e_{ex-2}$	$\rightarrow 1$

Table 3. Specifying $S(s)$ as a function of strings

6. Method of direct supervisor synthesis on the basis of SDES model for real-time automation systems (RTAS)

The investigations set forth in sections 4, 5 were carried out for SDES with off-line components that were controlled via blocking mechanism as pee the scheme shown in Fig.

4. At the same time, RTAS has a number of features that are useful to apply for control modelling and engineering.

- First, RTAS is featured by control subdivision into two sublevels of control: the level of actuators that executes operations control and a process control level that provides operation sequences.
- Second, actuators are passive but can receive operative commands, execute them autonomously and provide feedback.
- Third, while RTAS engineering, a technologist defines specifications (the required operation sequences), and it is advisable that in a synthesized supervisor, the structure of sequences was preserved and the synthesis result, as to its complexity, was linearly dependent on initial specification.

The papers on the synthesis of logical devices (Kuznetsov, 1975; Ambartsumyan, Potekhin 1977) contained similar requirements and synthesis methods were called standard realization. According to the papers on standard realization methods, such approach has the following advantages:

- The obtained result is always "recognizable" by the author of initial specifications;
- The result complexity is proportional to the scope of initial data;
- The number of operations in the synthesis procedures is also linearly dependent on initial data.

Basic paradigm of standard realization is the synthesis of object control system (device) by syntactic transformation of this object behaviour specification. Therefore, standard realization is the engineering method that guarantees the engineering result of acceptable complexity and for acceptable time, provided there is the initial description of the object behaviour

With the above mentioned RTAS features and standard realization idea taken into account, the present section pursues the objective to develop a supervisor synthesis method providing dependability – acceptable complexity of the result (supervisor) achieved for acceptable time (the number of operations).

This section is dedicated to the study of SDES with passive actuators. In such SDES, all controlled events are forced from the point of view of operation (Chalmers, Golaszewski, Ramadge, 1987) and the control is performed as per the scheme similar to that shown in Fig. 17.

Definition 6. A well-structured DES, for which the composition of uncontrollable part is defined as per Definition 1, all are forced, the required behaviour is defined by the specification language $K \subseteq E_d^*,(K \neq 0)$, and which is provided by supervisor S generating unambiguously controlled events E_c in such a way that K is fulfilled, will be called a **structured discrete event system with forced controlled events (SDESf)**.

Comments to the definition. SDESf should meet the condition of determinacy, i.e. for any string s admissible for the initial state, if its extension by a controlled event is possible, such extension for this string is unique. It is suggested that a structured DES with forced events should be realized according to the scheme (Fig. 17) in which supervisor "perceives" all the events generated by G but initiates only controlled events.

Based on introduced notions, let's specify the tasks of this section.

For SDESf specified by G component set and K specification, they are as follows:

- Define a condition of K specification controllability.
- Examine the matter of a supervisor existence.

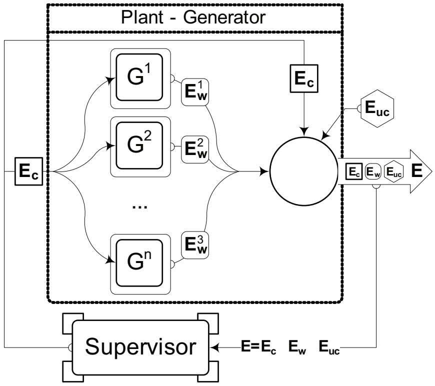

Fig. 17. The scheme of supervisory control for SDES with forced controlled events

- Elaborate the method of specification realizability analysis that will indicate if G and K are consistent.
- Develop the method of synthesis of supervisor S (if K specification is realizable) providing control in G in such a way that K is fulfilled, with the method synthesising S for acceptable time and S complexity having linear dependence on K complexity.

6.1 Study of SDES with forced events

In order to unambiguously define the behaviour of SDES represented by $G = \langle G^1, G^2, \ldots G^n \rangle$ collection, it is necessary to specify all the system states and their admissible transitions (structure and weighing functions). A traditional tool used for such tasks in discrete systems is the building of attainability tree. In section 5 of the present paper, as a basic instrument to study SDES behaviour, it is proposed to use the algorithm $\Re$ that actually is a procedure of H graph traversal. At this walk, for any reached state of H, is formed $VIS = \langle q^1_{r,1}, q^2_{r,2}, \ldots, q^n_{r,n} \rangle$ - a vector of initiated states of each of $G=<G^1,G^2,\ldots,G^n>$ components, which appears sufficient to build a tree of attainability. It would be logical to use intermediate results of algorithm $\Re$ at supervisor synthesis. The way to this is set forth below. Important is the fact that the synthesis task can be divided into two main subtasks: the analysis of H graph structure and the analysis of complete states.

Structure analysis For further study, we shall need to examine states q_i in which the selection (fork) in the transition graph, defining machine H, takes place. Without the loss of generality, we assume that there are no mixed forks in the transition graph of H. In other words, if more than one edge originates from q_i, these edges are always weighed either only by uncontrollable events or, on the contrary, only by those controllable (feature F4 – forks separability feature worded in section 4).

The last condition in the defining set definition $\left[\omega(s) = \tau(q_i \to q_k)\right]$ states the fact of string s termination on $(q_i \to q_k)$ transition.

Definition 7. Let $\tau(q_i \to q_k)$ be a function with its value equal to the event weighing the transition $(q_i \to q_k)$, and $\omega(s)$ – the last event in string s. Then $\Phi^i_k = \{s \| [\delta^h(q_0, s)!] \wedge [\omega(s) = \tau(q_i \to q_k)]\}$ will be called a **defining set** of strings of k direction in fork q_i.

The last condition in the above definition $\omega(s)=\tau(q_i \to q_k)$ states the fact of the string s end on $(q_i \to q_k)$ transition.

Definition 8. Let O_i be a set of subscripts of states q_j to which there is a direct transition from q_i ; let $\theta(e)=\{c|uc|w\}$ be a function of event type; let $q_i \in Q^H$; $\lfloor O_i \rfloor \geq 2$. Then q_i is called a **correct selection** (fork), if only one of the following conditions is fulfilled:

- For all the transitions incidental to q_i, $\theta(\tau(q_i \to q_k))=uc$ is fulfilled (the selection on uncontrollable events);
- For all the transitions incidental to q_i $\theta(\tau(q_i \to q_k))=c$ is fulfilled (the selection on controllable events), with the defining sets on any pair of directions not intersecting, i.e. $\forall m,n:[m,n\in O_i \Rightarrow \Phi_i^m \cap \Phi_n^i=\varnothing]$.

The answer to the question, as to the existence of supervisor for SDES with forced controlled events, is given by the following theorem.

Theorem of SDESf controllability. Let a well-structured $G=\langle G^1,G^2,..,G^n\rangle$ be given, for which $E=\{E_w \cup E_c \cup E_{uc}\}$, all E_c are forced $E_d=\{E_c \cup E_{uc}\}$ and $K \subseteq E_d^*,(K \neq \varnothing)$. Non-blocking supervisor S such that $P_{E_{uc}}(L(s/G))=K\}$ exists then and only then when for any $s\in K$ (such that $\delta^h(q_0,s)!$) $\Re(s)$ = *True* as respects $G=\langle G^1,G^2,..,G^n\rangle$ and all selections in the transition graph of H are correct.

Theorem proof Necessity. The first part of condition: $\Re(s)$ = *True* is valid as shown in the proof of the theorem of controllability in section 5. Let's prove the necessity and sufficiency of the second condition: branching correctness. Proof is made by contradiction. Let there exist an unblocking supervisor S but for H the condition of branching correctness is not met. Then two options are possible, namely:

- Branching is mixed, i.e. for the transitions incident to q_i $\theta[\tau(q_i \to q_k)]=[c \wedge uc]$ is fulfilled. It is impossible as conflicting branching limitation.
- For q_i branching, the condition of empty intersection of defining sets is not fulfilled. Let s^i transfer H to q_i state, than there exists at least one event e_c^{i+1} that simultaneously weighs two different edges originating from q_i. On the other hand, since a supervisor exists, it is determinate and is defined as a function of strings, thus, for this option, two different values e_c^{i+1} and $[e_c^{i+1}]$, weighing the next pair of edges, must fit the same argument s^i. We have arrived at a violation.

The necessity is proved.

Sufficiency is proved constructively. Let $K \neq \varnothing$ be a language such that for any $s \in K$ $\Re(s)$ = *True* with respect to $G=\langle G^1,G^2,..,G^n\rangle$. We shall show that in such case there exists a supervisor unblocking for G and providing $P_{E_d}(L(S/G))=K$.

Let's define language M on K in the following way:

$$M=\left\{\varepsilon \cup \bigcup_{s\in K} \Re r(s)\right\} \tag{3}$$

Any string $u\in M$ is admissible for $L(G)$ as per construction in $\Re$. For this reason, $M \subseteq L(G)$.

For any $u \in M$ let's define:

$$S(u) = \begin{cases} e : \theta(e) = c \wedge \Re(P_{E_d}(u)e) = True \\ e : \theta(e) \neq c \wedge \Re(P_{E_d}(u)e) = True \\ \text{other } e \text{ not included in codomain } S \text{ for } u \end{cases} \quad (4)$$

The designed converter admits the following:

- all E_c possible (as to transition function for G) after u (string 1 from (4));
- ε instead of any event of $e \in \{E_w \cup E_{uc}\}$, if this event enters the definition area of corresponding transition in H or a certain component of G^k (string 2 from (4)).

Since machine H (generating K) does not contain deadlocks and liveloops, $L(S/G) = P_{E_d}^{-1}(K)$ by designing, and all $s \in P_{E_l}^{-1}(K)$ are admissible for G (as $\Re$=*True*), than S by construction also cannot contain deadlocks and liveloops, thus, S is non-blocking. The theorem is proved.

Comments to the theorem.

1. The proposed condition of controllability is formulated with respect to specification language K that is more expressive and compact then $L(S \backslash G)$, at least, because it is a projection of $L(S/G)$ on E_d.
2. For controllability, besides the requirement of positive experiment, it is necessary that all forks in the transition graph of H should be correct, which is effectively verified by the graph nodes review.
3. The condition of controllability for SDESf is worded as a limitation imposed only on specification language K but does not restrict language $L(S/G)$. Nevertheless, K is controllable as relates $G = \left\langle G^1, G^2, .., G^n \right\rangle$, provided it is prefix-closed, algorithm $\Re$=*True* for all $s \in K$, and all forks are correct. This condition is more strict than that in paper (Chalmers, Golaszewski, Ramadge, 1987) as it admits branching on controllable events, in case the selection is correct.

Let's consider possible branching variants on $e \in E_c$ - controlled events. Practically, the following situations are possible:

- Logical substantiation for choosing the continuation is in the pre-history.
- There is no logical substantiation in the past (the defining sets for both directions intersect but, at this, sequences are admissible for both branches.

This situation will be illustrated by the structure of transition graph shown in Fig. 18. Semantics of events, states and sequences will be described later in section 6.4. Herein we shall discuss a few peculiarities of forks in the transition graph. The edges of forks originating in states q_1,q_4 and q_{22}, in Fig. 18, are outlined by firm ellipses. The events: $e_{ex\text{-}1}$ – a round piece or $e_{ex\text{-}2}$ – a hexahedral piece, took place in the first outlined fragment, but in the situation of the following firm ellipses, there are no longer such events and a clamp choice should be made from memory of those events.

Another branching variant is referred to in the description of cutter-type choice – in Fig. 18, corresponding forks are marked by dashed ellipses. From the point of view of event sequence, both variants are admissible for $G = \left\langle G^1, G^2, .., G^n \right\rangle$ and there is no data to choose the variant of the process continuation. In principle, the second situation, in conformity with the theorem condition, testifies that K is not coordinated with $G = \left\langle G^1, G^2, .., G^n \right\rangle$ and SDES is not controllable with K. However, for practical tasks, such situation is settled by the addressing of algorithm to the external, as relates to given SDES, system (e.g. to operator).

Thus, when analysing forks (selection) of H graph on controllable events, two aspects, important for supervisor S engineering, were revealed. First, for every branching on controllable events $q_i \begin{cases} \rightarrow & q_i' \\ \rightarrow & \ldots \\ \rightarrow & q_i' \end{cases}$, it is a unique extension $(s'_{q_i} \neq s'_{q_n})$ that corresponds to string s'_{q_i}, and this provides determinacy of S. Second, the events defining the condition of selection (direction) either happened in the past or lie outside SDES structure.

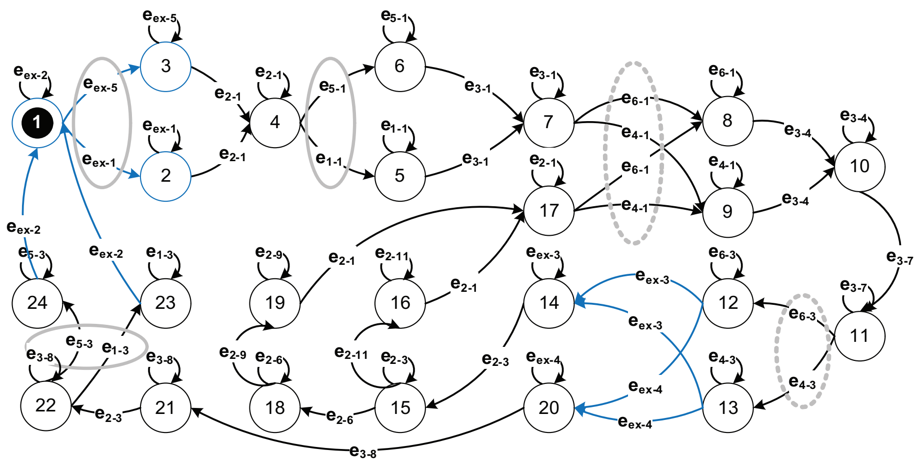

Fig. 18. Graph of *H* specifications

In any case, as of the moment of the analysis of situation with branching, the events, conditioning it, either happened, and the selection should be requested as a new event, or the selection is impossible to define by prehistory and then it should be requested from external sources. For providing such request, let's design machines of special kind: selection agents. For all states of branching origin q_i, an individual agent – a machine of $A_{qi}=\langle Q_a, E_c, \delta_a, \Gamma_a, \lambda_a, q_0 \rangle$ kind is built on controllable variables. A transition graph A_{q_i} is shown in Fig.19.

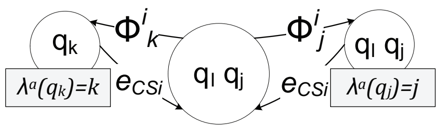

Fig. 19. Machine-agent of selection

The discipline of interconnection of supervisor S with branching machine-agent is as follows: on S reaching state q_i, after which it is necessary to make choice (arrive at a decision), S, through its special output, sends a request to A_{q_i}. In accordance with the discipline accepted, A_{q_i} replies issuing a direction index $a_{q_i} = \{k|j\}$, (not necessarily 1 of 2, possibly 1 of many). At this, a_i will be used as index. Fig. 20 illustrates a control scheme.

Analysis of complete states To answer the question about the consistency of supervisor S and object G, SDES state analysis is required. The state of the set of primary components $VIS = \langle q^1_{j1}, q^2_{j1}, \ldots, q^r_{jn} \rangle$ reflects the state of control object $G = \langle G^1, G^2, \ldots, G^n \rangle$. The current state

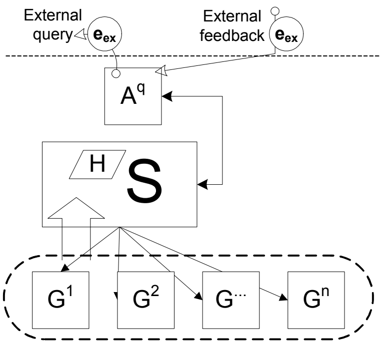

Fig. 20. Control scheme with selection agent

of *H* machine - q_r^h reflects the intentions to control (to limit free behaviour of *G*) for the purpose of solving some technological tasks. Thus, a complete SDES state is $V_{FS} = \left\langle q_r^h, q_{j1}^1, ..., q_{jm}^r \right\rangle$. A conventional technique of listing the complete attainable states in similar situations is evident: it is necessary to build a tree of attainability and, guided by the tree, to carry out the experiment on *H* machine and a set of $\left\langle G^1, G^2, .., G^n \right\rangle$ component machines. In the paper, it is proposed to analyze complete states by their "projection" on *H* transition graph, in parallel with the experiment on controllability.

For this purpose, let's set *H* and all the component machines to their initial states. We shall get a vector of initial states. Let's weigh *H* initial state by this vector. Then we shall make an experiment with a string composed of events E_d (let it be e_c^i), weighing *H* graph edges, and of the events corresponding to the reaction from one of the components $\left\langle G^1, G^2, .., G^n \right\rangle$ of a definite component machine G^i. At this, *H* will transit to another state q_r^h, with the following states adjoined: first, all the states of component machines $\left\langle G^1, G^2, .., G^n \right\rangle$ that are unchanged at this transition; second, by turns, all G^i component machine states corresponding to its reaction to e_c^i. These vectors form a block of states that weighs q_r^h states. The experiment fragment is shown in Table 4. From the fragment of the table of complete states, it is clear that one *H* node is associated with blocks of complete states and this results not only from including states and components "put into action" but also from the availability of multiversion attainment of the given state. For example, in state 10, there are 4 blocks corresponding to different state combinations for components G^1 and G^2. It is important that all the states inside blocks should successfully operate on subsets of events admissible in this state.

Reasoning from the above, the requirements to the method of complete states design and analysis are set forth as follows:

1. Complete states are formed as they are required in *H* and operations are processed in *G*;
2. The method should provide for the structure of data on *H* complete states and transitions. This structure should provide easy access to complete states at *H* transition graph traversal; the advancement and distribution of complete states along *H* must be accompanied by *H* and *G* consistency analysis.

The major novelty of this idea is that a set of complete states V_{FS} moves and spreads along *H* graph structure in compliance with the flow of possible events. It is important to note the following:

q^h	G^1	G^2	G^3	G^4	G^5	G^6
1	1	1	1	1	1	1
4	1	1-4	1	1	1	1
	1	1-4	1	1	1	1
10	4	4	4-7	1	1	4
	4	4	4-7	4	1	1
	1	4	4-7	1	4	4
	1	4	4-7	4	4	1

Table 4. Full states (fragment)

1. If, first, the experiment was made for every complete state in every node and it, at least once, was positive, and, second, all *H* edges were walked through, than the set of all attainable complete states was obtained. This is equivalent to the building of the tree of attainability.
2. If all transitions came into action, than the specification defined by *H* is controllable and the data acquired is sufficient to form *S* basis.

It is suggested that a supervisor should be synthesised via weighing *H* graph edges by new operations and output functions $\lambda_s(q_i, t_{i,j}) = \{e_c, \varepsilon\}$ defined on pairs of states and transitions. Output functions will "return" either controllable event e_c or empty symbol ε and they must keep their value over the whole transition $q_i \rightarrow q_j$.

6.2 Synthesis of supervisor for SDESf

Supervisor engineering will be made based on FSM of special type.

Definition 9. A **machine active at transitions (TAM)** is a finite machine $S = (Q_s, E, \delta_s, \rho_s, \lambda_s, \Gamma^s, \Gamma^\tau, Q^s_{,}, q_0)$ in which the set of states Q^s, set of events *E*, transition functions δ_s, functions of admissible events Γ^s a set of necessarily attainable states Q^s_m and the initial state q_0 are defined conventionally. Control functions $\Gamma^\tau, \rho_s, \lambda_s$ of TAM are defined in the following manner:

- $\Gamma^t_i : Q^s \rightarrow \{t_{i,j} \left| \{j : \delta_s(q_i, \Gamma_i)\} = q_i \right\}$ is a function of possible transactions (transitions). This function associates every edge originating from q_i with string $t_{i,j} \in E^*$ which, when performed, initiates in *S* a transition $q_i \rightarrow q_j$; thus, at *S* operation, both states and transitions are active.
- $\rho_s(q_i) = e_{q_i}$ Moor-type function of outputs defined only at forks on controllable events ($|O_i| \geq 2; \theta(q_i) = c$); for the rest of q_i, $\rho_s(q_i) = \varepsilon$.
- $\lambda_s(q_i, t_{i,j}) = \{e_c | \varepsilon\}$ - a machine output function, defined on a pair [state– string of transition], equal either to controlling event or to empty symbol and keeps its acquired value over the whole transition $q_i \rightarrow q_j$

Apparently, a machine, active at transitions (TAM), has a number of destinations:

- "Language generator" *L(S)*. Let's present any path incident to the initial state q_0 in *S*, as iteration of concatenations of pairs [state–outgoing edge] expressed as $r_{0,l} = \bullet^l_{i=0}[q_i r_{i,j}]$, than $L(S) = \{s \left| : s = \bullet^l_{i=0}[q_i := \lambda^s(q_i, r_{i,j} \bullet t_{i,j})] \right\}$ is a set of strings obtained from the set of paths by substitutions of corresponding events and strings.

- "Direction pointer" – Milly-type output function successfully relevant to the definition of operator able to admit or turn down controllable events. However, it is very important that the function is defined on states and substrings $S(s_{0,l}) = \begin{cases} \varepsilon \text{ for } q_0 \\ \lambda^s(q_i, t_{i,l}) \end{cases}$.
- "Internal interconnections". Provides interconnection with selection machines-agents that interface SDESf with external media - a supplier of incontrollable events of e_{uc} type.

From the point of view of the theory of finite machines, S is a machine of mixed– type: it has output $\rho_s(q_i) = e_{q_i}$ depending only on states, which is typical for Moor machine, as well as output $\lambda_s(q_i, t_{i,j}) = \{e_c | \varepsilon\}$ typical for Milly machines; furthermore, the latter is defined at transition.

Supervisor S is designed, basing on specification H, by the special algorithm of syntactical transformation $\Im(G,H) \to S$. Machines-agents are supposed already defined, so, the transformation is made according to the following scheme:

$$\begin{array}{lllllllll} H & = (& Q^h, & E_d, & \delta_h, & & \Gamma^h, & & Q^h_m, & q_0 &) \\ & & \downarrow & \downarrow & \downarrow & & \downarrow & & \downarrow & \downarrow & \\ S & = (& Q^s, & E, & \delta_s, & \rho_s, \lambda_s & \Gamma^s, & \Gamma^t, & Q^s_m, & q_0 &) \end{array}$$

Thus, supervisor synthesis method must solve the following tasks:

- form the vectors of complete states for every state Q^h;
- put in action all the transitions (edges) of H;
- should the experiment be positive, to build for S main missing constructions $\rho_s, \lambda_s, \Gamma^\tau$.

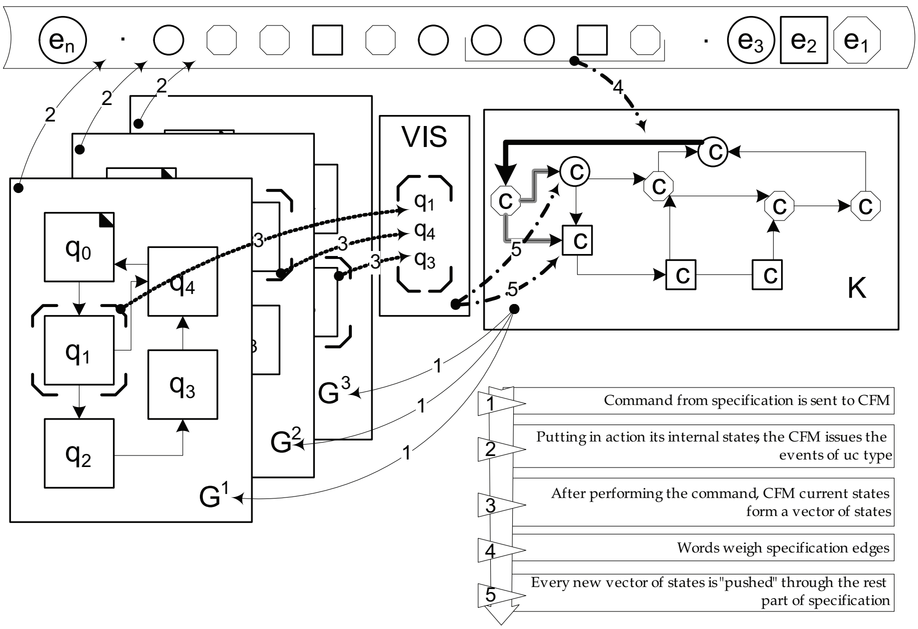

Fig. 21. Data scheme of algorithm $\Im$

The proposed algorithm $\Im$ which fulfils the method of direct supervisor engineering, for the purpose of clearness, will be depicted graphically as data structure and the algorithm diagram (Fig. 21). Algorithm $\Im$ processes specification *K*, defined by a transition graph, carries out the simulation of control command operation (arrows 1 in Fig. 21) in component machines G^i. The component machines "put into action" the transitions, in conformity with the command. As the result, algorithm $\Im$ forms:

- word $e_c e_{w1} \dots e_{w_n}$ representing operation fulfilled (arrows 2 in Fig. 21);
- next complete state $VIS := \left\langle q^1_{j1}, q^2_{j1}, \dots, q^r_{jm} \right\rangle$ (arrows 3 in Fig. 21).

Specification graph is processed as shown in Fig. 22. Block inscriptions correspond to algorithm steps. We would like to draw your attention to the fact that the algorithm is constructed as the traversal (block 4) of graph with unprocessed complete states (the first unprocessed complete state $\langle q^h{}_0, q^1{}_0, q^2{}_0 \dots q^n{}_0 \rangle$ is created at initialization – block 1). For every

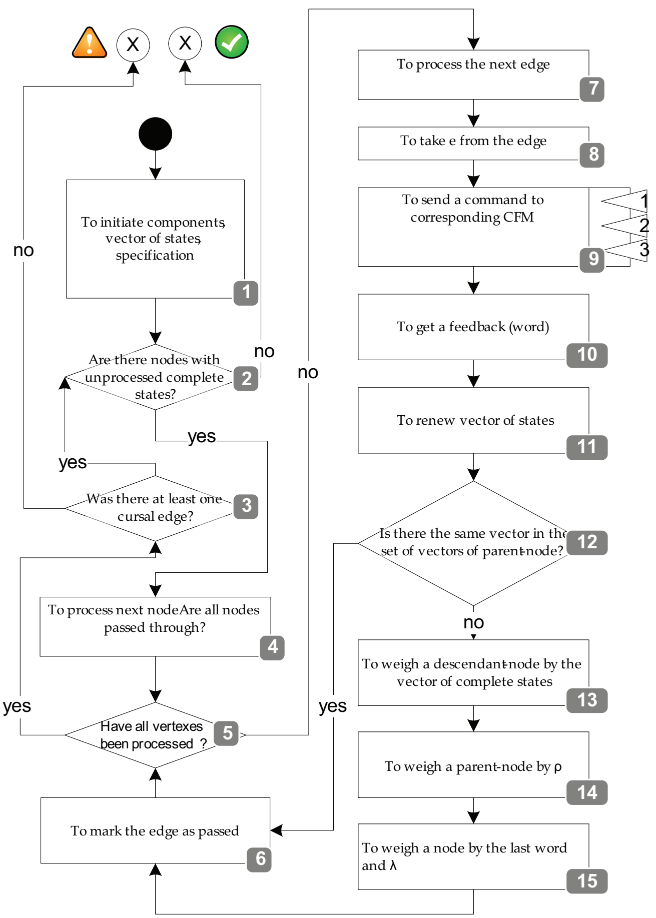

Fig. 22. Block-diagram of algorithm $\Im$

state, a loop on outgoing edges (block 5) is formed. For every edge, the weighing by functions ρ, λ and operation $e_c e_{w1} ... e_{w_n}$ takes place (blocks 14, 15) once. On termination of the traversal of all H nodes and edges, we get the set of all admissible states. If all the transitions took place, than H is controllable (ticked-off output) and the acquired data define the weighing of machine - supervisor S. If graph traversal is terminated ahead of schedule (the output marked with "!" symbol) than specification K and object G=<G^1, G^2, …, G^n> are incompatible.

6.3 Study of algorithm $\Im$

The purpose of the method study is to assess its complexity and time characteristics. The main question is whether the main features of standard realisation methods, are preserved, namely: linear dependence of the result complexity and spent time on the initial data scope. Partially, the answer to this question may be given by the following theorem:

Theorem on standard realization. Given: $G = \left\langle G^1, G^2, .., G^n \right\rangle$, language K specified by machine $H = (Q_h, E_d, \delta^h, \Gamma^h, Q_m^h, q_0)$ for which the set of transition graph edges is designated by R. Than algorithm $\Im$, based on $G = \left\langle G^1, G^2, .., G^n \right\rangle$ and $H = (Q_h, E_d, \delta^h, \Gamma^h, Q_m^h, q_0)$ specification, constructs (as per the scheme of transition-active machine) supervisor S such that project $P_{Ed}(L(S/G)) = K$ and, at this, S complexity on the **data scope** $\le O(MAX(\left|Q^h\right|, |R|))$, and the **number of operations** to design $S \le O(|R|)$

Proof. The fact that the first theorem part is true follows from the method, though the proof by induction on string length, can be easily developed. The validity of the second part – the complexity of S presentation (specification), namely: $\le O(MAX(\left|Q^h\right|, |R|))$ [1] follows from the fact that all S constructions are obtained by redefining H constructions and by including new constructions (block 6 of the algorithm) associated with states and edges of H graph transitions and limited by the data sets from G and H. From the above, it follows that the complexity of $S \le O(MAX(\left|Q^h\right|, |R|))$. The validity of the last theorem statement on the number of operations follows from the fact that the total number of the executed algorithm blocks from 2 to 6 on all states $\sum_1^n |O_i|$ equals the number of H edges - $|R|$. Which required. Thus, for the case, when the complete states one by one take their places in H states, the linearity of dependence of the number of operations on the number of edges, is maintained but in more complicated cases, the occurrence of "additional" complete states in H weighing structure results in the iteration of transitions analysis.

6.4 Example 2

The proposed method will be illustrated by the example of supervisor synthesis for a milling machine with 6 mechanisms: a clamp for round pieces (1), turntable (2), spindle (3), rectangular cutter (4), angle clamp (5), round cutter (6). Kinematics of this machine is similar to that of the machine from section 3.3 (Fig. 4) but in the considered machine, the processing of 2 types of pieces with different fastening and by different tools (mechanisms G^5 and G^6) are foreseen. Each mechanism is simulated by corresponding CFM $\{G^n\}$. The nodes

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1 The formula runs as follows: S has the order of magnitude maximal of two values: the cardinal number of the set of states or the cardinal number of the set of edges.

correspond to the space position and edges – to events. Event semantics is presented in Appendix 1.

Respective CFM is shown in Fig. 23, by colour, in transitions, are marked the events of e_c type, ticked-off is the initial state q_0.

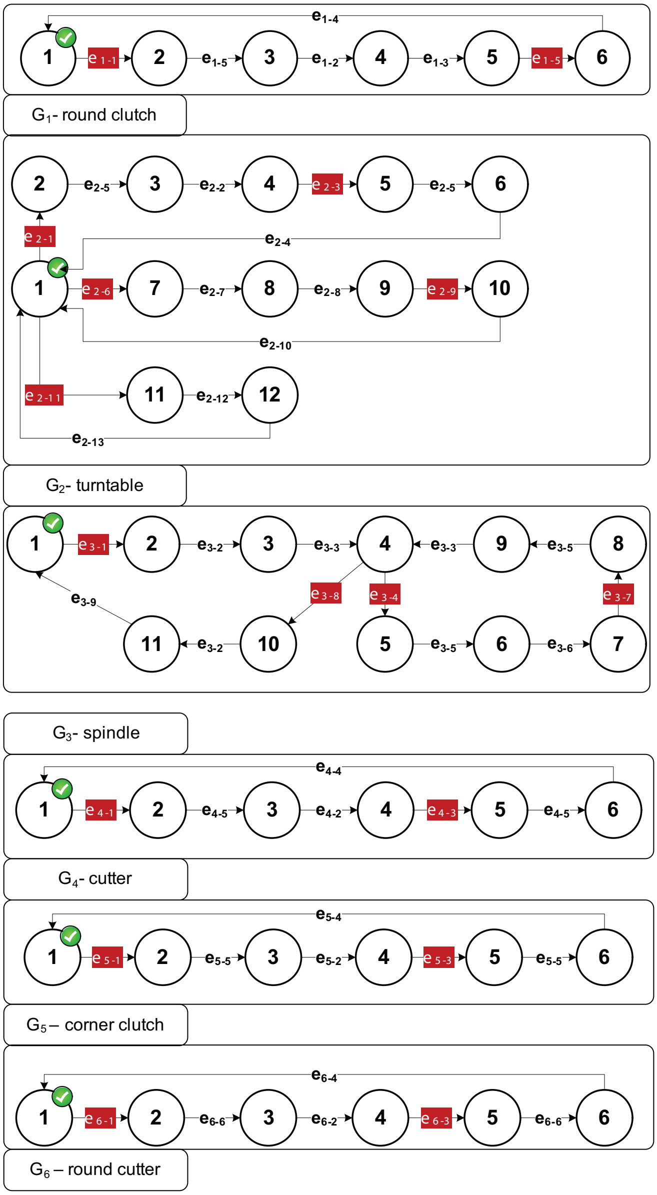

Fig. 23. Component finite machines $G^1, G^2, \ldots, G^6$

The required machine behaviour is informally presented by text specification in Appendix 2. This behaviour is formalized by finite machine $H=(Q_h, E_d, \delta^h, \Gamma^h, Q_m^h, q_0)$, with a graph of transitions shown in Fig. 18, section 6.1. The states of machine $Q^h=\{q_1,...,q_{23}\}$ correspond to the steps of processing and the edges – to the operations of component machines.
The proposed method was applied to analyse *G*=<*G*^{1}, *G*^{2}, …, *G*^{n}> object and *H* specification. The experiment $\Re$ showed the consistency of *H* and *G*. Then, the graph of supervisor (Fig. 24) was obtained. Entering a node, the edges relevant to the same operation have common marking (e.g. the edges entering node 7). In the supervisor graph, every edge is weighed by G^i CFM component operation and supplemented by the events of relevant reaction. Events e_{ex} are incontrollable, the edges with these nodes do not change. The comparison of two graphs reveals their structure identity. This illustrates that the complexity of supervisor designed by the proposed method, linearly depends on the complexity of initial specification.

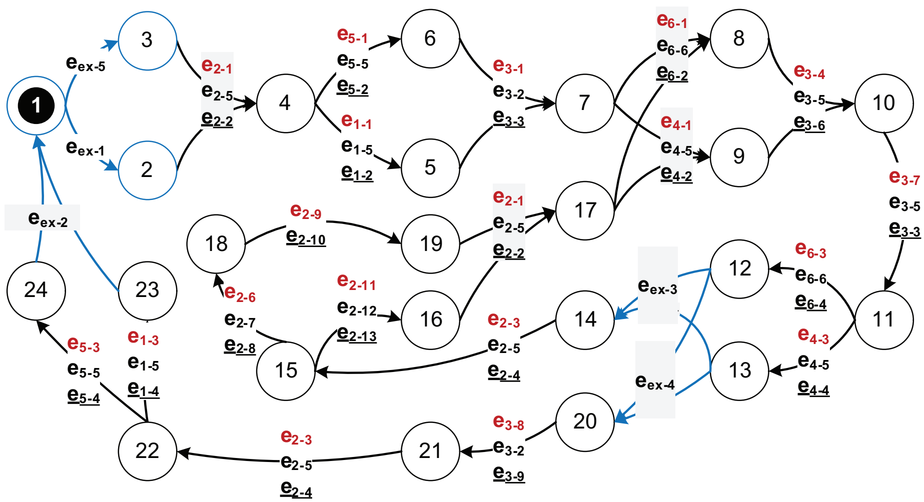

Fig. 24. Supervisor graph

7. Conclusions

SDES model proposed herein, does not use component composition in the explicit form but operates $\langle G^1, G^2, ..., G^n \rangle$ set and $K \subseteq E_d^*$ specification language specified by $H=(Q^h, E_d, \delta_h, \Gamma^h, Q_m^h, q_0)$ machine (recall that $E_d = E_c \cup E_{uc}$ is a language over a set of commands and conditions). Such approach to the description model is more economical, than that in *L(G)* language and is much more expressive than the one based on parallel composition $\bigoplus_1^n G^i = G^i \oplus ... \oplus G^n$ and $K \subseteq L(G)$.
Thus, the proposed SDES model and the procedure of its operation take maximum account of the SDES (real-time automation system) peculiarities mentioned in the introductory part. There is a ground to believe that thereby it will be possible to avoid the «explosion of states» at supervisor synthesis. The proved theorem of controllability for SDES builds a theoretical

basis for further studies and a base for programming and experiments on the stream of real tasks.

Thus, (turning back to the problem stated in Introduction) it can be declared that herein is developed a theoretical basis for a new technique of machine control engineering that excludes ambiguity and mistakes in the initial specification of a control object as a "black box".

As the result of research pursued, the conditions of SDES and SDESf controllability were formulated, the matter of supervisor existence was studied, the method of specification realizability verification was shown.

The condition of controllability was worded with respect to specification language *K* that is more expressive and compact (being a project of *L(S/G)*) than language *L(S/G)* traditionally used in the models with parallel composition.

The paper suggests the structure of supervisory control, contains the study of the method of supervisor *S* synthesis based on the object model and specification (*G* and *K*). It also illustrates a linear dependence of supervisor *S* complexity on the number of edges of *H* machine.

At the same time, the number of synthesis operations (time complexity) remains linear only for the specification in which complete states, one at a time, are disposed on *H*, i.e. the number of operations for the designing of $S \le O(|R|)$. Generally, the appearance of "second" complete states in the structure of *H* weighing, results in the repeated analysis of transitions and the linearity is violated. However, practically, for real tasks, this phenomena, reflecting a designer's aspiration to specify commands sent to aggregates (actuators) more economically, does not lead to a considerable growth of the number of operations.

8. References

Ambartsumyan A.A. (2009) Supervisory Control of Dynamic Discrete-Event Systems. *Automation and Remote Control*, No.8 (August 2009), pp. 156-166

Ambartsumyan, A.A., Kazansky, D.L. (2008). Complex automation of technological processes with the event model involved. *Procedings of 17th IFAC World Congress*

Ambartsumyan A.A., Bronishtov S.A. (2006) *Event models of process control directed at the protection against personnel's erroneous actions.* «Greenwich LTD », Moscow

Ambartsumyan A.A., Potehin A.I. (2003) Development of control mechanisms of objects with continuous technology on base of channel event models. *Automation and Remote Control*, No 4 (April 2003)

Ambartsumyan, A.A., Prangishvili, I.V., Poletykin, A.G. (2003). Power plants: the analysis of state and the proposal of enhance automation. *Problems of control*, No.2 (March 2003)

Ambartsumyan A.A., Potekhin A.I. (1977) Standard realization of asynchronous machine *Automation and Remote Control;* No.5, (May 1977) pp.67-83

Cassandras C.G., Lafortune S. (2008) *Introduction to discrete event systems* « Springer Science+Business Media, LLC ». USA.

Chalmers Golaszewski C. H., Ramadge P. J. (1987) Control of discrete-event processes with forced events. *Proc. 28th Conf. Decision Control.* p. 247-251, Los Angeles

De Queiroz, M.H., Cury, J.E.R. (2000) Modular supervisory control of large scale discrete-event systems. Discrete Event Systems: Analysis and Control. *Proc. WODES'00*, pp. 103-110.

Gaudin, B., Marchand, H. (2003) Modular supervisory control of asynchronous and hierarchical finite state machines. *Proc. ECC*, pp. 13-25

Gilard Langer. HoMuCS (1999) *A methodology and architecture for Holonic Multicell Control Systems Preface*. KPB -2-99; ISBN 87-90855-00.

Jo Wyns. (1999) *Reference architecture for Holonic Manufacturing Systems - the key to support evolution and reconfiguration.* ISBN 90-5682-164-4, K.U.Leuven

Kuznetsov O.P. (1975) Logical machine graphs and their transformations *Automation and Remote Control,* No. 9, (September 1975) pp.149-158

Ramadge J. G., Wonham W. M. (1989) The control of discrete-event systems *IEEE Trans. Automat. Control.*. 77(1). p. 81-98.

Ramadge J. G., Wonham W. M. (1987) Supervisory control of a class of discrete event processes *SIAM J. Control Optimization*. 25(1). p. 206-230.

Sujeet Chand. (2005) From electric motors to flexible manufacturing: control technology drives industrial automation. *IFAC*

Van Brussel H., Valckenaers P., Bongaerts L.,Peeters P. (1998) Reference Architecture for Holonic Manufacturing Systems: *PROSA. Computers in Industry.* p.37- 47.

Yoo, T.-S., Lafortune, S A (2002) General architecture for decentralized supervisory control of discrete-event systems. *Discrete Event Dynamic Systems: Theory & Applications* – No. 12(3), pp. 335-377

Appendices

Appendix 1

event	operation	event	operation
e_{1-1}	To clench	e_{3-8}	Feed ->>
e_{1-2}	Clamp is closed	e_{3-9}	Parked
e_{1-3}	To unclench	e_{4-1}	To switch on
e_{1-4}	Clamp is open	e_{4-2}	Working
e_{1-5}	clamp is moving	e_{4-3}	To switch off
e_{2-1}	To fix	e_{4-4}	Stopped
e_{2-2}	Table is fixed	e_{4-5}	Unstable rotation
e_{2-3}	To unfix	e_{5-1}	To clench
e_{2-4}	Table is unfixed	e_{5-2}	clamp is closed
e_{2-5}	Locker is moving	e_{5-3}	To unclench
e_{2-6}	To make a ¼ turn	e_{5-4}	Clamp is open
e_{2-7}	Table is moving	e_{5-5}	Clamp is moving
e_{2-8}	Table is turned through ¼	e_{6-1}	To switch on
e_{2-9}	To switch off turning mechanism	e_{6-2}	Working
e_{2-10}	Table is stopped	e_{6-3}	To switch off
e_{2-11}	To tilt plane	e_{6-4}	Stopped
e_{2-12}	Is tilting	e_{6-5}	Unstable rotation
e_{2-13}	Angle is achieved	e_{ex-1}	Piece is on the table (round)
e_{3-1}	<<- to feed	e_{ex-2}	Piece is removed from the table
e_{3-2}	Feed zone	e_{ex-3}	Processing is not finished
e_{3-3}	Operating position	e_{ex-4}	Processing is over
e_{3-4}	<- to feed	e_{ex-5}	Piece is on the table (hexahedral)
e_{3-5}	Operational zone	e_{ex-6}	To choose usual cutter
e_{3-6}	Operation is over	e_{ex-7}	To choose round cutter
e_{3-7}	Feed ->		

Table of system events

Appendix 2

1	On arrival, a piece is clenched by a clamp
2	After clamp operated, spindle is transferred from parking to working position (to the left)
3	After spindle shifted to working position, cutter is turned on
4	After cutter is turned on, a smooth feed to the left utmost position takes place (end of operation)
5	After operation is over, spindle is fed back to the right up to working position
6	After spindle occupied working position, a positioner turns the table through ¼.
7	After the table is fixed, the next operation is executed until the processing is over
8	After the round is made, a spindle parks, a clamp is unclenched, a signal of piece readiness is sent
9	Before parking, to switch off cutter, to wait until it stops
10	Operator chooses a cutter type and a cutting angle

Table of text specifications

6

An Approach to Technological Processes Automation using Technological Coalitions Based on Discrete Event Models

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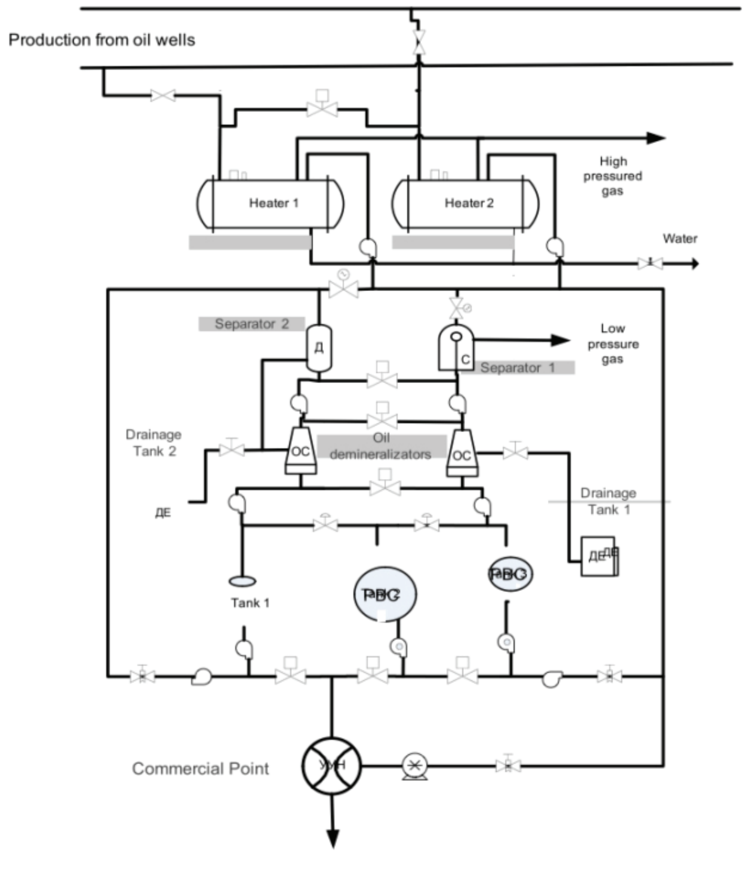
1. Introduction

There is a common feature in all control systems in big plants that use complicated technologies. It is that their control systems usually consist of two parts. There is the automatic control part for simple control tasks and the supervisory control part for other tasks. Functional division between these parts is not stable and depends on how mature is the automatic control part. Of course the share of automatic control generally tends to increase, even though in the more complex cases this growth is checked by the lack of suitable algorithms. Thus supervisory (i. e. human) control will always remain necessary until algorithmization of all aspects of technological processes is completed. Today there are several methodological problems which remain outside the scope of existing approaches to control system design, which causes inherent flaws in the resulting algorithms. We propose to introduce a new approach that will address these issues, and we will explain our approach using a common type of industrial technologies called flow technologies. A few words about these.

A lot of different tanks, valves, pumps, separators, desalters (demineralizers), heaters, fractionators, coolers, petroleum gas flare system, boosters and some other devices (aggregates) are connected usually by pipes or conveyor belts and some flows of different substances pass through them while the properties of these substances undergo numerous changes. This is what in the present paper we are going to call “flow structure of technology” or just “flow technology”. We must stress that we will consider here only big plants which have a lot of types of technological equipment. We should notice that flow technologies are used extensively in oil and gas industry, chemistry (cryochemistry), power engineering, hydrometallurgy and in other types of heavy industries, manufactures and processing plants. We have here roughly outlined the areas where our research is likely to prove useful; those interested in the technological aspects of particular industries should refer to the literature on the subject. Flow technology is quite a common kind of technology – for example, we really can refer to processes of production and preparation in oil fields all over the world. Multi-field plants show appropriate example of this technology. It is a big illusion to think that the black liquid (the pure oil) is produced direct from wells. Usually only an oil-gas-water-sand mixture is really produced from the wells. Figure 1 below shows the structure of a typical oil-plant. There are several input flows from different oil-fields and there is one output for oil, one for gas, one for water (in most cases). We can refer an example of control concept (Chacon et al., 2004) but we developed another view and approach for control. Different combinations of equipment can be used for oil processing depending on raw oil characteristics (sulfur, water, dissolved gas, sand etc). There are a lot of combinations and, it is important, none of these combinations is stable for a long time. The period of stability is between 2 and 8 hours usually.



Example of flow technology: Typical structure of technology by production of oil (light version)

Fig. 1.

We'll focus on general flow technology control algorithms applicable to any of the above-mentioned industries. As we know there are three fundamentally different types of control functions in industrial applications:

-1st type - the local protections and alarms (simple one-step action, used for accident prevention. They are really very simple: "IF condition THEN action". The action itself is usually a one-step instruction to a single aggregate like open/close/switch_on/switch_off etc),

-2nd type - the local regulators (used to prevent certain parameters going above or below the required level. The regulator continually controls the position of a pump or valve at any given moment based on the values of technological parameters using P, PI or PID rules),
-3rd type - the multistep logical algorithms for group control (or MSLAs). MSLAs are used to determine how different hardware components in a flow technology context interact with each other.
All these types of control functions were invented and implemented in 20th century. The first two types are already completely formalized and automated. They are mature enough and this is confirmed by their worldwide use in real manufacturing. There are a lot of implementations and modifications of them and we won't discuss them any more in the present paper.
Our target is the third type of control functions, MSLAs. They are not popular in real manufacturing to the present day and we have difficulties with them. We'll try to answer why. MSLAs, although repeatedly tried, have not been found to perform satisfactorily in real life conditions because they can only work for a very short time before they have to be updated or modified. Hence there is an urgent need for change in design methods used for this type of algorithms. We should explain in somewhat greater detail what is in fact wrong with these algorithms and their design method.
In real life there are a lot of interfering factors which can disturb or upset the normal functioning of algorithms. We must consider different external and technological factors and parameters which can appear. All the three above-mentioned types of algorithms should ideally have the ability to register and process external changes, i. e. be adaptive. This is not an issue for type 1 and 2, there are easy and well-known ways to customize them. But there are no such easy ways for MSLAs. As a result it is typical for them to lose control ability.
Some time ago we commissioned a study the object of which was to find out how and to what extent MSLAs were actually being used in various industries. The results were not unexpected, though far from optimistic. We found that 45% to 60% of users stopped using MSLAs within the first 2 months, while after 3 months this figure rose to 75%. In all cases where MSLAs were no longer used an operator had to take over. When we asked what caused this change, the answer was quite simple. There are two reasons. The first reason has to do with the constantly changing properties of the substances being processed (raw oil, etc.). A single rigid algorithm simply ignores these changes, many of which are critically important. The second reason is changes in hardware introduced in the course of normal upgrades and maintenance of equipment (monthly or/and weekly) and the consequent small (but accumulating) changes in operating requirements. For example, when any part is replaced with a technologically compatible but slightly different part, the new part will interact with other devices in a more or less different way than the old part did. This fact of parts being constantly replaced with other non-identical parts (e.g., from another manufacturer or with slightly different specifications) is the basis for all (or nearly all) interfering factors for MSLA. Software developers didn't anticipate this and therefore made no provision for this in their algorithm. As a result the small changes in the characteristics and/or technological requirements of several hardware components can cause very deep changes and often require a full rebuilding of the MSLA. This problem doesn't destroy type 1 and 2 algorithms, but it is a serious problem for type 3 algorithms. We call this problem of increasing inability of the system to adapt to changing conditions "aging of MSLA" or "becoming out of date".

A few comments about "aging of MSLA". Is the situation of "MSLAs aging" capable for improvement in principle? That is the question. MSLAs are usually designed before real launching of flow-technology. After a very brief period of real use MSLAs won't be able to provide adequate control any more because they will not be able to absorb the latest changes. We can of course completely rewrite the algorithm each time, but this is hardly an efficient approach. The problem is there isn't any regular (scientific) method and suitable tools for tracking changes and assimilating them in the body of MSLA. It is absolutely clear that the larger a MSLA is (i.e. the larger the number of steps it contains) the more vulnerable it is to external changes. These algorithms are destroyed by their big size.

The classical (and usual) way to describe the functioning of the algorithm today is to build an appropriate Finite State Machine (FSM) (e.g. a Moore machine or a Mealy machine) or a Petri Net (or to use another method based on these). After that it is necessary to supplement the control algorithms with some existing SCADA. It works, but for simple cases only. It appears that there is a fatal flaw in this method of design for MSLAs which results in algorithms that are unusable in the real world. Is it possible to separate the solvable and the non-solvable part of the problem for MSLAs? It seems at first sight that it is not a scientific problem. We did not expect to find many papers about MSLAs and about this problem. There is some truth in that, as we understood later, after looking in different sources (Wonham & Ramadge, 1988, Jennings et al.,. 2001, Yoo & Lafortune, 2002, Cassandras & Lafortune, 2008). Some other aspects were discussed during congresses and conferences (Golaszewski & Ramadge, 1987, Zambonelli et al., 1994, De Queiroz & Cury, 2000, Akesson et al., 2002, Gaudin & Marchand, 2003). There is not wide bibliography but where there is a will there is a way – and we started looking for some scientific solution to this problem.

This concludes the semantic introduction and the general description of the problem. We have determined the type of technology for investigation and sketched the main problems. Some results are below.

2. Different ways to use the Finite-State Machines in case of real control and in case of classical transformations of strings.

We have to spend some time and to draw the reader's attention to basic things. The ideal control situation as a general concept is the situation of informational interaction between two components. In this situation there is always a controlled component and a controlling component. The controlled component informs the controlling component about its events using a special pre-arranged alphabet. The controlling component receives information from the controlled component and sends the functionally defined, appropriate command; also using a special alphabet. The ideal control situation for MSLA is often described by means of FSM (e.g. Moore machine or Mealy machine). Let us look at a classical definition of a Finite-State Machine (FSM). As we know there is its classical definition, suitable for most applications:

$$A=<S, X, Y, \delta, \lambda>, \text{ where}$$

S is a set of states.
X is an input alphabet (a finite, non-empty set of symbols).
Y is an output alphabet (a finite, non-empty set of symbols).
δ is function for states $(S,X) \rightarrow S$ (the state-transition function).
λ is function for outputs $(S,X) \rightarrow Y$.

We have to admit that the FSM is appropriate for cases involving string transformation. But real-life control situations are far more complex than that, and cannot be reduced to string transformation alone. There is difference between string transformation and real control situations. The nature of real control must allow the existence of additional external information of different types which can possibly affect the outcome - but hard-coded sets of transformation instructions (X→Y) do not allow for any adaptive behaviour. As we see the classical definition of FSM serves only situation of transformation of strings. The classical definition of FSM allows to have only functionally defined commands. Availability of additional data and any special handling of them as basis for case of control didn't foreseen in the classical definition (Fig. 2).

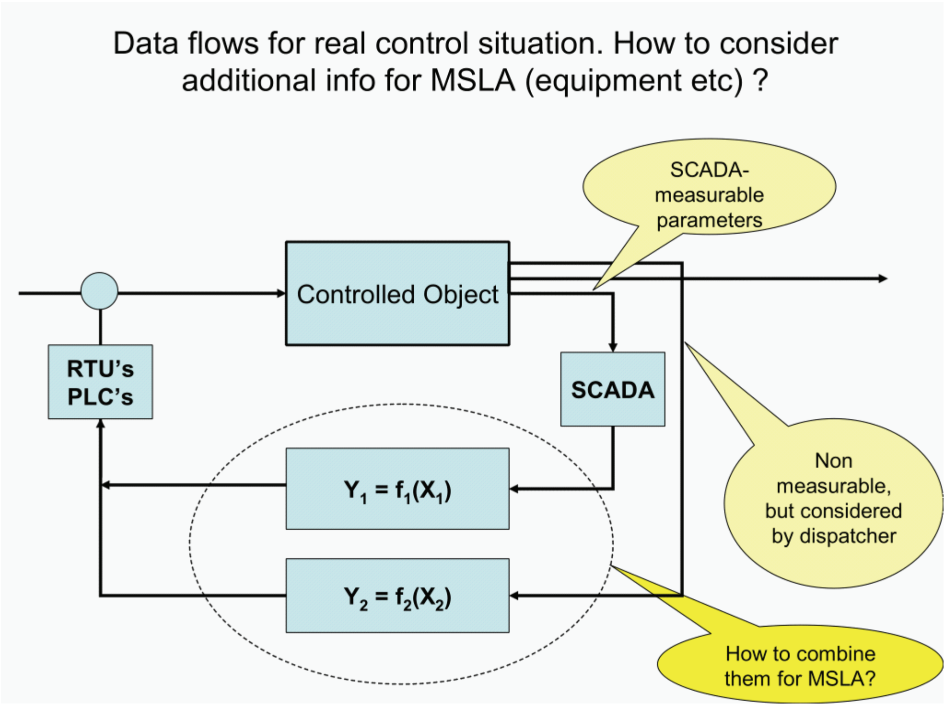


Fig. 2. The real control situation

We can see that operational staff (dispatcher) works in other reality and manages necessary types and sources for additional data, every time may be with other method. The real situation of control with using of MSLA is:

- Reading a part of data using SCADA:
- Based on this input, the system determines what additional data is required in order to correctly modify the output action, and where this data is located;
- Definition types of additional data, sources of them and extraction methods;
- Searching and receiving these additional data;
- Combining all data from all sources, analyze;
- And, finally, defining the appropriate control action based on all the data received from all sources.

The mentioned practical features are light version these things, which pull and feed the control theory for flow technology today. They determine a way which must be passed (done) and tasks which must be solved.

3. Discussion about concept of Technological Coalitions

Before we start to consider the above mentioned different external changes and try to adapt MSLA for them we should spend some time for decomposition of technological processes and to give some necessary previews and introductions for new ideas. First of all we are going to introduce and discuss a new concept named "The Technological Coalition" as a special part of technological process and corresponding part of algorithms for its control.

We use decomposition of technological process not as it is used in most cases, not only as a tool for decreasing the complexity of technology description. We use it as tool for finding and delimiting areas of instability, changeability in the technological process. What does it mean ? It means that any new change (factor) which will appear will be localized in Technological Coalition (TC).

The second assumption is that all TCs behave in the same way. The same behavior means that the same operations can be determined.

$$TC=\langle A, R, LCA, M\Phi, M\Psi, MS, LC\rangle$$

A – set of separate devices for different technological needs. Any reservoirs, valves, sand collectors, pumps, separators, drip pockets, desalters (demineralizers), heaters, freezers, fractionators, precipitation tanks, coolers, sewage tanks, components for flare system, boosters and etc. They are collectively known as "equipment" or "devices" or "aggregates". Each type of equipment (aggregate) has its own local control algorithm (included in a special set named LCA – see below).

R - defines physical links which connect product inputs and outputs of different aggregates. It means for most cases some pipes or other transporters. The flows of different substances pass through them and various parameters of these substances change in the process.

A and R together build a TN – an oriented graph of Technological Net. The concept of a TN is too well known to require any examples.

LCA – set of local control algorithms for each type from A. We prefer to use Moore-Automat Model for each element of LCA, but it isn't necessary.

MΦ, MΨ, MS are tables with a special purpose – they collect changes and give possibility to consider and process them.

LC – Life Cycle of TC (see below) described as an oriented graph having six special states.

The traditional division into the controlled object (technological process) and the control system (algorithms, MSLA) is changed here. Please note that A, R, LCA represent the flow technology, LC – is a part of control system. The TC consolidates parts of both sides. And the TC isn't the result of decomposition of our flow technology only.

The TC as an abstract idea doesn't have exactly one, precise and absolutely clear interpretation for operating staff and for software developers. We realize it. In most cases we can associate the TC with an idea of "route" (as sequence of technological devices), but not always. Note that a list of TC's appears on the phase of pre-design of control system, but implementation is often not clear on this phase. Moreover, it will be better when technological specialists and control specialists develop the list of TC's together.

It is often right that all devices of TC serve different characteristics of whole stream of substance. This stream has technological comprehension as indivisible (is viewed as indivisible). On the other hand, we suggest that MSLA should only be used to control such controlled object as TCs, not for other purposes. Thereby we'll define the special rule of correct using for term "MSLA". But a problem of coordination between different MSLA will appear. We'll try to find approach for decision of it later. So we have some important assumptions now:

- TC is possible. In other words, we can show that any single change which appears in the flow technological process or in equipment after retuning (replacment) will upset not all technological process but only one delimitable part of it. We'll call this part of whole technological process as TC but we'll understand it as special combination of controlled object and controlling object having formal definition.
- There is the common control architecture for all TC's irrelative of their size and local behavior. (Really it is only hypothesis. We are going to prove it later.)
- An operator will be able to manage TC using special tools.

Since we have defined TC as the controlled object, we have to explain what are the control commands for it. We assume that we do not have to physically build the TN, so our commands will not create structures, but deal with different states of a TC with an existing structure. Our commands are not commands for structure building. First of all we have to determine the needed states of TC and after that we'll determine appropriate commands. The commands will tell the TC to change from one state to another. Simplest way is to determine two states (is working now and isn't working now) but this will not be of much practical use. This is a very general view, of course. It contradicts none of the existing views but is not yet much help otherwise.

We need of course more pragmatic content for TC. How and where can we get meaningful states for TC? We shouldn't forget that we are going to invent and to use decomposition idea which allows to have the same behavior for all TCs. We should analyze the technological reality again. We can imagine and correct understand these operations as wake up, prepare, launch, get current state, tune, customize, shut down (and probably more additional commands) without semantic troubles. So we want to introduse some overview of possible states of TC's for future control systems designers. These commands are meaningful for any TC and they determine moving between states at the same time. Involving and shutting down of TC's won't be momentary. There are often a multi-step involving (preparing) process and\or multi-step shutting down (canceling) process. So, states of TC we can see on Fig. 3. By the way - there is a right question why number of states is equal to six? Is it a special requirement of flow technology or not? Are there any exceptions? Our answer – the real number of TC's-states may be more or less than six, of course. It depends on concrete application. Important thing is the equal number of states for all TC's. Only if all TCs have the same states in their LC we can suggest the universal control mechanism for control of them. But for flow technological processes six as number of states is preferably.

By the way, all these commands will be realized as methods for object oriented concept of TC's if somebody is going to put much effort in OOP-implementation of TC's.

Moving (by operator's supervision or under control of the automation system) trough these states is Life Cycle (LC) of any TC. We have steps for operator and some other steps for automated control system now. A clear division between an operator and automated control

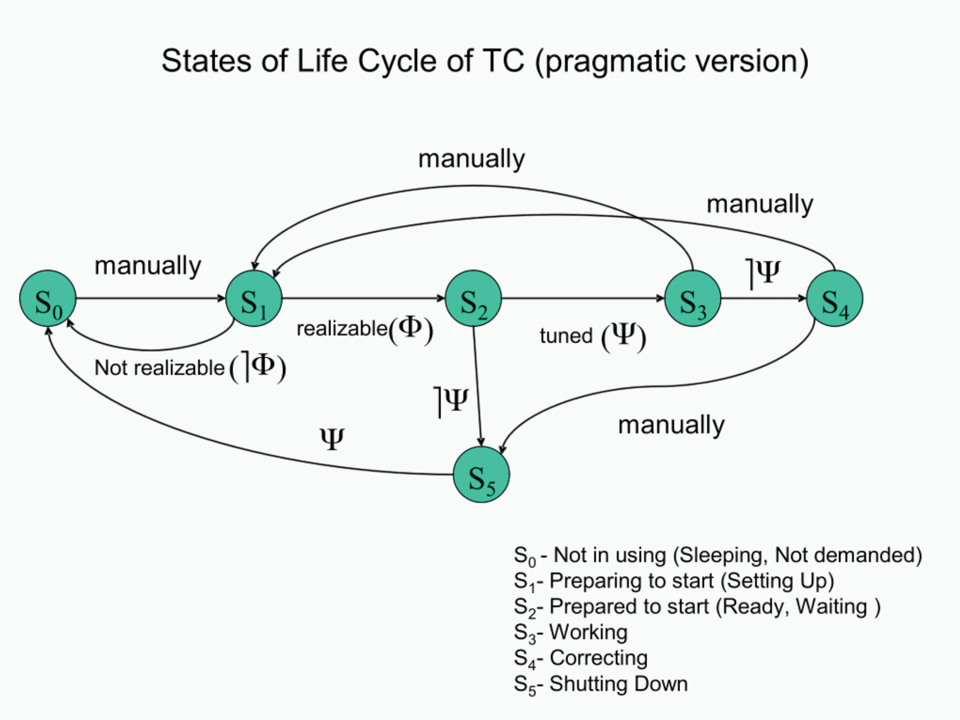


Fig. 3. The possibly states of LC

system allows to divide future efforts. Transitions marked "manually" need only right-designed human-oriented interface. As we can see transition marked otherwise need to connect with sensors and/or SCADA. There are some comments to transitions:

- $S_0 \rightarrow S_1$: First transition after sleeping. This transition managed by operator manually. Reasons for activity of dispatcher in this transition are out of this paper. Dispatcher can reject from his decision about waking up if it will necessary.
- $S_1 \rightarrow S_2$: Preparing to start (phase one). Intensive using of **MΦ-table** (see below)**.** Operator fills in this table self or asks technologist. Meaning of this step – to collect all necessary devices and to check them (they are in good working condition) and avoid involving of them in other active TC's. If realizing =OK then jump to S_2, else jump to S_0 and sending message to operator. If we have conflict(s) (necessary devices isn't free or not ready) then dispatcher can launch a special local subprocess for this aggregate.
- $S_2 \rightarrow S_3$: Preparing to start (phase two). Intensive using of **MΨ-table** (see below)**.** All necessary devices are included in TC but are not ready to work yet. For correct launching we must to prepare additional conditions. Level in tank_2 must be >= 3 m, for example. Or temperature of oil in pump must be >= 50^{o} C for correct starting, etc. There conditions can have logical or discrete or analog values. We associate them with devices (aggregates). The common conditions can exist too, certainly. Operator must launch and finish some additional local subprocesses for each device if it is necessary (oil-heating in bearings of involved pumps or filling of tank to necessary level, for

example). As result of this step we have a set of sequences for launching main technological process associated with TC. For example (abstractly): If (Level_12 > 3) then A4 (open). When all launching commands executed then the state of TC switches from S_2 to S_3.

- $S_3 \rightarrow S_4$, $S_4 \rightarrow S_1$: While we have S_3 the technological process is working normally. This is area for 1st and 2nd types of algorithms. Operator can solve to use slightly different configuration of technological devices. But operator doesn't want to use another TC. For example he (she) wants to start only an additional pump. Probably it is temporary changes. Anyway, it is necessary to check information about additional technological devices: jump to S_1. After checking (if "true") we return through S_2 to S_3.
- $S_3 \rightarrow S_4$, $S_4 \rightarrow S_5$: Operator have solved to change TC. Preparing to shutting down, checking for special conditions is needed. Operator usually has to use special commands or local procedures (manually or automatically). Changing of states $S_4 \rightarrow S_5$ means that all conditions are "true" and we can start shutting-down procedures immediately when we want.
- $S_5 \rightarrow S_0$: Shutting down procedures are finished. Shut down of TC is complete.

Most likely that S_3 is the state in which TC stays maximum period of time. It is normal but we shouldn't forget about other states. It is well known that for example an airplane has normal state (the flight) maximum period of time but the more dangerous and more required for the precise control are the other states (take-off and landing).

It is clear from practical experience that some devices for technological reasons can sometimes change their belonging to TC. It is true but each device must belong to only one TC at any given moment. In our oil processing example we stated that raw oil from different oil fields contains slightly different levels of sulphur. It requires different equipment and different routes (different connections) for processing. So, the staff should switch some pipes, pumps, valves which are serving other routes now. It means that our opinion about temporary belonging to TC is mainly true for pipes, pumps, valves. There is a special state S_4 in which it is possible. If TC has received external request for some device then there are some different variants of TC-reactions in this situation. For example:

- Check current availability of device. If it is free now then just "to lend" it
- If there is not availability then to ignore external request
- "To lend" required device to another TC but after finish shutting down procedure for current (giving) TC (postponed lending) but to start shutting down procedure for current TC
- Other scenarios...

Please note the following. On the one hand, we localized correct area for MSLA using (only for TC). On the other hand, we declared standartized LC for TC. From this it follows that MSLA can have standartized structure. In other words, we can build one algorithm for any TC if only each TC will have the same LC. In that way we changed an old approach. We suggest to modify MSLA's changes considering practice from building a new algorithm every time if only we fixed some changes to configuring one time developed algorithm. It is important thing. MSLA will be standartized part of conrtol system now.

It is clear that MSLA's aging problem didn't disappear with suggestion of TC. We could only localize external influences without considering them. We also need a special generating tool which must be available for using not in design phase but in running phase (see Fig. 4). Probably it will a special extension of SCADA-software.

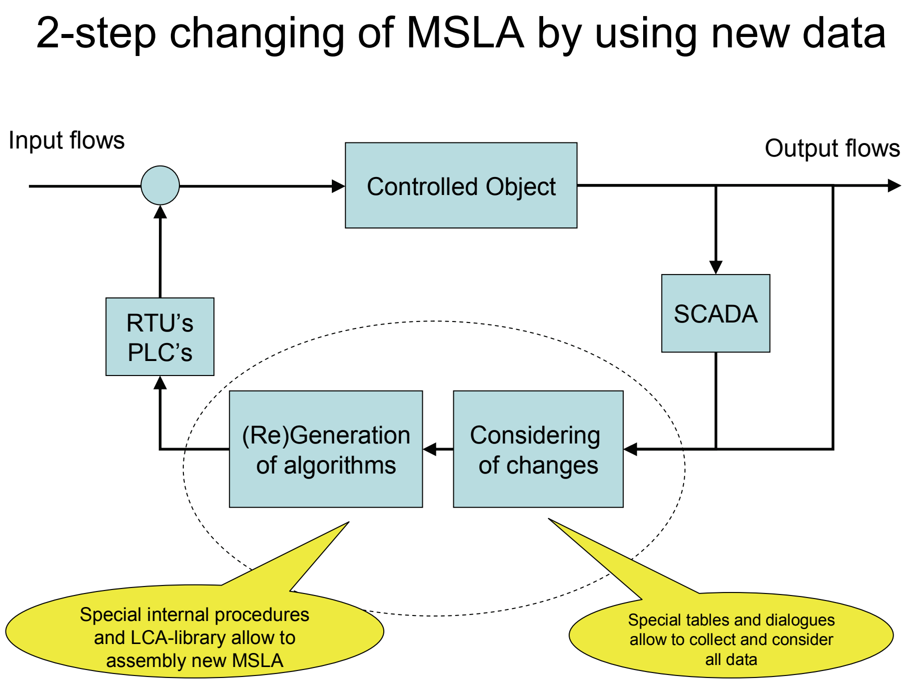


Fig. 4. Including the considering and generating parts in the feedback loop

4. Tools for external changes management

If we return to TC's definition then we can see there some MS, MΨ, MΦ. Yes, there are some tables which describe all involving aspects for each device. The horizontal axis is devices from A, vertical axis is set of foredesigned TC's.
The first table is MS. It contains device's states needed to involving to any TC, states for starting of any TC. It is clear that different TC's can theoretically require different starting states from the devices. All states for all devices we can get from Local Cycle of Aggregate (LCA). Each LCA is a simple FSM for one device. We can suppose that LCA is a part of TC. Or, otherwise we can think that LCA is a common information resource (like a software library), external for all TC's. Important that we can extract from LCA command sequences needed for transition from any state of given device to any other state.
If we have current states (we will use an additional table MT for current states of technological devices - from SCADA) and states from MS it seems after that that we'll be able to assembly TC launching program only with conjunction different command sequences for any device. We think it will be better when we postpone mentioned assembling yet. Now it is the best moment to consider last changes which we discussed formerly. We are going to suggest using two new tables MΨ and MΦ. All additional conditions which must be considered are entered into these tables. Commands which are prepared from LCA must be sent to controllers after allowing conditions from MΨ and MΦ.

Example of MΦ-table – conditions for involving aggregates in each TC(readiness and not in repairing)

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
TC_1	$H_2=1$	q_1	$B9<2$	$F_2=4$	q_3		q_4		q_3
TC_2		q_2	q_2	$F_{22}=1$	$K_4=1$	q_3	$U_{12}<28$	q_1	
TC_3	q_3		$(U-Y)<4$	q_2	q_3	$K_4=1$	q_1	Q_5	$KL_{17}<5$
TC_4	$K_4=1$	$(U-Y)<5$		$F_{23}=1$	$K_6=1$		$Q_{53}<90$	$KL_{23}<0$	
TC_5		$(U+K)>$ $(K+H)$		q_4	q_4	$F=44$	$KL=<9$		q_7

Example of MΨ-table – additional conditions for involving aggregates in TC

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
TC_1	$H_2=1$	q_1	$B9<2$		q_3		q_4		q_3
TC_2		q_2	q_2		$K_4=6$	q_3	$U_{12}<28$	q_1	
TC_3	q_3		$(U-Y)<4$	q_2	q_3		q_1	Q_5	$KL_{17}<5$
TC_4		$(U-Y)<5$			$K_6=1$		$Q_{53}<90$	$KL_{23}<0$	
TC_5		$(U+K_2)>$ (K_4+H_5)		q_4	q_4	$F=44$	$KL=<9$		q_7

5. General mechanism of considering and control

TC is functioning not alone. There are some other TCs, which can at the same time launcing, working, configuring, shutting down. The right environment for the one TC are the other TCs.

There are two virtual sets in our vision: a Set of Active TC's (SAC) and a Set of Passive TC's (SPC). In a real production process each TC belongs to SAC or to SPC. The changing between SAC and SPC under supervision of dispatcher or under special algorithms is the abstract vision of our flow technological process. Objects for changing between SAC and

SPC are the TC's (see Fig. 5). Let we agree that integrated flow technological process for each moment of time is the SAC. Any of TC can change its current belonging (to SAC or to SPC) during technological process a lot of times. It depends only on technolocal needs and\or dispatcher's will (wish).
Destination of the control system in this vision is supporting correct changing (TC-moving) between SAC and SPC according technological needs and operator's will. Inside this task there is another task, more local, but no more important: to support the LC of each TC.

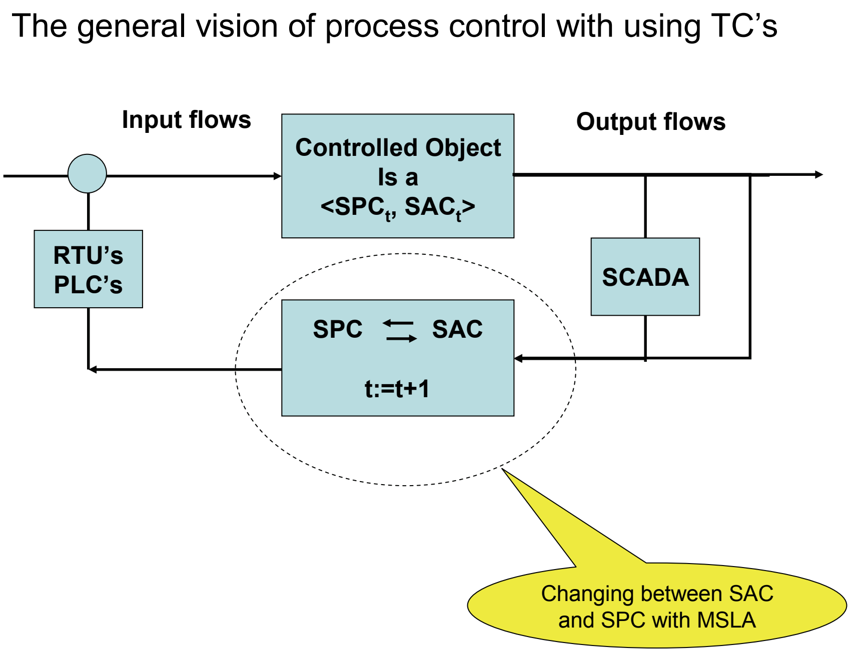


Fig. 5. SAC and SPC are the main controlling parts.

When we have certain SPC/SAC and want to change SPC/SAC for next point of time we 'll do the same actions for any points of time. These actions are included in MSLA. Note that the MSLA is not any multistep algorithm. It is the multistep algorithm having TCs as controlled objects and working with SPC/SAC. It is possible to have a lot of working instances of MSLA: each one for serving one TC (its LC). Steps for any MSLA and for any states of LC are equally.
How does it work together? The behavior and steps of high-level interpretation mechanism for MSLA are the following:

- All TC's belong to SAC or SPC. All TC's including in SAC are working. Low level automated control systems (PLC's and RTU's) are working, structure of flows is defined by an active TC's, flows function are under control of alarms and local regulators, and a set of actual events is formed.

- Operator can observe active TC's (using SCADA) and can understand if they are working correctly.
- Depending on the real situation in manufacturing, operator selects a necessary strategy by launching and shutting down for each TC. Once time operator makes decision to change SPC/SAC: to launch a TC_j or to shut down TC_k (some external events have occurred). Operator selects a concrete TC to launch or to shut down manually and after that he (she) can entrust the matter of control to MSLA (MSLA begins to implement control mission). Current states of all needed devices are read through SCADA (by MT-table). Possible collisions (sharing some aggregates with another working TC's) are solved by operator using special human-oriented dialog.
- Preparing to assembling starts when all collisions are solved. If necessary the monitor (or operator) makes some queries to fill in the special tables for actual data (new conditions for involving devices are possible). **MΦ** and **MΨ** are using now. The monitor reads a new data from mentioned tables. Low level vision of MSLA for PLC-executing is set of sequences "condition→action". Two parts of data are combined by logical assembling in the one multi-step program. This set of sequences is goal of assembling and it requires two types of source data - new conditions (from **MΦ** and **MΨ)** and new actions (from LCA)
- Assembling of programs starts. Monitor reads current and targeted states. If LC-graph has transition with MΨ or MΦ for these states then monitor makes data reading. Most important by launching is transition from S_2 to S_3 (see LC-graph of TC) and by shutting down - transition from S_4 to S_5. By generating of control a special logical assembler (SLA) extracts sequences of necessary commands from the mentioned LCA-library. By generating "shutting down"-program the SLA uses the LCA too. Logical assembling is completed when we have the list of instructions (abstractly example): if (conditions from $\mathbf{M\Phi_i}$ and $\mathbf{M\Psi_i}$ are **"true")** then extract_commands_from_LCA_i ($\mathbf{MT_i}$, $\mathbf{MS_i}$). A number of sequences equal of number of devices. Mentioned in expression above substring "extract_commands_from_LCA_i($\mathbf{MT_i}$, $\mathbf{MS_i}$)" means that the SLA expands this command (as whole instruction) into set of commands based on the accordingly finite automat from LCA. It is important to note that the SLA makes only substitution from the LCA for each instruction. The necessary order (sequence) of turning on of different devices in the real flow we can get by using **MΨ-table.** For example we can add to formal conditions for aggregate in **MΨ-table** a special conjunctive term for considering that previous device got right state before.
- Finally, the algorithm for launching TC_j and (or) "shutting down" TC_k is assembled and ready to start now. The monitor or operator launches each assembled and ready to start "fresh" algorithm. Local PLC's and RTU's must implement this algorithm after loading instructions. Special software for uploading a programs into memory of PLC's is available and we don't focused on it here.
- Launching and shutting down processes are working and controlled by operator. Monitor receives back answers from PLC's and RTU's.
- If processes have finished OK then would be to refresh (to update) SAC/SPC. MSLA is complete. Go to 1.

Note, we didn't formalize merging and dividing of different TC but it is possible in nearest modifications of the control mechanism. The special mechanism for sharing (or for "lending") several supporting devices (mainly such as pumps) between different TC will be described in next publications of autors. So we have that slightly corrected principle of decomposition (we are looking for and use coaltions of technological devices which have standartized behavior - LC) and not complicated extracting- and re-assembling procedures allow to have standartized MSLA as part of control system and to get rid of mentioned problem of “aging”. The general view is on the Fig 6.

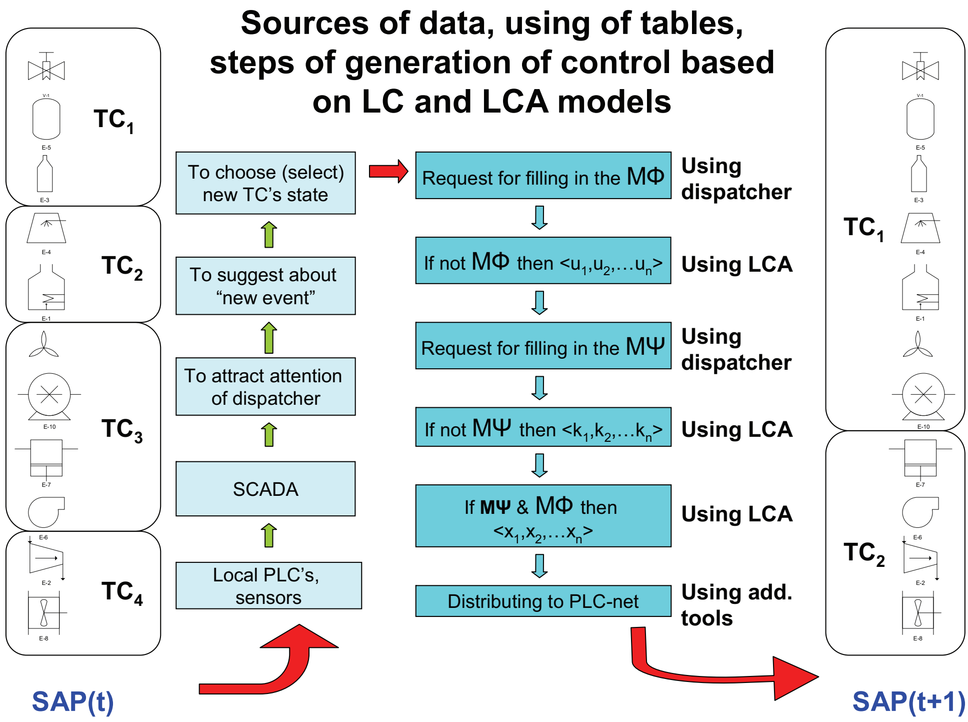


Fig. 6. All components are working together.

6. Conclusion

It was stated earlier that of the three types of control which were analyzed the MSLAs are the most likely to get out of date. Moreover, in most practical cases MSLAs work best immediately after being first implemented and started up, after which error accumulation inevitably begins. It is not a good idea to become reconciled to this fact. We have realized that classical FSM-approach doesn't work in practical cases of control. It causes MSLAs to fall into disuse, but current disadvantages of MSLAs are not intrinsically insuperable. In any case it is now unacceptable to go from automation back to manual control. Today's industries require more and more automation for increasingly complex technological processes. But as of today the real technological equipment is not yet like P'n'P devices and not all necessary control standards are implemented or even exist. We hope that we were able to explain why the classical FSM approach leads to increasingly unsatisfactory performance of MSLAs in real life situations. Their developers didn't consider possible changes in control logic after maintenance, repair or technological changes. This destroys MSLA in the end.

We need to return to the reality of big plant control. FSM is able only to transform strings $\alpha \rightarrow \beta$ but real control has more than one step. The real control situation must assume the worst thing: that the controlled object has changed. On receiving information from the controlled object there is often a choice (or alternative) $\alpha \rightarrow \beta$ or $\alpha \rightarrow \gamma$ and we need additional information to make the right choice. The real situation is "if (α and Ψ) then β else γ". Ψ is that additional, often even non-formalized, but technologically meaningful information, not received from SCADA usually. It is important to make the transition from the fully determined situation of string transformations to the real situation of big plant control. Note, that type 2 algorithms (PI, PID) are inherently adaptable (since coefficients can be tweaked) and are in the control situation from the beginning, but MSLAs are not.

How to impart such adaptive potential to MSLAs, which are rigid and inflexible by definition? We can try and anticipate all possible changes in our system and represent them as distinct states of the FSM. However, the total number of such states will soon grow so huge that we will not be able to perform the necessary calculations. We know that we'll bump into the dimension problem. This proves that this is the wrong way. But as technological changes are unavoidable and cannot be ignored, they must be classified and considered. The right (new) way is as follows. We introduce into the feedback loop our model with TC's states and MS, Mψ, MΦ. Our approach allows to:

- Identify the current state of the process in the controlled object.
- Understand which information must be gathered additionally for this particular state.
- Generate the correct control incorporating the additional information during assembling procedure.

The classical FSM performs only 1st and 3rd tasks. Moreover, the FSM performs 3rd task with a one-step fully predefined function. We implement this task with a special command-generating procedure.

So, after the identification of the current state by means of our model (incorporated into the feedback loop) we suggest that outputs should not be generated right away, but with a delay for gathering the additional information (MS, Mψ, MΦ) and assembling controlling outputs using LCA. Now we can point out exactly where the adaptive potential of MSLAs is. It appears only if we change single-step FSM functions to two-step procedures.

First, we introduced the concept of TC. The initial conception, building, implementing of any TC must be realized very carefully and with full attention to details. We are sure that only cooperation between technologically thinking people and experts in the area of control systems can give useful results, at least in the first stages. After that we'll have some experience and will be able to construct any TCs correctly. TC can help to solve problems caused by huge unwieldy MSLAs and can localize (and subsequently process) external changes.

A word or two about other possible uses of our approach. For example, we know that there is a problem for driverless (fully automatic) cars to drive from point A to point B in the city. Moving through city, from one intersection to the next intersection is essentially like MSLA. Crossroads are points for collecting new information (new changes) and generating new control output. TC is a part of route in which appeared new information doesn't affect to decision making and routing.

To sum up, we can hope that some principles which allow to build the new control system for the flow industries have been here developed and explained. The new control system has adaptive potential which helps to cut down maintenance costs.

7. References

Akesson, K., Flordal, H., Fabian, M. (2002). Exploiting modularity for synthesis and verification of supervisors. *Proceedings of the IFAC World Congress*.

Ambartsumian A. A., Kazanskiy D.L. (2001) *Technological process control based on event modelling. Part I and II.* Automation and Remote Control, №10, 11; 2001.

Ambartsumian A. A., Kazanskiy D.L.(2008) The approach of complex technology automation with using of discrete event models in a feedback control , *Proceedings of 17th IFAC World Congress*, Seoul, 2008

Cassandras, C. G., Lafortune, S. (2008) *Introduction to discrete event systems.* Dordrecht: Kluwer AcademicPublishers, p. 848.

Golaszewski, C. H., Ramadge, P. J. (1987). Control of discrete event processes with forced events. *Proceedings of the 28th Conference on Decision and Control,* pp. 247–251, Los Angeles.

Gaudin, B., Marchand, H. (2003). Modular supervisory control of asynchronous and hierarchical finite state machines. *In European ControlConference*, Cambridge.

De Queiroz, M. H., Cury, J. E. R. (2000). Modular supervisory control of large scale discrete event systems. DiscreteEvent Systems: Analysis and Control, *Proceedings. WODES'00*, pp. 103-110.

F. Zambonelli, N. Jennings, M. Wooldridge. (1994) Organizational rules as an abstraction for the analysis and design of multiagents systems. *International Journal of Software Engineering and Knowledge Engineering* (1994).

Edgar Chacon, Isabel Besembel, Jean Claude Hennet. (2004) Coordination and optimization in oil and gas production complexes. *Computers in Industry №53; 2004*. pp. 17–37.

N. Jennings, P. Faratin, A. Lomuscio, S. Parsons, C. Sierra, M. Wooldridge. (2001) Automated negotiation: prospects, methods and challenges. *International Journal of Group Decision and Negotiation,* 10 (2), 2001, pp. 199-215.

Wonham, W. M., Ramadge, J. G. (1988). Modular supervisory control of discrete event systems. *Math Control Signals and Systems*, 1, pp.13-30.

Yoo, T.-S., Lafortune, S. (2002). A general architecture for decentralized supervisory control of discrete event systems. *Discrete Event Dynamic Systems: Theory&Applications,* 12(3), pp. 335-377.

7

Semi-Empirical Modelling and Management of Flotation Deinking Banks by Process Simulation

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1. Introduction

Energy use rationalization and the substitution of fossil with renewable hydrocarbon sources can be considered as some of the most challenging objectives for the sustainable development of industrial activities. In this context, the environmental impact of recovered papers deinking is questioned (Byström & Lönnstedt, 2000) and the use of recovered cellulose fibres for the production of bio-fuel and carbohydrate-based chemicals (Hunter, 2007; Sjoede et al., 2007) is becoming a possible alternative to papermaking. Though there is still room for making radical changes in deinking technology and/or in intensifying the number of unit operations (Julien Saint Amand, 1999; Kemper, 1999), the current state of the paper industry dictates that most effort be devoted to reduce cost by optimizing the design of flotation units (Chaiarrekij et al., 2000; Hernandez et al., 2003), multistage banks (Dreyer et al., 2008; Cho et al., 2009; Beneventi et al., 2009) and the use of deinking additives (Johansson & Strom, 1998; Theander & Pugh, 2004). Thereafter, the improvement of the flotation deinking operation towards lower energy consumption and higher separation selectivity appears to be necessary for a sustainable use of recovered fibres in papermaking.
Nevertheless, over complex physical laws governing physico-chemical interactions and mass transport phenomena in aerated pulp slurries (Bloom & Heindel, 2003; Bloom, 2006), the variable composition and sorting difficulties of raw materials (Carré & Magnin, 2003; Tatzer et al., 2005) hinder the use of a mechanistic approach for the simulation of the flotation deinking process. At this time, the use of model mass transfer equations and the experimental determination of the corresponding transport coefficients is the most widely used method for the accurate simulation of flotation deinking mills (Labidi et al., 2007; Miranda et al., 2009; Cho et al., 2009).
Solving the mass balance equations in flotation deinking and generally in papermaking systems with several recycling loops and constraints is not straightforward: this requires explicit treatment of the convergence by a robust algorithm and thus computer-aided process simulation appears as one of the most attractive tools for this purpose (Ruiz et al., 2003; Blanco et al., 2006; Beneventi et al., 2009). Process simulation software are widely used in papermaking (Dahlquist, 2008) for process improvement and to define new control strategies. However, paper deinking mills have been involved in this process rationalization

effort only recently and the full potential of process simulation for the optimization and management of flotation deinking lines remains underexploited.

This chapter describes the four stages that have been necessary for the development of a flotation deinking simulation module based on a semi-empirical approach, i.e.:

- the identification of transport mechanisms and their corresponding mass transfer equations;
- the validation of model equations on a laboratory-scale flotation cell;
- the correlation of mass transfer coefficients with the addition of chemical additives in the pulp slurry;
- the implementation of model equations on a commercial process simulation platform, the simulation of industrial flotation deinking banks and the comparison of simulation results with mill data.

After the validation of the simulation methodology, deinking lines with different configurations are simulated in order to evaluate the impact of line design on process efficiency and specific energy consumption. As a step in this direction, single-stage with mixed tank/column cells, two-stage and three-stage configurations are evaluated and the total number of flotation units in each stage and their interconnection are used as main variables. Explicit correlations between ink removal efficiency, selectivity, energy consumption and line design are developed for each configuration showing that the performance of conventional flotation deinking banks can be improved by optimizing process design and by implementing mixed tank/column technologies in the same deinking line.

2. Particle transport mechanisms

Particle transport in flotation deinking cells can be modelled using semi-empirical equations accounting for four main transport phenomena, namely, hydrophobic particle flotation, entrainment and particle/water drainage in the froth (Beneventi et al., 2006).

2.1 Flotation

In flotation deinking system, the gas and the solid phases are finely dispersed in water as bubbles and particles with size ranging between ~0.2 – 2 mm and ~10 – 100 µm, respectively. The collision between bubbles and hydrophobic particles can induce the formation of stable bubble/particle aggregates which are conveyed towards the surface of the liquid by convective forces (Fig. 1a). Similarly, lipophilic molecules adsorbed at the air/water interface are removed from the pulp slurry by air bubbles (Fig. 1b). The rate of removal of hydrophobic materials by adsorption/adhesion at the surface of air bubbles, r_n^f, can be described by the typical first order kinetic equation

$$r_n^f = k_n \cdot c_n \tag{1}$$

where c_n is the concentration of a specific type of particle (namely, ink, ash, organic fine elements and cellulose fibres) and k_n its corresponding flotation rate constant,

$$k_n = \frac{K_n \cdot Q_g^{\alpha}}{S} \tag{2}$$

Q_g is the gas flow, α an empirical parameter, S is the cross sectional area of the flotation cell and K_n is an experimentally determined parameter including particle/bubble collision dynamics and physicochemical factors affecting particle adhesion to the bubble surface.

2.2 Entrainment

During the rising motion of an air bubble in water, a low pressure area forms in the wake of the bubble inducing the formation of eddies with size and stability depending on bubble size and rising velocity. Both hydrophobic and hydrophilic small particles can remain trapped in eddy streamlines (Fig. 1c) and they can be subsequently entrained by the rising motion of air bubbles.

Particles and solutes entrainment is correlated to their concentration in the pulp slurry and to the water upward flow in the froth (Zheng et al., 2005).

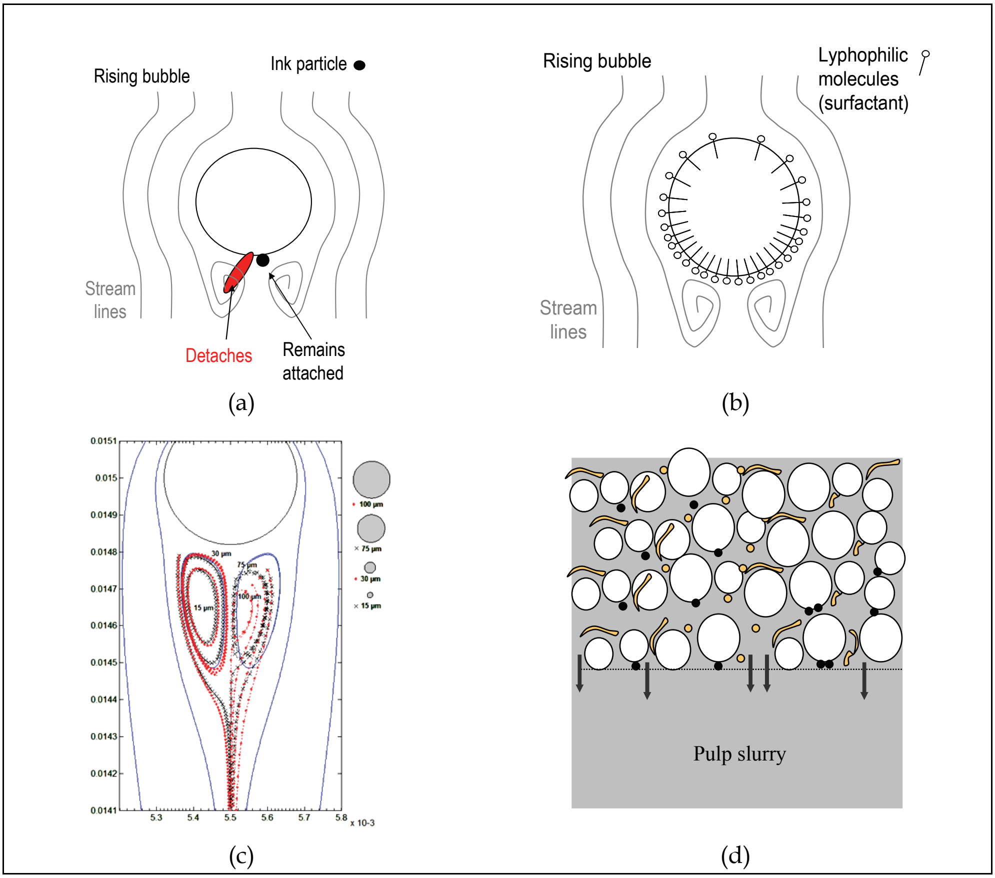


Fig. 1. Scheme of transport mechanisms acting during the flotation deinking process. (a) Particle attachment and flotation, (b) liphopilic molecules adsorption, (c) influence of size on the path of cellulose particle in the wake of an air bubble (Beneventi et al. 2007), (d) water and particle drainage in the froth.

The rate of removal due to entrainment, r_n^e, can be modelled by the equation:

$$r_n^e = \frac{\phi \cdot Q_f^0}{V} c_n \tag{3}$$

where $\phi = c_{0f}/c_n$ is the entrainment coefficient, c_{0f} is particle concentration at the pulp/froth interface, Q_f^0 is the water upward flow in the froth in the absence of drainage and V is the pulp volume in the flotation cell.
The total rate of removal due to both flotation and entrainment is given by the sum of the two contributions, i.e. $r_n^{up} = r_n^f + r_n^e$.

2.3 Water and particle drainage in the froth

At the surface of the aerated pulp slurry, a froth phase is formed with water films dividing neighbouring bubbles and solid particles either dispersed in the liquid phase or attached to the surface of froth bubbles (Fig. 1d). Despite the complex dynamics of froth systems (Neethilng & Cilliers, 2002), water and particle drainage induced by gravitational forces can be considered as the two main phenomena governing mass transfers in the froth.
The water drainage through the froth, described using the water hold-up in the froth (ε), and the froth retention time (FRT) in the flotation cell were taken as main parameters:

$$\varepsilon = \frac{Q_f}{Q_f + Q_g}, \tag{4}$$

$$FRT = \frac{h}{J_g + J_f} \tag{5}$$

where Q_g and Q_f are the gas and the froth reject flows, h is the froth thickness and J_g, J_f are the gas and water superficial velocities in the froth. In flotation froths, the decrease of water hold-up versus time, is well described by an exponential decay (Gorain et al., 1998; Zheng et al., 2006)

$$\frac{\varepsilon}{\varepsilon_0} = e^{-L_d \cdot FRT} \tag{6}$$

where ε_0 is the water volume fraction at the froth/pulp interface and L_d is the water drainage rate constant.
By analogy with particle entrainment in the aerated pulp slurry, the rate of the entrainment of particles/solutes dispersed in the froth by the water drainage stream, r_n^{down}, is given by the equation

$$r_n^{down} = \delta \cdot c_{nf} \cdot Q_d / V \tag{7}$$

where $\delta = c_d/c_{nf}$ is the particle drainage coefficient, c_{nf} and c_d are particle concentrations in the froth and in the water drainage stream, respectively and Q_d is the water drainage flow.
In order to close-up Eqs. (1-7), perfect mixing is assumed in the lower part and two counter-current piston flows in the upper part (upward flow for the froth and downward flow for water drainage).

3. Validation of model equations at the laboratory scale

Mechanisms described by Eqs. (1-7) are extensively used in minerals flotation for the simulation of industrial processes. Nevertheless, due to the intrinsic difference between the composition and the rheological behaviour of minerals and recovered papers slurries, the use of Eqs. (1-7) for the simulation of industrial flotation deinking processes is not straightforward and model validation on a pilot flotation cell appears a necessary step.

3.1 Flotation cell set-up and flotation conditions

To run pilot tests, a 19 cm diameter and 130 cm height flotation column was assembled (Fig. 2). The flotation column has two main regions: a collection region, where the pulp slurry is in contact with gas bubbles, and a ~15 cm height aeration region, where the pulp is re-circulated in tangential Venturi aerators where the gas flow is regulated by using a mass flow meter. The froth generated at the top of the flotation column is removed by using an adjustable reverse funnel connected to a vacuum pump. The pulp level in the cell and the froth retention time before removal can be modified by adjusting the position of the overflow system and of the reverse funnel, respectively.
The retention time distribution obtained in the absence and in the presence of cellulose fibres (Fig. 3) shows that, whatever the liquid volume in the cell and the feed flow, the flotation cell can be described as a continuous stirred tank reactor (CSTR).
Flotation experiments were performed using a conventional fatty acid chemical system in order to test independently the contribution of air flow, pulp feed flow, pulp hydraulic retention time in the cell and froth retention time on the ink removal efficiency and the flotation yield. Experimental conditions are summarized in Table 1.

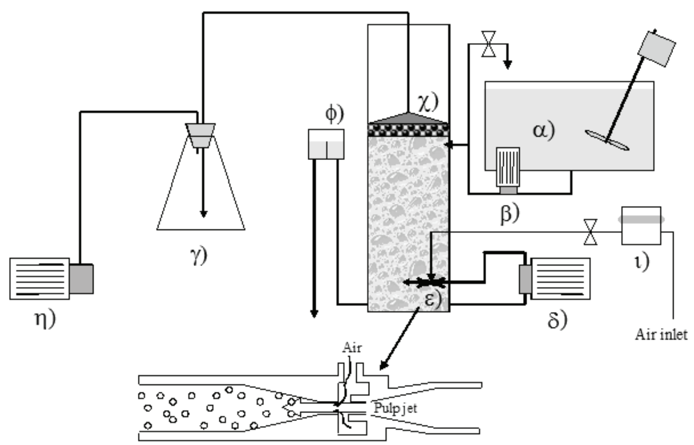


Fig. 2. Schematic representation of the flotation column used in this study. α) Pulp storage chest. β) Volumetric pump. χ) Adjustable froth removal device. δ) Volumetric pump to supply gas injectors. ε) Venturi-type air injectors. ϕ) Flotation cell outlet with adjustable overflow system. γ) Froth collection vessel. η) Vacuum pump. ι) Mass flow meter.

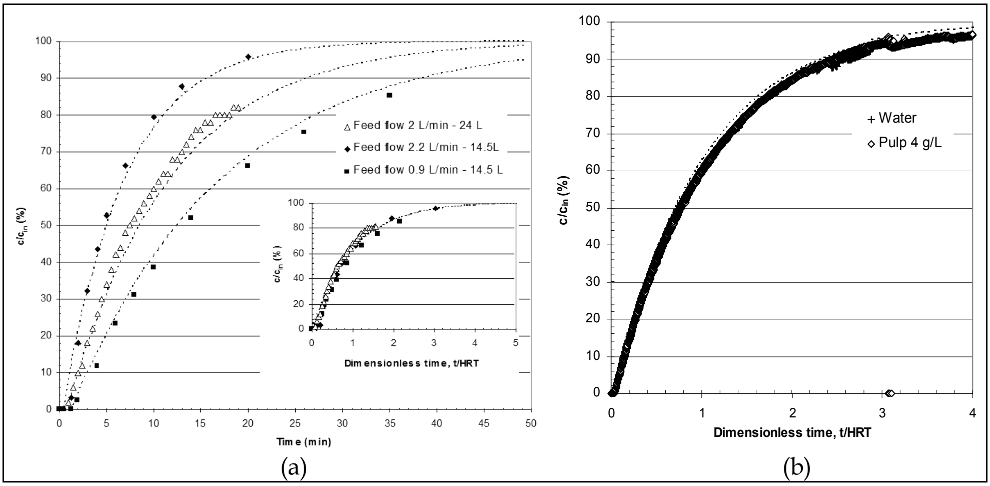


Fig. 3. Mixing conditions in the flotation column. Reactor response to a step type increase in the tracer concentration. (a) Effect of the feed flow and cell volume in presence of water (b) Effect of cellulose fibres. Dotted lines represent the CSTR response.

Cell Volume V (L)	Pulp flow Q_{in} (L/min)	Air flow Q_g (L/min)	Froth removal thickness h (cm)	HRT V/Q_{in} (min)	Air ratio Q_g/Q_{in} (%)
14.5	2	4	3 - 1.5 - 4 - 8	7.2	200
14.5	2	6	3 - 1.5 - 4 - 8	7.2	200
14.5	2	8	3 - 1.5 - 4 - 8	7.2	200
14.5	3.5	4	3 - 1.5 - 4 - 8	4.1	114
14.5	4.5	4	3 - 1.5 - 4 - 8	3.2	89
14.5	2.5	5	3 - 1.5 - 5 - 8	5.8	200
19.5	2.5	5	3 - 1.5 - 5 - 8	7.8	200
24	2.5	5	3 - 1.5 - 5 - 8	9.6	200

Table 1. Experimental conditions used to run flotation trials. The cross sectional area of the flotation column had a constant value, S = 283 cm^2.

3.2 Interpretation of experimental results with model equations

3.2.1 Water removal

Froth flows measured during flotation experiments were fitted by using Eqs. (5, 6) and the water volume fraction in the top froth layer before removal was plotted as a function of the froth retention time in the cell. Fig. 4 shows that the water fraction in the froth had an exponential decay with increasing retention time and that Eq. (6) fitted with good accuracy experimental data. The absence of froth recovery when the retention time was higher than 30 s indicates that, when the water fraction was lower than ~0.02, gas bubbles collapsed in the reverse funnel and froth recovery was no longer possible. The decrease of froth processability in the vacuum system was attributed to the destabilization of froth liquid film and to the typical increase in froth viscosity (Shi & Zheng, 2003) when increasing FRT.

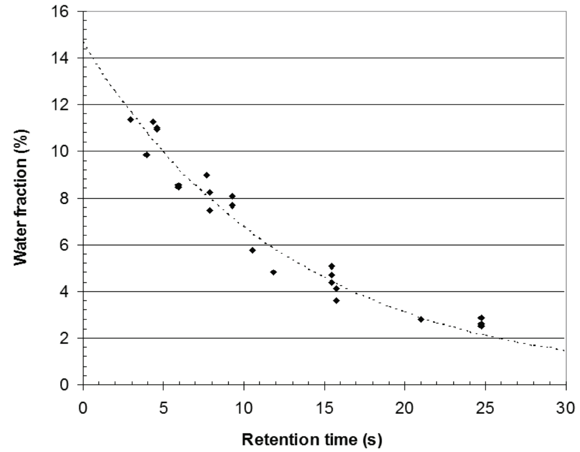


Fig. 4. Water volume fraction in the froth removed by the vacuum device (all tested conditions) plotted as a function of the froth retention time in the cell.

The frothing behaviour of the pulp slurry was therefore described by Eq. 6, with ε_o = 0.15 and L_d = 4.44 min^{-1}.

3.2.2 Ink removal

The variation of the ink concentration during the flotation transitory and steady states and with froth removal at different heights, were obtained by mass balance from Eqs. (2-7) and the models of reactors. In order to limit the number of free variables in the equation system, the entrainment coefficient of ink particles was assumed similar to that of silica particles with same size (Machaar & Dobby, 1992), namely ~0.2. As expected from Eq. (2), the increase in the gas flow gave a corresponding increase in the ink flotation rate constant which fairly deviated from a linear correlation, i.e. $k_{ink} = 0.15\ Q_g^{0.73}$ (k in min^{-1}, Q_g in L/min). The ink drainage coefficient given by model equations was δ_{ink} = 0.30, thus reflecting the limited drainage of ink particles through the froth and the low variation of ink concentration in the pulp when the froth removal height was increased (Fig. 5a). Flotation rate constants and ink drainage coefficient obtained by fitting experimental data were used to predict the contribution of cell volume and froth removal height on the residual ink concentration in the pulp. Calculated ink removal efficiencies matched with experimental values (Fig. 5b).

3.3.3 Fibres removal

This approach was repeated for fibres, fines and ashes. Since cellulose fibres are hydrophilic particles with large-un-floatable size (~1.5x0.1 mm), only entrainment and drainage were assumed to govern their transport during flotation.

Fitting of experimental data gave an entrainment coefficient extremely high for this class of large particles: ϕ_{fibres} = 0.30, and a drainage coefficient of δ_{fibres} = 0.80. The relevant contribution of entrainment was associated with the natural tendency of cellulose fibres to generate large flocks with small gas bubbles trapped in.

3.3.4 Fines and ash removal

Fines and ashes displayed an intermediate behaviour between ink and fibres. Fitting of experimental data gave low flotation rate constants proportional to the gas flow, $k_{fines} = 0.018\ Q_g$ for fines and $k_{ash} = 0.021\ Q_g$ for ash (k in min^{-1}, Q_g in L/min).

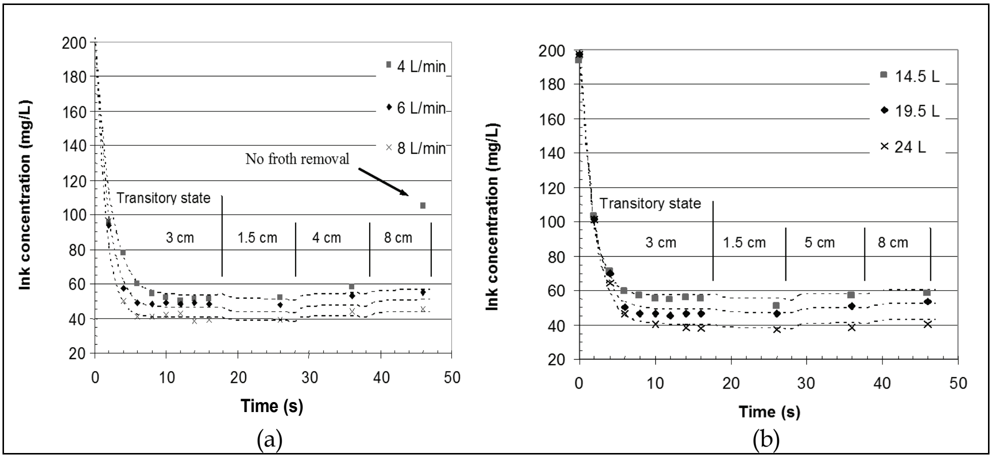


Fig. 5. Variation of ink concentration plotted as a function of the flotation time and of the froth removal height. (a) Influence of gas flow on residual ink concentration, pulp flow Q_{in} = 2 L/min, cell volume V = 14.5 L. Dotted lines represent experimental data fitting with model equations. (b) Influence of cell volume on residual ink concentration, pulp flow Q_{in} = 2.5 L/min, gas flow Q_g = 5 L/min. Dotted lines represent trends obtained from model calculations.

Like ink particles, entrainment coefficients for fines and ash were assumed similar to that of silica particles with similar size, namely ϕ_{fines} = 0.25 and ϕ_{ash} = 0.45 and, as expected for poorly floatable particles, drainage coefficients had high values, namely δ_{fines} = 0.85 and δ_{ash} = 0.8.

Present results show that model equations derived from the minerals flotation field allowed modelling the flotation deinking of recovered papers when using a conventional-fatty acid chemical system. The contribution of pulp flow, cell volume, viz. HRT, and froth removal height on ink removal and yield was predicted with good accuracy. However, chemical variables (such as the presence of surfactants), which can strongly affect the flotation deinking process, were not accounted in the model. As a step in this direction, the contribution of a model non-ionic surfactant on particle and water transport was investigated.

4. Correlation of transport coefficients with surfactant addition

Recovered papers may release in process waters a wide variety of dissolved and colloidal substances (Brun et al., 2003; Pirttinen & Stenius, 1998) which limit the use of conventional analytical techniques for the dosage of non-ionic surfactants. In order to avoid using over complex purification and analysis procedures, the surfactant concentration in the pulp slurry can be estimated using an indirect method based on the measurement of surface tension by maximum bubble pressure (Pugh, 2001; Comley et al., 2002). Thereafter, in the presence of a reference surfactant (in this study, an alkyl phenol ethoxylate, NP 20EO, added at the inlet of the flotation cell) it becomes possible to quantify the effect of surfactant concentration on particle, water and surfactant molecules transport during the flotation process and to establish direct cross correlations between surfactant concentration and transport coefficients.

4.1 Surfactant removal

The removal of surfactant molecules from the pulp slurry during flotation is strongly affected by surfactant concentration and by the froth removal thickness (Fig. 6a). Indeed, the increase in NP 20EO concentration boosted surfactant removal and decreased the impact of the froth removal thickness on the residual surfactant in the floated pulp. Surfactant removal rates and drainage coefficients (Fig. 6b) obtained by fitting experimental data with Eqs. (1-7), show that the removal rate constant increased with the equivalent concentration, while the drainage coefficient decreased. This trend was interpreted as reflecting the contribution of the initial surfactant concentration on bubble size and on froth stability: a decrease in bubble coalescence/burst in the aerated pulp and in the froth leads to an increase in the surfactant removal rate and a decrease in the drainage rate, respectively.

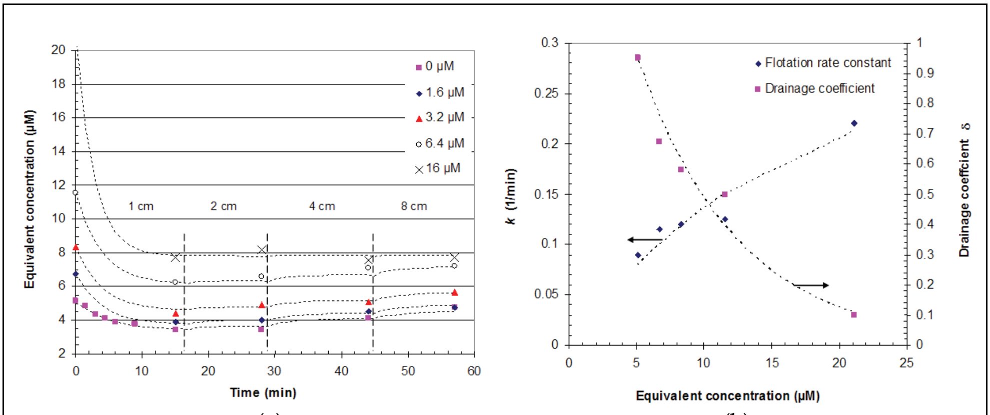


Fig. 6. Surfactant removal from the pulp slurry during flotation. (a) Decrease in the surfactant equivalent concentration in the pulp slurry during flotation plotted as a function of the froth removal thickness and of NP 20EO concentration (dotted lines represent data fitting with Eqs. (1-7). (b) Surfactant removal rate constant and drainage coefficient obtained from the interpolation of experimental data with model equations.

4.2 Gas and water hold-up

Fig. 7 shows that the rise in the surfactant flotation rate constant (Fig. 6b) can be ascribed to an increase in the gas hold-up with the surfactant concentration. This trend is due to the bubble stabilization induced by the adsorption of surfactant molecules on the bubble surface and the ensuing stabilization of liquid films formed between colliding bubbles (Danov et al., 1999; Valkovska et al., 2000). The water hold-up in the froth calculated from water recovery data and Eqs. (5, 6) shows an exponential decay (Fig. 8a) and the water hold-up at the pulp/froth interface, ε_0, increases with the surfactant concentration, whereas the water drainage coefficient, L_d, decreases (Fig. 8b). This trend reflects the NP 20EO contribution in i) decreasing bubble size in the aerated pulp, ii) stabilizing liquid films between froth bubbles and iii) preventing bubble burst in the froth.

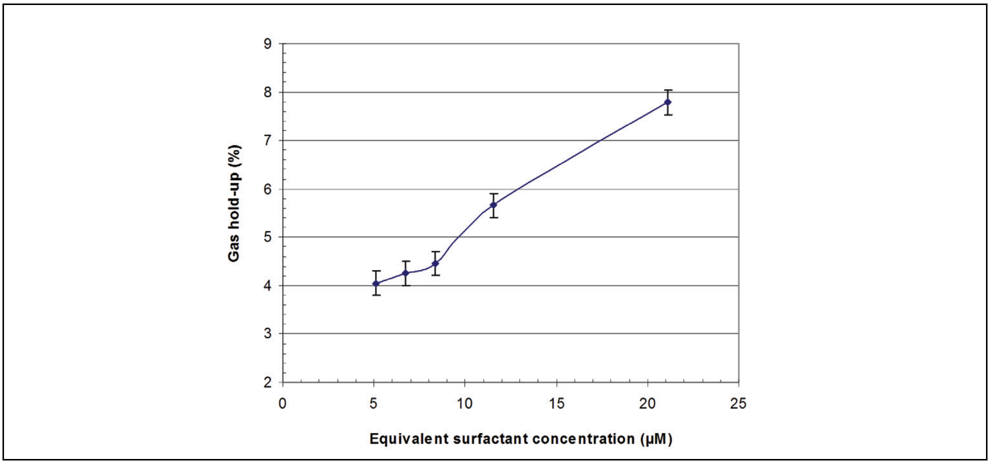


Fig. 7. Effect of the model non-ionic surfactant (NP 20EO) on gas hold-up. Air flow 2 L/min.

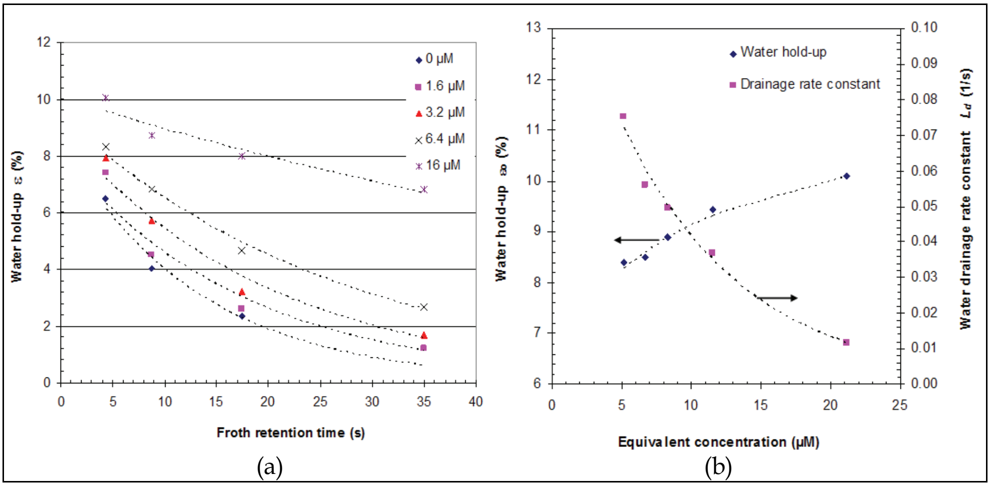


Fig. 8. Frothing behaviour of the pulp slurry in the flotation cell. (a) Water hold-up in the froth plotted as a function of the froth retention time and of the added non-ionic surfactant concentration. Dotted lines represent data fitting with Eq. 7. (b) Water hold-up at the froth/pulp slurry interface and water drainage rate constant.

4.3 Ink removal

In the absence of surfactant, ink particles are efficiently removed during flotation (Fig. 9a). However, ink removal is strongly affected by the low frothing behaviour of the pulp slurry

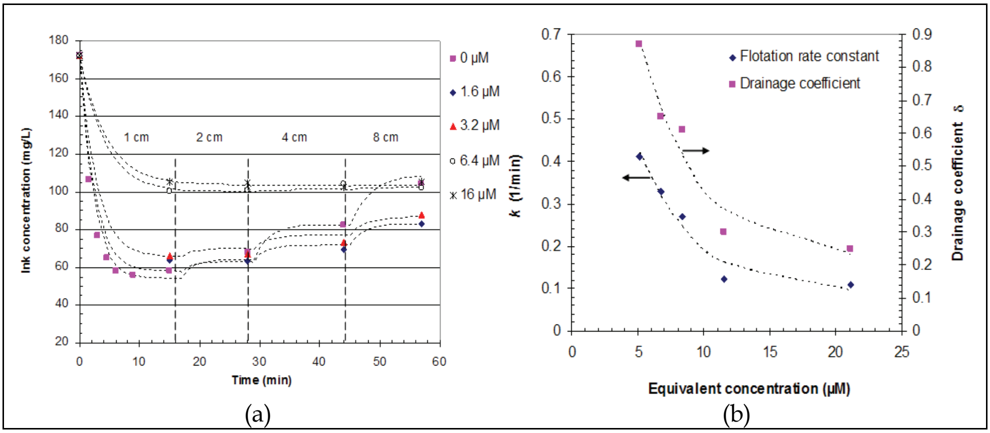


Fig. 9. Effect of surfactant concentration on ink removal. (a) Variation of ink concentration in the pulp after flotation. (b) Ink flotation rate constant and drainage coefficient.

(Fig. 8) and the increase in the froth removal thickness is responsible for a strong increase in the residual ink concentration in the floated pulp. The addition of surfactant (NP 20EO) in the pulp slurry reduces the ink flotation rate constant (Fig. 9.b) and ink removal sensitivity to the FRT. For the highest surfactant concentration, 16 µM, the ink concentration is not affected by the froth removal thickness thus reflecting the stabilization of froth bubbles. The decrease of the ink flotation rate constant for increasing NP 20EO concentration is due to non-ionic surfactant adsorption at both the bubble/ and ink/water interface which induces a decrease in both bubble surface tension and ink/water interfacial energy (Epple et al, 1994). In the froth phase, the non-ionic surfactant improves bubble stability and water hold-up reducing ink particles detachment due to bubble burst and their drainage from the froth into the aerated pulp slurry (Fig. 9b).

4.4 Fibre removal

The transfer of hydrophilic cellulose fibres in the froth decreases when increasing the surfactant concentration (Fig. 10a). As obtained for surfactant and ink, the froth stabilization due to NP 20EO addition progressively suppresses the contribution of the froth removal thickness on fibre concentration and at the highest surfactant dosage the froth has a constant fibre concentration. The decrease in the fibre entrainment coefficient shown in Fig. 10b is associated with the suppression of fibre flocculation by calcium soap and with a decrease of bubble entrapment in fibre flocs and of the convective motion of fibre/bubble flocs towards the froth.

The constant fibre drainage coefficient (Fig. 10b) indicates that fibre drainage is mainly governed by the intensity of the water drainage flow. Fillers and fine elements have a behaviour similar to that of ink particles, i.e. the increase in surfactant dosage depressed fillers/fines flotation and drainage.

5. Simulation of conventional flotation deinking banks

5.1 Implementation of model equations in a process simulation software

Within the current industrial context (environmental and safety constraints, globalization of the economy, need to shorten the “time to market” of products), computer science is more

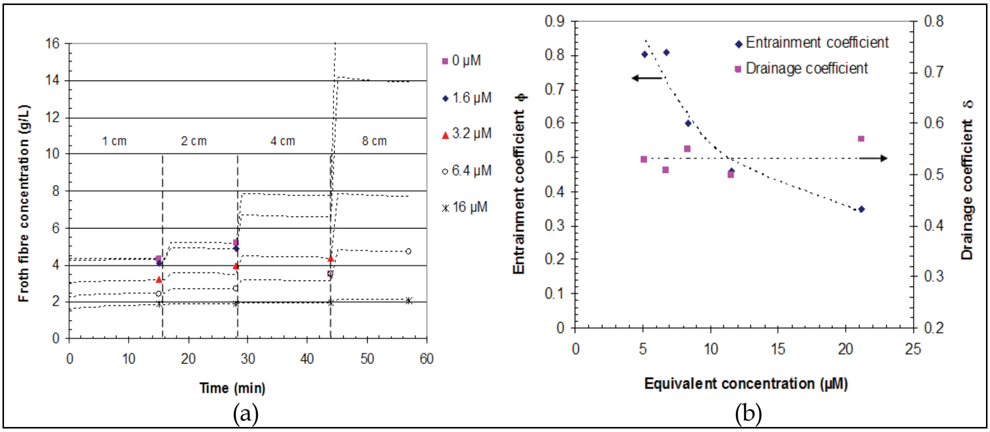


Fig. 10. Fibre removal in the froth. (a) Influence of froth removal height and surfactant concentration on the fibre concentration in the froth during flotation. (b) Fibre entrainment and drainage coefficients plotted as a function of surfactant concentration.

and more often used to design, analyse and optimize industrial processes. This specific area, called "Computer Aided Process Engineering" (CAPE), knows a big success in industries such as oil and gas, chemical and pharmaceutical. Process simulation software are used by chemical engineers in order to provide them with material and energy balances of the process, physical properties of the streams and elements required for equipment design, such as heat duty of exchangers or columns hydraulics. Moreover, process simulation software can also be used for cost estimates (capital expenditure, CAPEX and operational expense, OPEX), to evaluate environmental or security impact, to optimize flowsheets or operating conditions, for debottlenecking of an existing plant, for operator training… At a conceptual level, two kinds of process simulation software exist, the "module oriented" and the "equation oriented" approaches. Software based on this last approach are mainly dedicated to process dynamic simulation (Aspen Dynamics, gPROMS) and they can be compared to solvers for systems of algebraic and differential equations, directly written by users. The "module oriented" approach is adopted by most of the commercial process simulation software (Aspen Plus, Chemcad, Pro/II, ProSimPlus) and correspond to the natural conception of a process, which is constituted by unit operations dedicated to a specific task (heat transfer, reaction, separation). A general view of the structure of these software is provided on Fig. 11.

These software provide unit operation library, including most common units such as chemical reactors, heat exchangers, distillation or absorption columns, pumps, turbines, compressors and, sometimes, some more specific equipments such as brazed plate fin heat exchangers, belt filters.

User supplies operating and sizing parameters of each unit operations (also called modules) and linked them with streams, which represent material, energy or information flux circulating between the equipments of the real process. Other important parts of a process simulation software are the databases and the physical properties server, on which rely unit operations models to give consistent results, and solvers, which are numerical tools required to access convergence of the full flow sheet.

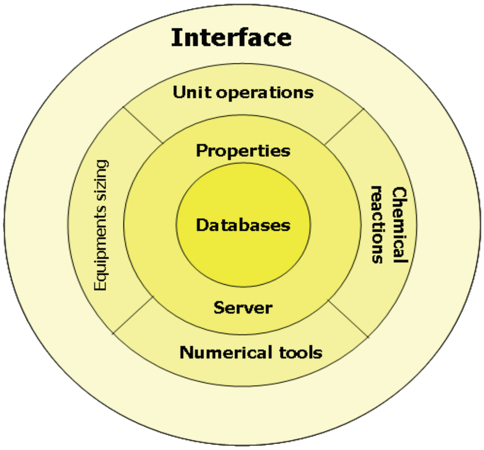


Fig. 11. Structure of a process simulation software.

Pure component databases include fixed-value properties (molar weight, critical point characteristics, normal boiling point…) and correlation coefficients for temperature-dependent properties (liquid and vapour heat capacity, vapour pressure, liquid and vapour viscosity…). The main reference for thermophysical properties of pure components is DIPPR (Design Institute for Physical Property Data, http://dippr.byu.edu/) which includes, in its 2008 version, 49 thermophysical properties (34 constant properties and 15 temperature-dependent properties) for 1973 compounds. This number of compounds is to compare with the number of chemical substances referenced by the Chemical Abstracts (http://www.cas.org/), which was greater than 33 millions in 2008. The difference between these two figures shows the importance to have models to predict pure physical properties. These models can be based on chemical structure or intrinsic properties of the molecule (molar weight, normal boiling point, critical temperature…), but they are then mainly reliable for a given chemical family. The use of molecular simulation becomes more and more frequent to compute missing data.

Modelling of a physical system rests on the knowledge of pure component and binary properties. Thus, binary interaction parameters between compounds are generally required by thermodynamic models to obtain the mixture behaviour. These parameters are obtained by fitting experimental data to thermodynamics model, the main sources of these data being the DECHEMA (http://www.dechema.de/en/start_en.html) and the NIST (http://www.nist.gov/index.html). Two kinds of methods exist in order to compute fluid phase equilibria. The first way to solve the problem consists in applying a different model to each phase: fugacities in liquid phase are calculated from a reference state which is characterized by the pure component in the same conditions of physical state, temperature and pressure, ideal laws being corrected by using a Gibbs free energy model or an activity coefficients model (NRTL, UNIQUAC, UNIFAC…). Fugacities in vapor phase are calculated by using an Equation of State (ideal gases, SRK, PR…). These methods are used in order to represent the heterogeneity of the system and are classically called heterogeneous methods. Their use covers the low pressure field and it should be noted that they do not satisfy the continuity in the critical zone between vapour phase and liquid phase. The second way to solve the fluid phase equilibria calculation consists in homogeneous methods, which apply the same model, usually an Equation of State, to the two phases, allowing thus to ensure continuity at the critical point. Equations of State with their classical mixing rules (SRK, PR, LKP…) are included in this second category. However, the field of application of these model is limited to non polar or few polar systems. By integrating Gibbs free energy models in the mixing rules for Cubic Equations of State, some authors succeeded in merging both approaches. These models are often called combined approach. It has to be noted that some specific models have been developed for some particular fields of application, like electrolyte solutions, strong acids…

User interface helps users to transcribe its problem in the process simulation software language. Providers now propose graphical tools which allows user to build his flowsheet by "drag-and-drop". Numerous tools are also available to ensure fast access to information and convenient learning: information layers, colour management, right click, double click...

New communication standard, called CAPE-OPEN (http://www.colan.org/), is developed to permit the interoperability and integration of software components in process simulation software. Thanks to this standard, a commercial process simulation software can now use a unit operation or a thermodynamic model developed by an expert. With this approach, a process simulation software becomes a blend of software components focused on the real needs expressed by the user.

Within this context, correlations shown in Figs. 6-10 and Eqs. (1-7) were coded in FORTRAN in order to obtain a module for the flotation deinking unit operation. The effect of non-ionic surfactant concentration and distribution on ink removal selectivity was then simulated for the conventional multistage flotation system shown in Fig. 12.

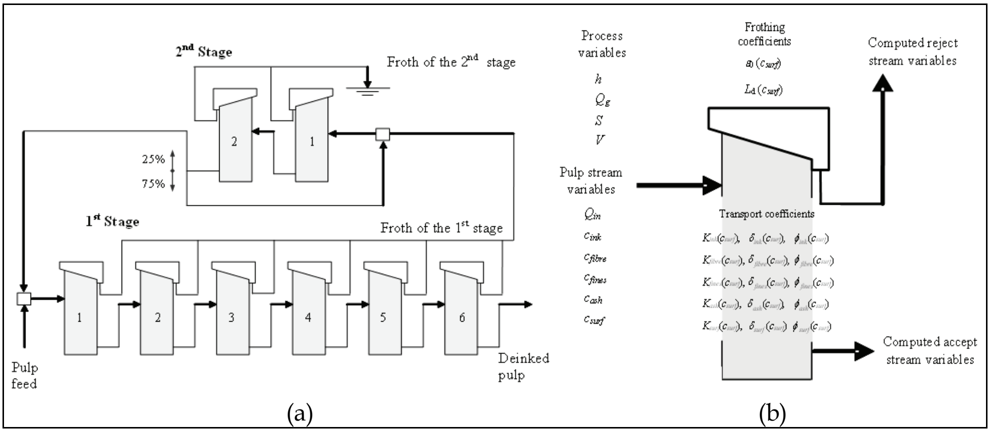


Fig. 12. Scheme of the conventional multistage deinking line simulated in this study (a) and of relevant pulp stream, flotation process and particle transport variables used to simulate each flotation unit (b).

In the simulated system (Fig. 12), a pulp stream of 32000 L/min is processed in a first stage composed by six flotation cells in series. The outlet pulp of the sixth cell is considered as the outlet of the entire system, whereas, froths generated in the first stage are mixed and further processed in a second stage made of a series of two flotation cells. The froth of the second stage is the reject of the entire system. In order to insure a froth flow sufficient to feed the second stage and to avoid ink drainage, the froth is removed from the first stage with no retention and 75% of the pulp stream processed in the second stage is circulated at the inlet of the second stage. The remaining 25% is cascaded back at the inlet of the first stage. The froth retention time in the second stage ranges between 10 s and 4 min to stabilize the water reject to 5% (i.e. 1600 L/min). Main characteristics of the flotation line used to run simulations are given in Table 2.

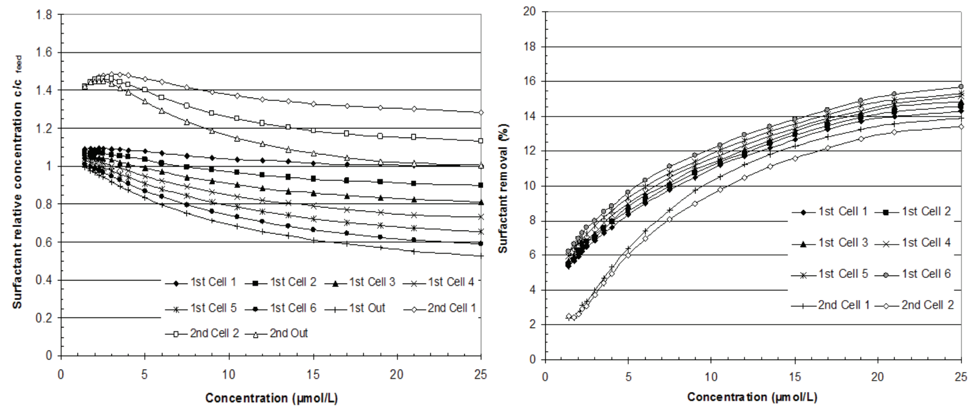
Overall mass balance calculations involving multi stage systems were resolved using a process simulation software (ProSimPlus). Transport coefficients in each flotation cell composing the multistage system were calculated from the surfactant concentration at the inlet of each unit.

Volume (L)	Feed flow (L/min)	Aeration rate per cell (%)	Cross section (m^2)	Feed consistency (g/L)	Line capacity (T/day)
20000	40000	50	12	10	580

Table 2. Characteristics of each flotation cell in the simulated de-inking line.

5.2 Surfactant removal

As shown in Fig. 13a, for a constant surfactant concentration in the pulp feed flow, the surfactant load progressively decreases when the pulp is processed all along the first and the second stage. However, within the range of simulated conditions, the surfactant concentration in the second stage is ~1.5 times higher than in the first stage indicating the low capacity of the first line to concentrate surfactants in the froth phase. Surfactant removal efficiencies illustrated in Fig. 13b show that flotation units in the first stage have similar yield which asymptotically increases from ~6% to ~15%. This trend can be associated to the influence of surfactant concentration on the flotation rate and on pulp frothing. With a low



(a) (b)

Fig. 13. Effect of surfactant concentration in the pulp feed flow on surfactant distribution and removal. Surfactant concentration (a) and removal (b) in each flotation unit composing the multistage system.

surfactant concentration in the feed flow, surfactant removal in flotation cells of the second stage is lower than in the first stage. Similar yields are obtained with extremely high surfactant concentrations, i.e. >15 µmol/L. The different froth retention time in the first and in the second stage is at the origin of this trend. Indeed, in the first stage the froth is removed with no retention and surfactant molecules are subjected only to flotation and entrainment. Whereas, in the second stage the froth retention time ranges between 10 s and 4 min in order to promote water drainage and to stabilise the froth flow at 1600 L/min.

5.3 Ink removal

For all simulated concentrations, mixing the feed pulp with the pulp flow cascaded back from the second stage gives an increase in the ink concentration at the inlet of the first stage (Fig. 14a). In general, the ink concentration progressively decreases all along the first and the second stage, however, the ink distribution in the deinking line is strongly affected by the surfactant concentration. Fig. 14a shows that, at high surfactant load, the ink concentration along the deinking line progressively converges to the ink concentration in the feed flow. In this condition, the collision and the attachment of ink particles to air bubbles is disfavoured, flotation is depressed and ink removal is due to the hydraulic partitioning of the pulp flow into the reject and the floated pulp streams.

Ink removal versus surfactant concentration plots illustrated in Fig. 14b show that in all flotation cells of the first stage ink removal monotonically decreases, while in the second stage a peak in ink removal appears at 3 µmol/L. For all simulated conditions, ink removal in the second stage is lower than in the first stage. This behaviour is associated to different froth retention time and surfactant concentration in the two stages (Fig. 13a).

The peak in ink removal in the second stage reflected the progressive depression of ink upward transfer from the pulp to the froth by flotation and of ink drop back from the froth to the pulp by drainage. At low surfactant concentration, < 3 µmol/L, ink removal is governed by particle transport in the froth. The froth is unstable and bubble burst and water drainage induce ink to drop back into the pulp with an ensuing decrease in ink removal. At

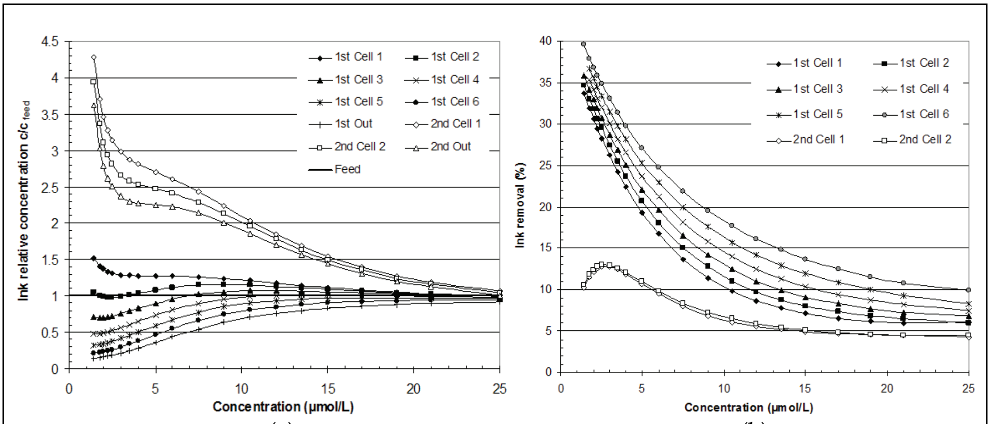


Fig. 14. Ink distribution and removal in the flotation line at increasing surfactant concentration in the pulp feed flow. (a) Ink concentration, (b) ink removal.

high surfactant concentration, > 3 µmol/L, froth bubbles are progressively stabilized and ink drainage is reduced. The presence of a maximum in the ink removal vs. surfactant concentration curve corresponds to the best compromise between froth stabilization and ink floatability depression.

5.4 Process yield

Simulation results show that both the variation of surfactant load in the pulp feed flow and its distribution in the two flotation stages affect the yield of the deinking line. Except for a peak in ink removal in the second stage at 3 µmol/L, Fig. 15a shows that the ink removal efficiency of the entire deinking line progressively decreases when increasing surfactant concentration.

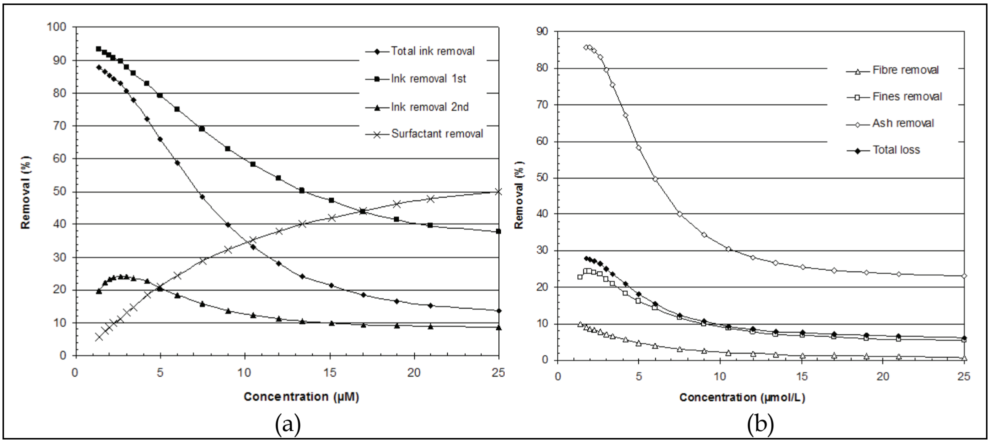


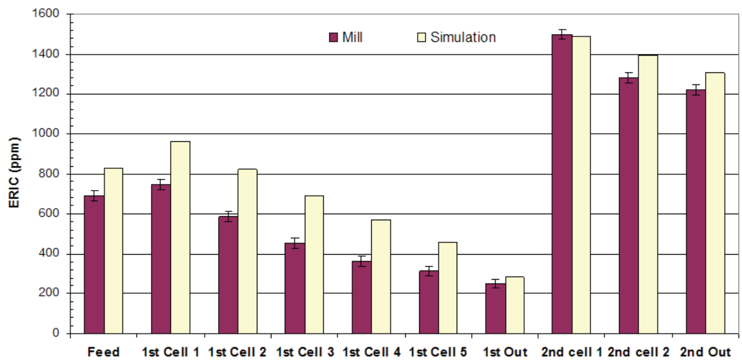
Fig. 15. Total ink and surfactant removal (a) and fibres, fines, ash loss (b) plotted as a function of surfactant concentration in the pulp feed flow.

Similar trends are obtained for fibre, fines and ash (Fig. 15b) and only surfactant removal increases when increasing the surfactant load in the pulp feed flow. Fig. 15 shows that with a surfactant load in the pulp flow comparable with the amount released by a standard pulp stock composition of 50% old newspaper and 50% old magazines, i.e. ~4 µmol/L, ink is efficiently removed (~70%), fibre, fines and ash loss have realistic values for a deinking line, i.e. 5, 19 and 65% respectively, and surfactant removal does not exceed 17%. The high sensitivity of the process yield to the surfactant load in the pulp stream and the low surfactant removal efficiency lead to assume that a conventional deinking line weakly attenuates fluctuations in the amount of surface active agents released by recovered papers with a direct effect on the stability of the process yield and on surfactant accumulation in process waters.

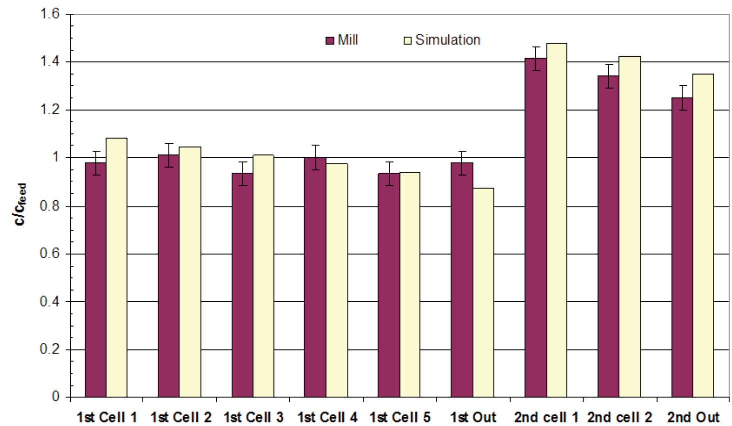
5.5 Comparison of simulation results with mill data

Fig. 16a shows that the residual ink content obtained by simulation with a surfactant load of 4 µmol/L is in good agreement with data collected during mill trial. In the first stage, residual ink obtained from simulation displays higher values than experimental data. This mismatch can be ascribed to the different ink load in the pulp feed flow.

The residual ink content in the floated pulp (ERIC) is lower than that of the model pulp used in laboratory experiments and to run simulations (i.e. 830 ppm). When using the industrial pulp composition to run simulations this discrepancy is strongly attenuated.
The variation of the surfactant concentration in the deinking mill is in good agreement with simulation results. Fig. 16b shows that surfactant concentration in the first stage is nearly constant and the decrease predicted by process simulation can not be observed since it is within the experimental error. As predicted by the simulation, the surfactant concentration in the second stage is 1.4-1.5 times higher than in the first stage and it progressively decreases all along the line. Ink and surfactant removal determined for the industrial deinking line in the first and second stages matches with quite good accuracy with the yield predicted by process simulation (Fig. 17) thus indicating that particle and water transport mechanisms used for the simulation of the industrial line describe with reasonable accuracy the deinking process.



(a)



(b)

Fig. 16. Comparison of residual ink concentration (a) and surfactant relative concentration (b) obtained from process simulation with mill data.

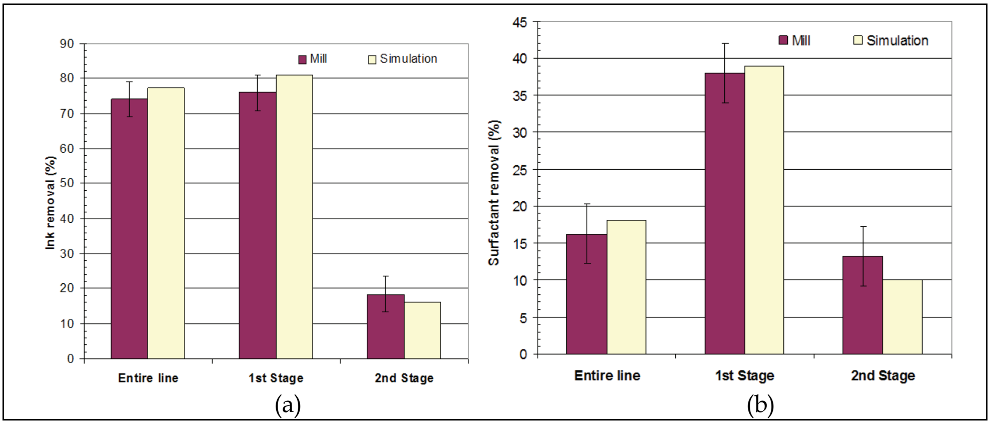


Fig. 17. Comparison of ink (a) and surfactant removal (b) obtained at the industrial scale with simulation results.

6. Optimization of deinking lines by process simulation

6.1 Deinking line layout

In order to clarify the contribution of multistage deinking lines design on ink removal and process yield, six bank configurations of increasing complexity are modelled. As summarized in Table 3, flotation banks are assembled using flotation cells with two different aspect ratios, 0.7 for the tank cell, 2 for the column cell, and with a constant pulp capacity of 20 m^3. With both cell geometries, pulp aeration is assumed to take place in Venturi aerators with an aeration rate Q_g/Q_{pulp} = 0.5 and a pressure drop of 1.2 bar (Kemper, 1999). To run simulations under realistic conditions, the superficial gas velocity in a single column cell is set at 2.4 cm/s, which corresponds to an air flow rate of 10 m^3/min or half that in the tank cell. Similarly, the pulp flow processed in flotation columns is limited to a maximal value of 10 m^3/min. Fig. 18a-d illustrates the four single-stage lines simulated in this study. The first case (Fig. 18a), consists in a simple series of flotation tanks, with common launder collecting flotation froths from each cell to produce the line reject. The number of tanks is varied from 6 to 9. In order to limit fibre loss, rejects of flotation cells at the end of the line are cascaded back at the line inlet (Fig. 18b) while the froth rejected from the first few cells is rejected. Using this configuration, the simulation is carried out with the number of tanks in the line and cascaded reject flows being used as main variables. In the third configuration (Fig. 18c), the pulp retention time at the head of the line is doubled by placing two tanks in parallel followed by a series of 7 tanks whose rejects are returned at the line inlet. The last single-stage configuration (Fig. 18d) consists in a stack of 4 to 6 flotation columns in parallel, followed by a series of 3 to 5 tanks whose rejects are sent back to the line inlet. The aim of this configuration is to increase ink concentration and pulp retention time at the head of the line and to assess the potential of column flotation for ink removal efficiency.

As depicted in Fig. 18, two- and three-stage deinking lines were also simulated. As previously mentioned, the two-stage line shown in Fig. 18e is the most widely used one in flotation deinking. In this classical configuration, reject of the first stage, are generated in 5 to 9 primary cells in series. To recover valuable fibres in these combined reject stream, rejects of the primary line are processed in a second stage with 1 to 4 tanks. The number of flotation tanks in the first and in the second stage is here used as main variable to optimize the line design. The three-stage line shown in Fig. 18f is made of a first stage with 7 to 8 flotation tanks, a second stage with 2 tanks and a third stage with 1 tank. The pulp processed in the third stage is partitioned between the inlets of the third and of the second stage.

Pulp volume (m^3)	Cross section (m^2)	Aspect ratio h/d	Pulp feed flow (m^3/min)	Air flow (m^3/min)	Superficial gas velocity (cm/s)	Gas hold-up+ (%)	Ink flotation rate constant (1/min)	Ink removal (%)
20	12	~0.7	40	20	2.8	10-20	~0.45	20-35
20	7	~2	$40/m^*$	10	2.4	30-40	~0.52	50-65

Table 3. Relevant characteristics of flotation units used to assembly the flotation lines simulated in this study. + Estimated assuming a bubble slip velocity relative to the pulp downstream flow of ~7 cm/s.

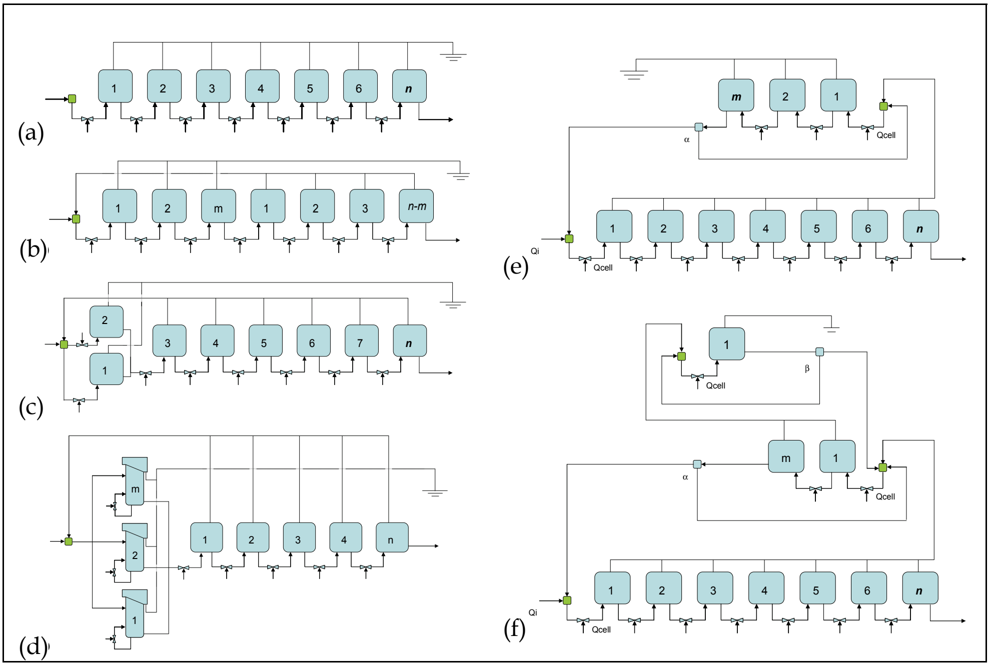


Fig. 18. Flotation lines simulated in this study. (a) Simple line made of a series of n flotation cells. (b) Line with n flotation cells with the reject of the last n-m cells cascaded back at the line inlet. (c) Line composed by n flotation cells with the first two cells in parallel and the remaining cells in series. The reject of the last n-2 cells is cascaded back at the inlet of the line. (d) Line composed by a stack of m flotation columns in parallel and a series of n cells. The reject of flotation cells is cascaded back at the inlet of the line. (e) Conventional two-stage line with n cells in the primary stage and m cells in the secondary stage. (f) Three-stage line with n = 8, m = 2.

The pulp processed in the second stage is partitioned between the inlets of the second stage itself and of the first stage. In order to limit the number of variables, all simulations are run with zero froth retention time. Under this condition, ink removal and fibre/fillers loss are maximized because particle and water drainage phenomena from the froth to the pulp are suppressed but this is obtained at the expense of ink removal selectivity. Simulation results are therefore representative of deinking lines operated at their maximal ink removal capacity.

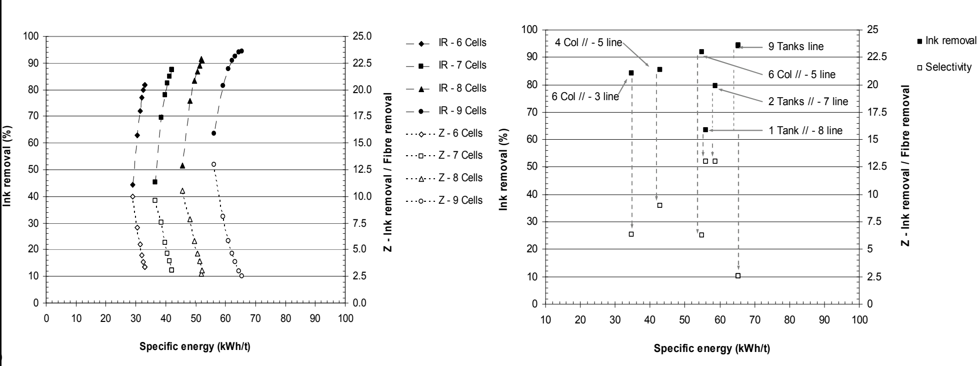
6.2 Ink removal selectivity and specific energy consumption

Flotation lines assembled here for simulation purposes are characterized by a fixed (tank cells) and an adjustable (column cells) feed flow. Since the introduction of recirculation loops modifies the processing capacity and the pulp retention time in the whole line, predicting particle removal efficiencies is not sufficient to establish a performance scale between different configurations. Consequently, the specific energy consumption, which is given by the equation

$$SE = \frac{P_{inj} \cdot \sum_n Q_g}{\rho \cdot Q_{out} \cdot c_{out}} \tag{8}$$

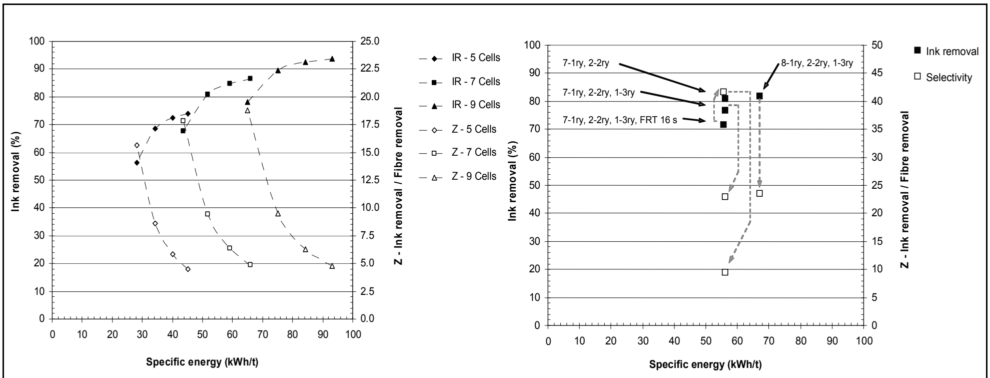
where Q_g is the gas flow injected in each flotation cell (n) in the multistage system, P_{inj} the pressure feed of each static aerator (1.2 bar), ρ the aeration rate Q_g/Q_{pulp} (0.5 in the simulated conditions), Q_{out} and c_{out} are the pulp volumetric flow and consistency at the outlet of the deinking line, the ink removal efficiency and the ink removal selectivity (Z factor) (Zhu et al., 2005), have to be taken into account to establish a correlation between process efficiency and line design.

Fig. 19a illustrates that when the cascade ratio is raised in single-stage lines, the deinking selectivity increases by 4-5 times, whereas the specific energy consumption slightly decreases. Reduced energy is caused by a net increase in pulp production capacity. However, these gains are generally associated with a decrease in ink removal. Hence, the reference target of 80 % ink removal with selectivity factor Z = 8 could only be obtained with a line made of 9 tanks with a cascade ratio of 0.6 and a specific energy consumption of 60 kWh/t. Because target ink removal and selectivity can be achieved only by increasing energy consumption, this configuration does not represent a real gain in terms of process performance. The addition of a high ink removal efficiency stage comprising a stack of flotation columns in parallel at the line head, Fig. 19b, reduces specific energy consumption by 25-50 %. Nevertheless, the efficient removal of floatable mineral fillers and the absence of hydrophilic particle drainage in the froth limits the selectivity factor to ~7.5. According to experimental studies (Robertson et al. 1998; Zhu & Tan, 2005), the increase of the froth retention time and the implementation of a froth washing stage would improve the selectivity factor with a minimum loss in ink removal. Under these conditions, a flotation columns stack equipped with optimized froth retention/washing systems would markedly decrease specific energy consumption. Similarly to the results obtained for single-stage lines, Fig. 20a shows that improved ink removal selectivity in two-stage lines is coupled with a decrease ink removal.



(a) (b)

Fig. 19. Ink removal efficiency and selectivity obtained for tested configurations plotted as a function of the specific energy consumption. (a) Flotation line composed by 6 to 9 flotation cells and with the reject of the last *n-m* cells cascaded back at the line inlet (Fig. 18a-b). (b) Flotation line composed by a stack of flotation cells or columns in parallel followed by a series of flotation cells (Fig. 18c-d).



(a) (b)

Fig. 20. Ink removal efficiency and selectivity obtained for tested configurations plotted as a function of the specific energy consumption. (a) Deinking line composed by a 1ry and a 2ry stage with different number of flotation cells in the two stages (Fig. 18e). The legend in the pictures indicates the number of cells in the 1ry stage. b) Line of 3 stages (Fig. 18f).

The selectivity factor appears to be directly correlated to the number of flotation tanks in the secondary line as it progressively decreases from ~17.5 to 5 when increasing the number of tanks in the second stage. Selectivity drops when the reject flow increases which, for two- and single-stage lines, is induced by the increase of the number of tanks in the second stage and the decrease of the cascade ratio, respectively.

In turn, ink removal efficiency is found here to be governed by the number of cells in the first stage. Fig. 20a shows that, with a constant number of tanks in the second stage, ink removal increases by 10 % for each additional cell in the first stage, while selectivity slightly increases. Seven tanks in the first stage and two tanks in the second stage are needed to reach the target of 80 % ink removal and a selectivity factor of 9. With this configuration, the specific energy consumption of the two-stage line (52 kWh/t) is lower than the energy required by a single stage line with the same deinking efficiency/selectivity (60 kWh/t). Overall, the best energetic efficiency is given by the single line with a stack of six flotation columns at the line head (Fig. 19b).

If we consider the two-stage line with ink removal and selectivity targets as reference system, the addition of a third stage with a single tank boosts up selectivity, slightly decreases ink removal from 81 to 78% and does not affect specific energy consumption (Fig. 20b). The selectivity index of the three-stage line can be further increased from 21.5 to 41 by setting at 16 s froth residence time in the third stage cell. However, the selectivity gain is coupled to a decrease in ink removal from 78 to 72 % and the need for an additional tank in the first stage to attain the ink removal target of 80 %. With this last configuration of 8 tanks in the first stage, 2 tanks in the second stage and 1 tank in the third stage, 80 % ink removal is attained along the highest selectivity factor of all tested configurations. However, the gain in separation efficiency results in a sizeable increase in the specific energy consumption. As for the other tested configurations, the effective benefit provided by this configuration should be thoroughly evaluated in the light of recovered papers, rejects disposal and energy costs.

7. Conclusions

This chapter summarizes the four steps that have been necessary to develop and validate a process simulation module that can be used for the management of multistage flotation deinking lines, namely, i) the identification of mass transfer equations, ii) their validation on a laboratory-scale flotation cell, iii) the correlation of mass transfer coefficients with the addition of chemical additives and iv) the simulation of industrial flotation deinking banks.

Due to the variability of raw materials and the complexity of physical laws governing flotation phenomena in fibre slurries, general mass transport equations were derived from minerals flotation and validated on a laboratory flotation column when processing a recovered papers pulp slurry in the presence of increasing concentration of a model non-ionic surfactant.

Cross correlations between particle transport coefficients and surfactant concentration obtained from laboratory tests were used to simulate an industrial two-stage flotation deinking line and a good agreement between simulation and mill data was obtained thus validating the use of the present approach for process simulation.

Thereafter, the contribution of flotation deinking banks design on ink removal efficiency, selectivity and specific energy consumption was simulated in order to establish direct correlations between the line design and its performance. The simulation of a progressive increase of the line complexity from a one to a three-stage configuration and the use of tank/column cells showed that:

- In single-stage banks, ink removal selectivity and specific energy consumption can be improved by increasing the cascade ratio (i.e. the ratio between the number of cascaded cells and the total number of cells in the line) with a minimum decrease in the ink removal efficiency. Above a cascade ratio of 0.6, the ink removal efficiency drops.

- The addition of a stack of flotation columns in the head of a single stage line gives an increase in ink removal selectivity and a decrease in specific energy consumption.
- In two-stage banks, the ink removal efficiency is mainly affected by the number of flotation tanks in the first stage, whereas, the number of cells in the second stage affects the fibre removal, which linearly increases with the number of cells.
- The addition of a third stage allows increasing ink removal selectivity with a negligible effect on the ink removal efficiency and on the specific energy consumption.
- Overall, the best deinking performance is obtained with a stack of flotation columns at the line head and the three-stage bankg.

8. Acknowledgement

This paper is the outline of a research project conducted over the last four years. Authors wish to thank Mr. J. Allix, Dr. B. Carré, Dr. G. Dorris, Dr. F. Julien Saint Amand, Mr. X. Rousset and Dr. E. Zeno for their valuable contribution.

9. References

Beneventi, D.; Allix, J.; Zeno, E.; Nortier, P.; Carré, B. (2009). Simulation of surfactant contribution to ink removal selectivity in flotation deinking lines, *Sep. Purif. Technol.*, 64 (3), 357-367.

Beneventi, D.; Benesse, M.; Carré, B.; Julien Saint Amand, F.; Salgueiro, L. (2007). Modelling deinking selectivity in multistage flotation systems. *Sep. Purif. Technol.*, 54 (1), 57-67.

Beneventi, D.; Rousset, X.; Zeno, E. (2006). Modelling transport phenomena in a flotation deinking column. Focus on gas flow, pulp and froth retention time, *Int. J. Miner. Process.*, 80 (1), 43-57.

Beneventi, D.; Zeno, E.; Nortier, P.; Carré, B.; Dorris, G. (2009). Optimization and Management of Flotation Deinking Banks by Process Simulation, *Ind. Eng. Chem. Res.*, 48 (8), 3964–3972.

Blanco, A.; Dahlquist, E.; Kappen, J.; Manninen, J.; Negro, C.; Ritala, R. (2006). Modelling and simulation in pulp and paper industry. Current state and future perspectives, *Cellulose Chem. Tech.*, 40 (3-4), 249-258.

Bloom, F. (2006). A mathematical model of continuous flotation deinking, *Math. Comp. Model. Dyn. Sys.*, 12 (4), 277-311.

Bloom, F.; Heindel, T. J. (2003). Modeling flotation separation in a semi-batch process, *Chem. Eng. Sci.*, 58 (2), 353-365.

Brun, J.; Delagoutte, T.; Blanco, A. (2003). Identification and quantification of the main sources of dissolved and colloidal materials in recovered papers, *Revue ATI*, 57 (4), 12-18.

Byström, S.; Lönnstedt, L. (2000). Paper recycling: a discussion of methodological approaches, *Resour. Conserv. Recycl.*, 28 (1), 55–65.

Carré, B.; Magnin, L. (2003). Printing processes and deinkability, *International paperworld*, 12, 41-45.

Chabot, B.; Gopal, A.; Krinshnagopalan (1996). Flexographic newspaper deinking: treatment of wash filtrate effluent by membrane technology, 4^{th} *Research Forum on Recycling*, Chateau Frontenac, Quebec, October 7-9, 233-242.

Chaiarrekij, S.; Dhingra, H.; Ramarao, B. V. (2000). Deinking of recycled pulps using column flotation: energy and environmental benefits, *Resour. Conserv. Recycl.*, 28 (3-4), 219-226.

Cho, B.U.; Ryu, J.Y.; Song, B.K. (2009). Modeling and simulation of separation process in flotation system, *J. Ind. Eng. Chem.*, 15 (2), 196-201.

Comley, B.A.; Harris, P.J.; Bradshaw, D.J.; Harris, M.C. (2002). Frother characterization using dynamic surface tension measurements, *Int. J. Mineral Process.*, 64, 81-100.

Dahlquist, E. (2008). Process Simulation for Pulp and Paper Industries: Current Practice and Future Trend, Chem. Prod. Process Modeling, 3 (1), 18.

Danov, K.D.; Valkovska, D.S.; Ivanov, I.B. (1999). Effect of Surfactants on the Film Drainage, *J. Colloid Int. Sci.*, 211, 291-303.

Dorris, G. M.; Nguyen, N. (1995). Flotation of model inks. Part II. Flexo ink dispersions without fibres, *J. Pulp Paper Sci.*, 21 (2), 55-62.

Dreyer, A.; Britz, H.; Renner, K.; Heikkilä, P.; Grimm, M. (2008). Circuit designs for secondary accept in deinking flotation. *Proceedings of the 13th PTS-CTP Deinking Symposyum*, 16, 15-17 April 2008, Leipzig, Germany.

Epple, M.; Schmidt, D.C.; Berg, J.C. (1994). The effect of froth stability and wettability on the flotation of a xerographic toner, *Colloid Polym. Sci.*, 272, 1264-1272.

Gorain, B.K.; Harris, M.C.; Franzidis, J.-P.; Manlapig, E.V. (1998). The effect of froth residence time on the kinetics of flotation, *Miner. Eng.*, 11, 627-638.

Hernandez, H., Gomez, C. O.; Finch, J. (2003). A. Gas dispersion and de-inking in a flotation column, *Miner. Eng.*, 16 (8), 739-744.

Hunter, N. (2007). Fuel plus from the forest: a short review and introduction to the biorefinery concept, *Appita J.*, 60 (1), 10-12.

Johansson, B.; Strom, G. (1998). Surface chemistry of flotation deinking: effect of various chemical conditions on ink agglomerate character and floatability, *Nord. Pulp Pap. Res. J.*, 13 (1), 37-49.

Jordan, B.D.; Popson, S.J. (1994). Measuring the concentration of residual ink in recycled newsprint, *J. Pulp Paper Sci.*, 20 (6), 161-167.

Julien Saint Amand, F. (1999). Hydrodynamics of deinking flotation, *Int. J. Mineral Process.*, 56 (1), 277-316.

Kemper, M. (1999). State-of-the-art and new technologies in flotation deinking, *Int. J. Mineral Process.*, 56 (1), 317-333.

Labidi, J.; Pelach, M. A.; Turon, X.; Mutjé, P. (2007). Predicting flotation efficiency using neural networks, *Chem. Eng. Process.*, 46 (4), 314-322.

Maachar, A.; Dobby, G.S. (1992). Measurement of feed water recovery and entrainment solids recovery in flotation columns, *Canadian Metallurgical Quarterly* 31, 167-172.

Miranda, R.; Blanco, A.; Negro, C. (2009). Accumulation of dissolved and colloidal material in papermaking-Application to simulation, *Chem. Eng. J.*, 148 (2), 385-393.

Neethling, S.J.; Cilliers, J.J. (2002). Solids motion in flowing froths. *Chem. Eng. Sci.*, 57, 607-615.

Nguyen, A.V.; Harvey, P.A.; Jameson, G.J. (2003). Influence of gas flow rate and frothers on water recovery in a froth column, Miner. Eng., 16, 1143-1147.

Pirttinen, E.; Stenius, P. (1998). The effect of dissolved and colloidal substances on flotation deinking efficiency, *Progr. Paper Recycl.*, 7, 38-46.

Pugh, R.J. (2001). Dynamic Surface tension measurements in mineral flotation and de-inking flotation systems and the development of the on line dynamic surface tension detector, *Miner. Eng.*, 14, 1019-1031.

Robertson, N.; Patton, M.; Pelton, R. (1998). Washing the fibers from foams for higher yields in flotation deinking. *Tappi J.*, 81 (6), 138–142.

Ruiz, J.; Ottenio, P.; Carré, B. (2003). La simulation numérique au service des papetiers, ATIP, 57 (3), 24-31.

Schwarz, S.; Grano, S. (2005). Effect of particle hydrophobicity on particle and water transport across a flotation froth, *Colloids and Surfaces A: Physicochem. Eng. Aspects*, 256, 157-164.

Shi, F.N.; Zheng, X.F. (2003). The rheology of flotation froths, *Int. J. Miner. Process.*, 69, 115-128.

Sjoede, A.; Alriksson, B.; Joensson, L. J.; Nilvebrant, N.-O. (2007). The potential in bioethanol production from waste fiber sludges in pulp mill-based biorefineries, *Appl. Biochem. Biotech.*, 137-140 (1-12), 327-337.

Tatzer, P.; Wolf, M.; Panner, T. (2005). Industrial application for inline material sorting using hyperspectral imaging in the NIR range, *Real-Time Imaging*, 11 (2), 99-107.

Theander, K.; Pugh, R.J. (2004). Surface chemicals concepts of flotation de-inking, *Colloids and Surfaces A: Physicochem. Eng. Aspects*, 240 (1-3), 111-130.

Valkovska, D. S.; Danov, K. D.; Ivanov, I. B. (2000). Effect of surfactants on the stability of films between two colliding small bubbles, *Colloids and Surfaces A: Physicochem. Eng. Aspects*, 175, 179-192.

Vera, M.A.; Mathe, Z.T.; Franzidis, J.-P.; Harris, M.C.; Manlapig, E.V.; O'Connor, C.T. (2002). The modelling of froth zone recovery in batch and continuously operated laboratory flotation cells, *Int. J. Miner. Process.*, 64, 135-151.

Volmer, M. (1925). Thermodynamic deductions from the equation of state for adsorbed material, *J. Phys. Chem.*, 115, 233-238.

Ward, A.F.H.; Tordai, L. (1946). Time dependence of boundary tensions of solutions. I. The role of diffusion in time effects, *J. Chem. Phys.*, 14, 453-461.

Zheng, X.; Franzidis, J.-P.; Johnson, N.W. (2006). An evaluation of different models of water recovery in flotation, *Miner. Eng.*, 19, 871-882.

Zheng, X.; Franzidis, J.-P.; Johnson, N.W.; Manlapig, E.V. (2005). Modelling of entrainment in industrial flotation cells: the effect of solids suspension, *Miner. Eng.*, 18, 51-58.

Zhu, J. Y.; Tan, F. (2005). Dynamic drainage of froth with wood fibres, *Ind. Eng. Chem. Res.*, 44 (9), 3336-3342

Zhu, J.Y.; Tan, F.; Scallon, K.L.; Zhao, Y.L.; Deng, Y. (2005). Deinking selectivity (Z-factor): a new parameter to evaluate the performance of flotation deinking process, *Sep. Purif. Technol.*, 43 (1), 33-41.

8

Meeting Organizational Performance with Shared Knowledge Management Processes

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1. Introduction

Research on knowledge management and organizational memory has a thriving history. Academics and practitioners have long focused on the structure of organizational memory (Walsh & Ungson, 1991) and its related knowledge processes (Spender, 1996), and have investigated characteristics and mechanisms of organizational memory focusing on retention bins (Walsh & Ungson, 1991), knowledge retention (Spender, 1996), and knowledge sharing processes (Hansen, 1999; Hayes & Walsham, 2003; Von Krogh, 2003). Furthermore, research has investigated the role of information technology repositories in the gathering and sharing of knowledge (Alavi & Tiwana, 2003) and has pointed out the connection between knowledge management and information technology (Franco & Mariano, 2007). Despite this manifest interest, a few empirical studies have been developed on organizational memory (Stein & Zwass, 1995) and most contributions have been theoretical studies (Walsh & Ungson, 1991; Stein, 1995).

This chapter is an empirical contribution to the knowledge management and organizational memory debates. The purpose of this chapter is to contribute to knowledge management theory and to provide a practical approach for managing information technology repositories. This study investigates how knowledge is stored and retrieved in a professional setting and contributes to define a comprehensive framework on the use of organizational memory systems to improve performance. Qualitative research methods are used to collect data from an American company through individual semi-structured interviews, on-site observations, and document analysis. The qualitative software package Atlas.ti® is used to analyze data. Findings highlight the importance of individual attitude, i.e. motivation and efforts, managerial support, and shared organizational technologies in the management of organizational processes and reveal factors influencing the processes of knowledge retention and retrieval. This study points out the role of shared organizational memory systems and suggests strategies to improve the effectiveness of information technology repositories.

The chapter is organized as follows. In the first section the relevant literature on organizational memory, knowledge management, and information technology repositories is discussed. Follows a detailed description of the research methodology and a list of methods used to collect and analyze data. Findings are presented and an interpretation of them is provided. The last section focuses on conclusions and implications for theory and practice. Limitations connected to empirical generalizability, and suggestions for future research are also discussed.

2. Background

The importance of organizational memory is considered by several studies (Huber, 1991; Walsh & Ungson, 1991) as a key component of organization success (Kogut & Zander, 1992). The literature on the processes of knowledge retention and retrieval is an extension of works on organizational memory (Walsh & Ungson, 1991), organizational knowledge (Polanyi, 1966), and knowledge management (Nonaka, 1994). How individuals store knowledge into the organizational memory and how they retrieve this knowledge to make decisions is crucial.

But what is organizational memory? Why should researchers and practitioners be interested in the processes of knowledge retention and retrieval from organizational memory?

Organizational memory has been defined in a variety of ways. The definition chosen for this study is stored knowledge "from an organization's history that can be brought to bear on present decisions" (Walsh & Ungson, 1991, p. 2).

Recent studies have demonstrated that the processes of knowledge retention and retrieval (Mariano & Casey, 2007; Gammelgaard & Ritter, 2005) are critical components of organizational memory. The analysis of these processes contributes to decision making (Shrivastava, 1983; Walsh & Ungson, 1991), reduces the time search of previous stored knowledge (Walsh & Ungson, 1991), and increases the organizational awareness of its own stored knowledge (Hansen et al., 1999; Franco & Mariano, 2009).

According to Walsh and Ungson (1991), memory retention structures are those organizational locations into which both existing and new knowledge can be stored. They are the locus of organizational memory (p. 61), a non-centralized and multiple memory nodes system made up of individuals and their own memories (Argyris & Schon, 1978), cultures (Schein, 1984), transformations (Cyert & March, 1963), structures (Walsh & Dewar, 1987), ecology – the workplace structure (Campbell, 1979), and external archives (Porter, 1980). As also stated by Shrivastava (1983) "organizational members know about these systems, even though some of the systems may not have been explicitly verbalized or documented" (p. 18).

This study considers the role of shared organizational memory systems – and how they can be managed – and suggests strategies to improve the effectiveness of information technology repositories. This study also addresses the problem of memory update. This process allows the preservation of the quality of the system (Goodman & Darr, 1998; Huber, 1991) and it safeguards the organization against the loss of knowledge caused by the effect of turnover (Argote et al., 1990; Carley, 1992).

3. Methodology

This was a qualitative case study research. In this study a social constructed knowledge claim (Creswell, 2003) was chosen to develop the research design. Meanings were constructed by human beings as they engaged with the world they interpreted (Crotty, 1998). Open-ended questions (Merriam, 2001) were used to let participants express their views. The study tried to understand the context and the setting (Creswell, 2003; Miles & Huberman, 1994; Yin, 2003) of participants through several visits to it. Information was personally gathered by the secondary researcher from informants (Merriam, 2001). The process was largely social and inductive (Creswell, 2003), with the generation of meanings from the data collected in the field (Miles & Huberman, 1994).

3.1 Research site and sampling strategy

The site of this study was located in Virginia (USA). The unit of analysis was individual action and the research setting was one division of the organization. This was an embedded research design (Yin, 2003). The main units of analysis were employees at the organization department level. Data were collected across five departments. At the time of data collection, 83 employees worked in the five departments. Sample determination was based on the position, department unit, and on tenure, as shown in Table 1.

Participant	Position	Department Unit	Tenure	Interview Type
P1	Consultant	Unit 3	6-23 Months	Face-to-Face
P2	Analyst and Consultant	Unit 2	24-48 Months	Face-to-Face
P3	Analyst	Unit 5	49+ Months	Face-to-Face, Email Feedback
P4	Consultant	Unit 2	6-23 Months	Face-to-Face
P5	Administrative Assistant	Unit 5	6-23 Months	Face-to-Face
P6	Consultant	Unit 3	49+ Months	Face-to-Face
P7	Executive	Unit 5	24-48 Months	Phone Call
P8	Consultant	Unit 2	49+ Months	Phone Call
P9	Editor	Unit 1	49+ Months	Face-to-Face
P10	Administrative Assistant	Unit 1	6-23 Months	Face-to-Face
P11	Executive	Unit 3	24-48 Months	Face-to-Face
P12	Designer	Unit 1	24-48 Months	Face-to-Face
P13	Analyst	Unit 4	6-23 Months	Face-to-Face
P14	Analyst	Unit 4	24-48 Months	Face-to-Face
P15	Analyst	Unit 4	49+ Months	Face-to-Face

Table 1. Details of participants

3.2 Data collection and analysis

This study was conduct in the United States in 2005. Fifteen individual semi-structured interviews (Merriam, 2001), in-site observations (Creswell, 2003), and document analysis (Merriam, 2001; Creswell, 2003) were employed to collect data. Participants were selected on the recommendations of a “key informant” (Miles & Huberman, 1994). In-site observations lasted two hours on average and an observation protocol was used to take field notes (Creswell, 1998). Private and public documents and audio-visual materials were also collected. They included the analysis of the organization memory systems, i.e. department hard drive folders, share points, and the organization Intranet. The use of member checks (Stake, 1995; Lincoln & Guba, 1985), peer debriefings (Creswell, 2003), and triangulation methods ensured the validity of this study (Kvale, 1989) and increased the accuracy and credibility of collected data (Lincoln & Guba, 1985) as shown in Table 2. Interview transcriptions were coded and analyzed through the help of Atlas.ti® qualitative data analysis software package. The coding activity (Miles & Huberman, 1994; Lincoln & Guba, 1985) involved four basic operations: adding codes, returning to codes and interrogating them in a new way, seeing new or previously not understood relationships within units of a given category, and identifying new categories. This collected information was summarized, detailed described, and an interpretation of it was made (Miles & Huberman, 1994).

Strategies	Techniques employed in this research study
(1) TRIANGULATE DATA SOURCES	Data were triangulated examining evidence from four different sources of explanation: observations, individual interviews, document analysis, and audio-visual material
(2) USE OF MEMBER-CHECKS	Interview transcripts were sent to all participants. Informal member-checks with employees during the time spent in the organization were also conducted by the secondary researcher. Two participants and a department manager were also asked to determine whether they felt the final report was accurate
(3) USE OF RICH, THICK DESCRIPTIONS	Rich descriptions of the research context and the setting were made with detailed explanation of data collection and data analysis processes
(4) CLARIFY THE BIAS	Before data collection, the secondary researcher asked herself the interview questions and she detailed defined her role within the division and in the process of this research study
(5) PRESENT DISCREPANT INFORMATION	In the qualitative narrative, all discrepant information run counter to the themes was fully presented and discussed
(6) SPEND PROLONGED TIME IN THE FIELD	The secondary researcher spent almost two months in the research setting. Descriptions of the site and the people involved in the study were made
(7) USE OF PEER DEBRIEFING	Three graduate students were invited to review the qualitative narrative and ask questions about the study

Table 2. Validating the accuracy of findings

4. Findings

We studied knowledge retention and retrieval processes. Participants had to gather knowledge stored in shared organizational technologies or informal social networks and use it in their day-to-day decisions. Organizational memory systems, individual attitude, i.e. motivation and effort, and managerial support emerged as critical elements in the management of organizational processes and formed the basis for the development of our framework on organizational performance. In the following paragraphs we discuss findings with respect to the structures, processes, and solutions, and we present our framework on the use of organizational memory systems to improve performance.

4.1 Structures: organizational memory systems

Two groups of organizational memory systems emerged from data collection and analysis. The first group referred to social networks and regarded the informal gathering of knowledge from coworkers or managers.

The second group pointed out the role of shared organizational technologies in the retention and retrieval of organizational knowledge. We discuss this second group of organizational memory systems. The decision is made because even though the role of social network has received increased attention in the literature and has represented a crucial topic in the management of organizational knowledge, its discussion is beyond the scope of this paper. In this paper the focus is on the role of organizational memory systems, i.e. shared organizational technologies in the retention and retrieval of organizational knowledge.

From data analysis, three organizational memory systems were identified: (1) web-based tools, i.e. Intranet and share points; (2) non-web based tool, i.e. hard drives; and (3) hard copy documents, e.g. department policies and procedures. In addition, personal laptops and email folders were mentioned as individual dispersed memory systems to store and retrieve valuable knowledge.

A major finding regarded the effectiveness of these organizational memory systems. A common problem was connected to the impracticality to retrieve knowledge from a centralized system due to its disperse location within the organization. This problem leaded to two distinct but complementary issues: duplication of knowledge, and knowledge loss. The first effect created knowledge overload with impacts on the knowledge retrieval process; the second effect prevented the organization from being able to retain valuable knowledge for future uses and forced employees to reinvent the wheel in the decision making process. It was found that duplication of knowledge and knowledge loss were related to the individual attitude of employees, the allocation of working hours – including the time spent to keep the organizational memory systems updated –, and the managerial support, and that the organizational culture impacted the correct implementation and use of the organizational memory systems:

"It's a cultural thing. You can have all the tools that you want but if there is not a culture that uses these tools…if you are not going to find the value, you are not going to use it..." [P2]

A secondary finding related to the types of organizational memory systems being used. Both web-based tools, i.e. Intranet and share points, and non-web based tool, i.e. hard drives, were extensively utilized in all department units. Hard copy documents were also considered as valuable sources of knowledge. From the analysis of individual interviews it turned out that only in one department unit participants did not mention personal laptops or email folders as valuable sources of knowledge but focused on the centralized non-web based repository. Counterintuitively, we might say that the broad use of such a centralized hard drive might have influenced the working style of employees, as a participant claimed:

"I think we are better at what we do now, we are more detail-oriented, we have more processes and policies. Like the AAR, and the hard drive… you have to store more stuff on the hard drive now, you know, if I have just written this piece of paper and I have just probably left it on my desk, I will put it on the hard drive, so the using of the hard drive for everything which contributes to build our own knowledge. In the past we didn't which is why we lost all the knowledge when people left" [P14]

Table 3 summarizes information on the use of organizational memory systems across the department units.

Department Unit	Intranet		Hard Drives	Hard Copy Documents
	Company Intranet	Share Point		
Unit 1	√		√	√
Unit 2	√	√	√	√
Unit 3	√		√	
Unit 4	√		√	√
Unit 5	√		√	
TOTAL	**5**	**1**	**5**	**3**

Table 3. The use of organizational memory systems

4.2 Processes: knowledge retention and retrieval

From data analysis it came out that knowledge retention and retrieval were closely related knowledge processes.

As a general finding, it was found that individual attitude of employees, organization allocation of working hours, and managerial support impacted the correct implementation and use of the organizational memory systems which in turn affected the retention and retrieval of knowledge.

With regard to the knowledge retrieval process, three factors were likely to influence it: the lack of a centralized organizational memory system; the complexity in the identification of valuable knowledge to retrieve due to a lack of rules and procedures to update the organizational memory systems; and the lack of individual motivation and/or individual effort to keep the organizational memory system up-to-date. It was found that this last finding was affected by the culture of the department and the ability of managers to promote a sharing working environment where employees felt free to make their individual knowledge available to others to create a collective base of expertise.

The process of knowledge retention was influenced by the lack of rules and procedures to update the organizational memory system, the lack of training on how to use the organizational memory system software, and the lack of motivation/efforts of individuals to keep the organizational memory system updated.

In particular, the absence of detailed maintenance procedures forced the system to be informal and generated unofficial social networks which helped the gathering of tacit knowledge from coworkers or managers:

"*…if it doesn't have good updates…it's not going to be used. So...it's a sort like the chicken and the eggs and which comes first…there is inconsistency in what people put in into it* [the organizational memory structure] *and there is inconsistency in who is using the system...so because it is inconsistent that makes the process of gathering the knowledge inefficient because I am looking for things that may not even be there. And because of the inconsistency that forces the process to be very informal, so I just walk and I talk to them* [other coworkers]" [P1]

4.3 Solutions

An outline of possible solutions to improve the use of organizational memory systems and increase performance is presented with respect to knowledge retention and retrieval processes.

1. To avoid both knowledge loss and duplication of knowledge, suggested actions are related to the creation of a centralized organizational memory system to store explicit knowledge, e.g. policies, procedures, past projects, customer reports.
2. The facilitation of informal social network is suggested to improve the sharing of tacit knowledge, e.g. expertise and know how.
3. The creation of a sharing culture has to be facilitated by managerial support and has to include specific working hours to update the organizational memory system or create informal sharing of knowledge events, e.g. brown bag meetings.
4. Other recommended actions are related to the introduction of rules and procedures to update the organizational memory system to avoid inconsistency in the stored knowledge, e.g. codification procedures, along with training programs on how to use and update the repository.
5. Finally, the introduction of a web master to monitor both the structure and knowledge processes is recommended to keep the system up to date and facilitate its future use.

4.4 Outcome: the framework

The comprehensive framework developed from the analysis of data is shown in Figure 1 and explained in Table 4. It provides a representation of emerged themes and summarized the critical elements in the management of organizational knowledge processes to improve performance.

Structures	Knowledge Processes	Issues	Causes	Solutions
Disperse organizational memory systems	Knowledge retention	Knowledge loss	Individual attitudes Organizational mechanisms Managerial support	To create a centralized organizational memory system to store explicit knowledge To facilitate informal social network to share tacit knowledge To introduce rules/procedures to update the system, training programs on how to update it, and a web master to monitor it To support the creation of a sharing culture
	Knowledge retrieval	Duplication of knowledge		

Table 4. The framework and its related mechanisms

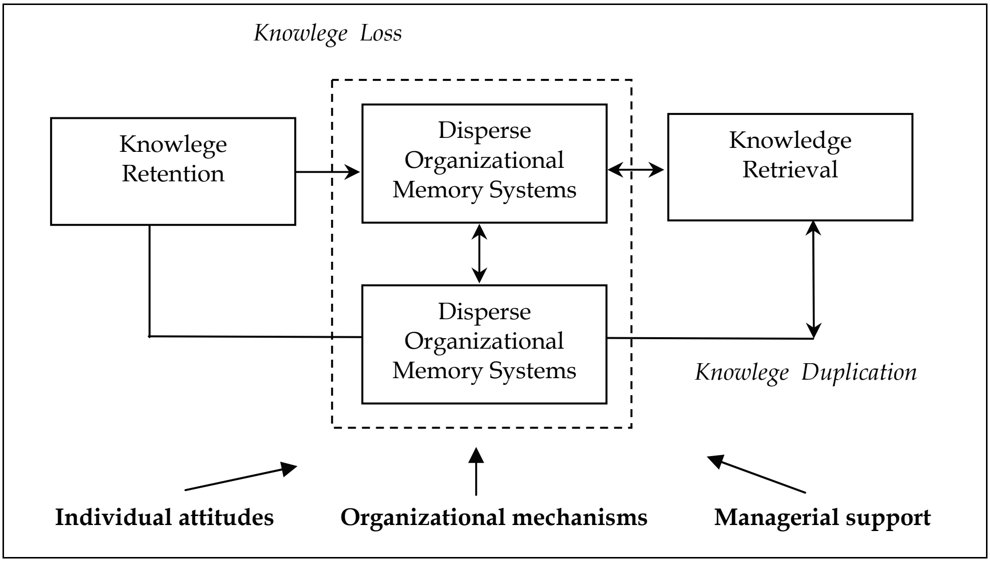

Fig. 1. The framework

5. Interpretation

This study was a qualitative contribution to the knowledge management and organizational memory debate. The purpose of this study was to investigate the role of shared organizational memory systems to suggest strategies to improve the effectiveness of information technology repositories.

Our findings indicate that internal archives were used to retain and retrieve knowledge. Participants used internal repositories such as Intranet (Hansen et al., 1999) – which included both share points and the company Intranet –, hard drives, and hard copy documents (Gherardi et al., 1998) confirming the importance of information technology tools to support knowledge processes (Alavi & Tiwana, 2003), i.e. creation, transfer, storage, and retrieval of knowledge.

A major problem was connected to the disperse location of organizational memory which in turn created duplication of knowledge and knowledge loss. The first effect impacted the knowledge retrieval process; the second effect prevented the organization from being able to retain valuable knowledge for future uses.

It was found that duplication of knowledge and knowledge loss were related to individual attitude, organizational mechanisms, managerial support, and organizational culture (Orlikowski, 1996).

In particular, the process of knowledge retention was influenced by the lack of rules and procedures to update the organizational memory system (Zack, 1999), the lack of training on how to use the organizational memory system software, and the lack of motivation/efforts of individuals to keep the organizational memory system updated (Orlikowski, 1993). Furthermore, the absence of detailed maintenance procedures forced the system to be informal and generated unofficial social networks which helped the gathering of tacit knowledge from coworkers or managers.

These findings confirmed that the luck of training affected the motivation to post notes or replies to it (Orlikowski, 1993) and pointed out the importance of ability, motivation, opportunity (Argote et al., 2003) and the organizational culture in the knowledge retention process. These findings are also consistent with the body of literature on intellectual capital (Brown & Duguid, 1998) and are congruent with research on social networks (Cross & Sproull, 2004).

These findings suggested strategies to improve the effectiveness of information technology repositories in terms of modifications to the organizational mechanisms, e.g. establishment of specific working hours to update the organizational memory, but also training programs and the introduction of a webmaster to monitor the organizational memory systems (Franco & Mariano, 2007).

This study also contributed to the analysis of organizational memory systems providing insights about a new knowledge source, i.e. personal laptops considered as valuable sources of explicit knowledge by 80% of participants. These repositories were considered as a place to retrieve knowledge about clients and past projects but also information technology repositories to store templates and lessons learned. Email folders were also mentioned as electronic tools to store and retrieve knowledge. These findings confirmed the criticality of single computer-based systems (Olivera, 2000) and the complementarily of knowledge retention and retrieval as critical organizational knowledge processes.

6. Conclusion, implications for theory and practice

Using empirical research data, this study investigated how knowledge is stored and retrieved in an American company and contributed to the growing body of literature on the use of knowledge, technology, and memory systems to improve organizational performance. It demonstrated the importance of individual motivation and efforts, managerial capabilities, and shared organizational technologies in the management of organizational processes and revealed factors influencing the processes of knowledge retention and retrieval. This study pointed out the role of shared organizational memory systems and suggested strategies to improve the effectiveness of information technology repositories.

The research data revealed that the process of knowledge retention and retrieval were influenced by individual attitudes, organizational mechanisms, and managerial support.

Three factors were likely to influence the knowledge retrieval process: the lack of a centralized organizational memory system; the complexity in the identification of valuable knowledge to retrieve due to a lack of rules and procedures to update the organizational memory systems; and the lack of individual motivation and/or individual effort to keep the organizational memory system up-to-date.

This last finding was also related to the culture of the department and the ability of managers to promote a sharing working environment.

The process of knowledge retention was influenced by the lack of rules and procedures to update the organizational memory system, the lack of training on how to use the organizational memory system software, and the lack of motivation/efforts of individuals to keep the organizational memory system updated. In turned out that the absence of detailed maintenance procedures to update the organizational memory systems forced employees to gather tacit knowledge from their coworkers through informal mechanisms of sharing, i.e. social networks.

Organizational culture, individual preferences, and training programs impacted the employees' willingness to update the organizational memory systems and had a consequence on the future use of those repositories.
Findings make implications for theory regarding the extend to which effective knowledge repositories might influence the employees' first preference to see out their colleagues to find knowledge.
Moreover, findings point out personal laptops and email folders as crucial electronic repositories to store valuable knowledge.
Findings suggest the need to facilitate a sharing culture through the support of managers who have to include specific working hours to update the organizational memory systems, create informal sharing of knowledge among employees, e.g. brown bag meetings, and promote the willingness to make individual expertise available to the other members of the organization.
Managers should also promote the introduction of rules and procedures to update the organizational memory system e facilitate training programs on how to use and update the repository. Finally, managers should select a person, e.g. webmaster to monitor both the organizational memory systems and the knowledge processes to ensure the correct update of the repositories and facilitate their future uses.

7. Limitations and future research

This study had limitations concerned the empirical generalizability because it was a single case study analysis.
This study focused only on knowledge retention and retrieval and did not consider other organizational knowledge processes.
Further research is needed to determine if similar factors influence the process of knowledge retention and retrieval, especially with regards to the impact of working hours on such a process. Also, future research should investigate the extend to which effective knowledge repositories might influence the employees' first preference to see out their colleagues to find knowledge.

8. References

Alavi, M. & Tiwana, A. (2003). Knowledge management: the information technology dimension, In: *Handbook of Organizational Learning and Knowledge Management*, M. Easterby-Smith & M. A. Lyles, (Eds.), 104-121, Blackwell Publishing Ltd., ISBN: 978-0-631-22672-7, Malden, MA

Argote, L.; Beckman, S. L. & Epple, D. (1990). The persistence and transfer of learning in industrial settings. *Management Science*, Vol. 36, No. 2, (February 1990) 140-154, ISSN: 1526-5501

Argote, L; McEvily, B. & Reagans, R. (2003). Managing knowledge in organizations: an integrative framework and review of emerging themes. *Management Science*, Vol. 49, No. 4, (April 2003) 571-582, ISSN: 1526-5501

Argyris, C. & Schon, D. A. (1978). *Organizational Learning: A Theory of Action Perspective,* Addison-Wesley, Reading, MA

Brown, J. S. & Duguid, P. (1998). Organizing knowledge. *California Management Review*, Vol. 40, No. 3, (Spring 1998) 90-111, ISSN: 0008-1256

Campbell, D. E. (1979). Interior office design and visitor response. *Journal of Applied Psychology*, Vol. 64, No. 6, (December 1979) 648-653, ISSN: 0021-9010

Carley, K. (1992). Organizational learning and personnel turnover. *Organization Science*, Vol. 3, No. 1, (February 1992) 20-46, ISSN: 1526-5455

Creswell, J. W. (1998). *Qualitative Inquiry and Research Design: Choosing Among Five Traditions*, Sage Publications, ISBN: 0761901442, Thousand Oaks, CA

Creswell, J. W. (2003). *Research Design. Qualitative, Quantitative, and Mixed Methods Approaches*, Sage Publications, ISBN: 0761924426, Thousand Oaks, CA

Cross, R. & Sproull, L. (2004). More than an answer: information relationships for actionable knowledge. *Organization Science*, Vol. 15, No. 4, (July-August 2004) 446-462, ISSN: 1526-5455

Crotty, M. (1998). *The Foundations of Social Research: Meaning and Perspective in the Research Process,* Sage Publications, ISBN: 0761961062, London

Cyert, R. M. & March, J. G. (1963). *A Behavioral Theory of the Firm*, Prentice-Hall, Englewood Cliffs, NJ

Franco, M. & Mariano, S. (2007). Information technology repositories and knowledge management processes. A qualitative analysis. *VINE: The Journal of Information and Knowledge Management Systems*, Vol. 37, No. 4 (Winter 2007) 440-451, ISSN: 0305-5728

Franco, M. & Mariano, S. (2009). The use of organizational knowledge in professional settings. A case study analysis, In: *Search of Knowledge Management: Pursuing Primary Principles*, A. Green, M. Stankosky & L. Vandergriff, (Eds.), 355-365, Emerald Group Publishing Limited, ISBN: 978-1-84950-673-1, Bingley, BD

Gammelgaard, J. & Ritter, T. (2005). The knowledge retrieval matrix: codification and personification as separate strategies. *Journal of Knowledge Management*, Vol. 9, No. 4, (July-August 2005) 133-143, ISSN: 1367-3270

Gherardi, S.; Nicolini, D. & Odella, F. (1998). Toward a social understanding of how people learn in organizations: the notion of situated curriculum. *Management Learning*, Vol. 29, No. 3, (September 1998) 273-297, ISSN: 1461-7307

Goodman, P. S. & Darr, E. D. (1998). Computer-aided systems and communities: mechanisms for organizational learning in distributed environment. *Management Information Systems Quarterly*, Vol. 22, No. 4, (December 1998) 417-440, ISSN: 02767783

Hansen, M. (1999). The search-transfer problem: the role of weak ties in sharing knowledge across organizational subunits. *Administrative Science Quarterly*, Vol. 44, No. 1, (March 1999) 83-111, ISSN: 0001-8392

Hansen, M. T., Nohria, N. & Tierney, T. (1999). What's your strategy for managing knowledge? *Harvard Business Review*, Vol. 77, No. 2, (March-April 1999) 106-116, ISSN: 0017-8012

Hayes, N. & Walsham, G. (2003). Knowledge sharing and ICTs: a relational perspective, In: In: *Handbook of Organizational Learning and Knowledge Management*, M. Easterby-Smith & M. A. Lyles, (Eds.), 54-77, Blackwell Publishing Ltd., ISBN: 978-0-631-22672-7, Malden, MA

Huber, G. P. (1991). Organizational learning: the contributing processes and the literatures. *Organization Science*, Vol. 2, No. 1, (February 1991) 88-115, ISSN: 1526-5455

Kogut, B. & Zander, U. (1992). Knowledge of the firm, combinative capabilities, and the replication of technology. *Organization Science*, Vol. 3, No. 3, (August 1992) 383-397, ISSN: 1526-5455

Kvale, S. (1989). To validate is to question. In: *Issues of Validity in Qualitative Research*, S. Kvale, (Ed.), 73-92, Studentlitteratur, ISBN: 0862382122, Lund, Sweden

Lincoln, Y. S. & Guba, E. G. (1985). *Naturalistic Inquiry*, Sage Publications, ISBN: 0-8039-2431-3, Newbury Park, CA

Mariano, S. & Casey, A. (2007). The individual process of knowledge retrieval: a case study of an American high-technology research, engineering and consulting company. *VINE: The Journal of Information and Knowledge Management Systems*, Vol. 37, No. 3, (Fall 2007) 314-330, ISSN: 0305-5728

Merriam, S. B. (2001). *Qualitative Research and Case Study Applications in Education*, Jossey-Bass, ISBN: 0787910090, San Francisco

Miles, M. B. & Huberman, A. M. (1994). *Qualitative Data Analysis: an Expanded Sourcebook*, Sage Publications, ISBN: 0803955405, Newbury Park, CA

Nonaka, I. (1994). A dynamic theory of the organizational knowledge creation. *Organization Science*, Vol. 5, No. 1 (February 1994) 14-37, ISBN: 1526-5455

Olivera, F. (2000). Memory systems in organizations: an empirical investigation of mechanisms for knowledge collection, storage and access. *Journal of Management Studies*, Vol. 37, No. 6 (September 2000) 811-832, ISSN: 0022-2380

Orlikowski, W. J. (1993). Learning from notes: organizational issues in groupware implementation. *The Information Society*, Vol. 9, No. 3 (Fall 1993) 237-250, ISSN: 1087-6537

Orlikowski, W. J. (1996). Improving organizational transformation over time: a situated change perspective. *Information Systems Research*, Vol. 7, No. 1, (March 1996) 63-92, ISSN: 1526-5536

Polanyi, M. (1966). *The Tacit Dimension*, Routledge and Kegan Paul, London.

Porter, M. (1980). *Competitive Strategy: Techniques for Analyzing Industries and Competitors*, Free Press, ISBN: 0029253608, New York, NY

Schein, E. H. (1984). Coming to a new awareness of organizational culture. *Sloan Management Review*, Vol. 25, No. 2, (January 1984) 3-16, ISSN: 1532-9194

Shrivastava, P. (1983). A typology of organizational learning systems. *Journal of Management Studies*, Vol. 20, No. 1, (January 1983) 7-28, ISSN: 0022-2380

Spender, J. C. (1996). Organizational knowledge, learning and memory: three concepts in search of a theory. *Journal of Organizational Change Management*, Vol. 9, No. 1, (January-February 1996) 63-78, ISSN: 0953-4814

Stake, R. E. (1995). *The Art of Case Study Research*, Sage Publications, ISBN: 9780803957671, Thousand Oaks, CA

Stein, E. W. & Zwass, V. (1995). Actualizing organizational memory with information systems. *Information Systems Research*, Vol. 6, No. 2, (1995) 85-117, ISSN: 1526-5536

Stein, E. W. (1995). Organizational memory: a review of concepts and recommendations for management. *International Journal of Information Management*, Vol. 15, No. 1, (February 1995) 17-32, ISSN: 0268-4012

Von Krogh, G. (2003). Knowledge sharing and the communal resource, In: *Handbook of Organizational Learning and Knowledge Management*, M. Easterby-Smith & M. A. Lyles, (Eds.), 372-392, Blackwell Publishing Ltd., ISBN: 978-0-631-22672-7, Malden, MA

Walsh, J. A. & Dewar, R. D. (1987). Formalization and the organizational life cycle. *Journal of Management Studies*, Vol. 24, No. 3, (May 1987) 216-231, ISSN: 0022-2380

Walsh, J. A. & Ungson, G. A. (1991). Organizational memory. *Academy of Management Review*, Vol. 16, No.1, (January 1991) 57-91, ISSN: 0363-7425

Yin, R. K. (2003). *Case Study Research. Design and Methods*, Sage Publications, ISBN: 0761925538, Thousand Oaks, CA

Zack, M. H. (1999). Managing codified knowledge. *Sloan Management Review*, Vol. 40, No. 4, (July 1999) 45-58, ISSN: 1532-9194

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Optimizing of Enterprise Communication Processes Management

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1. Introduction

Companies, especially Small and Medium Sized Companies (hereinafter only SME) must look for the ways and opportunities how to survive in time of economic and financial crisis and try hard to execute all companies' activities in an optimum way. The solution can be found in optimization of managing, decisions-making and production processes. To ensure it is critical to have required actual and valuable information. Company information system utilizing available information technologies, as a key of high quality information base and communication system - ensures obtaining, processing, provision and distribution of information. Due to the fact that management and decision making does not depend only on early and actual information but knowledge of managers and employees who prepare necessary documents are the most important – also importance of information and tasks required to prepare systems change. It can be stated that information revolution did not bring only a change in information understanding - its consequence is a change in a way of manipulation with information. It is critical to manage technologies used to cover information needs of environment in which they are spread and manage the way in which they are provided due to information needs of competent people through activities of which they change to knowledge. Both areas claim that this task is not simple due to the fact that it is not possible to define exactly all the factors which influence company knowledge management. An important part of this form of management is a human factor and ability of a company to utilize possibilities of information technologies the most effectively as well. The problem in such a way of management is a big dependence on employees´ knowledge which must be willing to share it with the others and on their skills and abilities to apply available IT and tools supported by them. Management of a system of such networks is very complicated especially when it is a must to consider the balance between costs ratio to solutions effectiveness since this is a very sensitive topic in the current crisis. The method of process management introduction to the area of company information and communication processes management that we suggest brings a chance to acquire mathematic apparatus to analyse complicated nets – complicated due to the great dependence on human factor share.

2. Necessity of enterprise communication processes management

Nowadays companies have to adapt quick changes in their surroundings and this is really a demanding process, where the way and speed of response condition the total success of doing business, it means whether a company strengthens its competitiveness or it may happen that a company loses its market place or fades. These influences and impacts make pressure on companies not only in a requirement to change the way of doing business but they often have to change the location, form or even line of business. Entering to new markets both local and foreign or necessity to provide new services as product added value or to change orientation towards a completely different type of production in dependence on customers and market requirements bring a necessity to be able to orientate in business conditions. If it is critical to reorganize company activities and processes or in a case that the place or line of business is being changed and some organization units fade or new ones are formed - it is necessary to carry out the changes within a short period of time and as effectively as possible.

New forms of team co-operation are created where a necessity of co-operation of more experts exists: team members do not come only from the organization itself, but they often co-operate, partners are particular clients themselves, for whom the organization produces its products or provides services, or they are other experts from the surrounding. In such forms of co-operation number of decisive and managing roles at lower level of company management goes up, importance of personal responsibility and employees´ competency growths and at the same time number of administrative and repetitive tasks decreases and this brings higher demands towards support of teams management and their mutual co-operation. Need for team co-operation of more experts often requires different point of view to see the reality in a company – not from the personal point of view but in a context with the opinions of other team members that should be accepted and adapted to. It means that it is necessary to know:

- To distinguish and change long-lived ideas and effects which influence total understanding of reality and following decision – making of company management,
- to overcome barriers in acceptation of opinions of colleagues in labour relations while the ultimate criteria should not be acceptance or non-acceptance of a particular opinion, e.g. due to the status, but based on knowledge and experience of team members what leads to increase of growth of learning organization.

Also entries to new markets bring the need to adapt company activities to other new form of co-operation. Enterprises must monitor the organization's environment and promptly react to its changes; they must use the manpower as an information source, as well as upgrade and minimize the set of business rules (i.e. legislation, standard specifications and instructions). This knowledge is also essential for doing business on any foreign market, where companies are supposed to cooperate with foreign partners. They also must flexibly adapt to different economic, legislative, social, demographic and cultural environment.

These requirements make pressure on company management since they have to modify or change common cycle of company activities very quickly due to the actual need, and it brings the requirement to determine new work activities precisely, to define competencies of team members, their responsibilities and competences for the work done, even without creation of new forms of organization structure. These claims result from the need:

- to ensure unique approach to required information from the point of view of more experts, what requires a need to unite technological platform of information systems,

- to change the way of management of setting for work with information and it requires:
    - to know exactly how to determine necessary activities connected with coverage of information needs,
    - to determine exactly who and for what type of activities is responsible,
    - to know the way how inspection of their execution will be carried out,
- to co-ordinate of more activities so that they present integrated sequence of processes and activities based on precise specification of their claims.

It is not enough just to make necessary information accessible, i.e. meet the requirement of quick information accessibility, but it is needful to change information understanding – its new dimension and value is not created through the fact that they are available more quickly, but through the fact that it is the base for knowledge development, while the most important share on knowledge quality has a human factor and its personal abilities. It can be stated that work with knowledge is equal to a necessity of change of utilized models of thinking, which presents a necessity of change of information interpretation in context with the actual state in a company and based on own knowledge and experience.

It requires precise identification of executed tasks, where process management has got its place. It does not concern only individual production processes but also process management of information processes and activities connected with creation of needful information and communication support. Through their utilization in combination with available information about changes in company surrounding the company obtains a tool to increase its competitiveness.

2.1 Role of information technologies in the enterprise communication system

The risk of doing business is closely related to the need of good knowledge in business area and terms of business in real condition by their partners as well as by their competitors – it's the key to whichever successful business deal and effective collaboration between partners or clients. As it was stated - changes happen even without planning and so it is necessary to change a way of information support provision in dependence on what type of changes occurs. Currently accessible information systems only in a small scale or not at all provide information about slough in a company and that is why also an ability to suppose in advance if suggested solution will present benefit or lost investment of a company is quite low. This situation brings the requirement to look for a simple solution aimed at risk elimination. This means to find the right solution concerning optimizing and investments to development of network, communication and information systems as well as people knowledge databases which help managers to concentrate on their core competencies.

Effective exploring of enterprise information sources brings the possibility how to increase the competitive advantages. Acquired data must provide information not only about common aspects of analysed processes but may be decomposed in time and by a location which will use them in a decision-making process. Next, an enterprise must provide information about itself - not only legal information, goodwill of management but also by acceptation of global policy and corporate culture. It is the role of external communication system.

All the terms and rules must be set strictly; they are supposed to reflect a real situation, support assignment and transfer of several changes in and out of the enterprise in accordance with changes in enterprises goals. For an effectively hyper-connected enterprise this means to achieve reduction of time to make a decision, increase of productivity and the ability to provide simple and consistent user experience by means of all types of communications. Generally, it means to have right information to succeed in communication with their partners. Managers can make claimed decision in expected reaction time.

Nowadays we know that people suffer from information overload; there's much more information concerning any given subject than a person is able to access. The result is that people are forced to depend on each other due to their knowledge. Know-who information rather than know-what, know-how or know-why information has become the most crucial. It involves getting to know who has the required information and being able to reach that person and being able to know how and from whom the information can be achieved – to know information source (Singh, 2007).

Therefore it is necessary to:

- contact the right person immediately (to achieve information about partners),
- provide information they need quickly, accurately and helpfully (information about the enterprise for partners),
- be able to interact with partners in a way that suits them best, whether personally, over the phone, SMS, via email or a website.

The reason is to find such solution that assures an effective utilization of enterprise communication network supported by common information and communication technologies (ICT) where the right information is always available to managers and front line staff to make right decision in their knowledge management processes. They help to eliminate barriers between voice, email, conference, video and instant messaging.

It means to bring solutions that support:

- clear and consistent processes for handling partners interactions,
- back office systems accessible through a common interface - so partners and product or service information are instantly retrievable,
- highly motivated staffs who come across as helpful and well informed.

It is required to achieve unified communication that provides an integrated access to people, information and other knowledge sources. Opened information technologies help to remove the barriers between existing used communication tools to do claimed decisions. Consequently, to make communication and collaboration process more effective, it is needed to create an opened and optimized communication structure that supports on-line exchange of information necessary for more flexible and operative decision-making and managing processes.

Unified communication solutions have to aggregate people, as well as systems and ICT to unified communication systems which create a unified decision support (Lohnert, 2008).

Gartner, Inc. analysts specify in the information technology research (Pettey, 2009) - the unified communication conditions that are focused to answer the following questions:

What? – Unifying of communication ways, systems, devices and applications:

- telephone data label, mobile voice, fixed voice, pager, chat, e-mail – allow connections with managers everywhere and anytime. These communication tools have technological restrictions due to various solutions and their accessing. There it is needed to know what solution to use to be successful by communication at the given time in its enterprise.

Why? – To achieve more effective, faster and simple communication. Various tools are used in different situations.

How? – Through using common and new ICT more effectively.

For all that if we want to bring an effective utilization of information to a top position in the business market competition process it is needed essential to know the weaknesses of enterprise communication network and consequently decide where it is necessary to invest finance to develop or innovate the functionalities as well as its management tools of such network in accordance with achieving above mentioned needs. To do it correctly we paid attention to analysis of a real condition in the SME enterprise aimed at using of communication system as a support of business activities, as well as to the above mentioned factors.

2.2 Current trends in communication technologies

Today more SME have ICT support of information and communication systems but they always don't exploit all abilities of their advantages. Just the problem is: it is more risky to decide about changes in the enterprise communication system due to limited finances. Incorrect leverage has to invoke weaken even bring to end all business activities of SME. There is necessary to analyse not only information sources but also factors like enterprise strategy, management concept, organizational structure, corporate culture, employee's knowledge, their abilities and finally their demands concerning information. It is critical to search such solutions which help effectively to manage information and communication processes.

The requirement of technologies management results from a basic problem of current period i.e. impact of information revolution – its consequences in companies is seen in a form of information strategy aimed at permanent innovation and purchase of the latest technologies to achieve the highest quality and the most modern technologies focused on getting a very quick and fast access to necessary information. This trend in companies caused that they often purchased technologies that enabled different functions and functionalities of information systems but only rarely were used by companies to support running processes and activities. Next there were the trends which allowed support of managing and decisive activities through information systems applied by them, but their innovation was very costly and the supports were applied quite seldom by companies. A permanent requirement towards users to adapt to new technologies, functionalities and surroundings seemed to a problem. Consequently next problematic point is heterogeneity of information systems platforms due to various IT platforms and data formats which formed a base of purchased solutions of information systems. This is the reason why the investment was perceived as ineffectively spent.

At first while companies used accessing of technologies to speed up access to required information the impacts of the above mentioned shortcomings were not monitored in a wide scale. But when it was necessary to ensure a common access of all interested employees to required information in both internal and external company surroundings through a net access the problem of data non-integrity and tools heterogeneity arose. Especially the way how companies were able to manage this fact i.e. how they solved the task of information platform unification and assurance of the form of co-operation determined their competitive advantage.

Apart from problem of non-integrity it is necessary to solve the problem of determination of opinions priority what is connected with identification of co-ordinates importance and their opinions and their position within a decision making process. In a network surrounding where team forms of co-operation are utilized it is very demanding to set priority position within the relationships hierarchy especially if this position is not identical with positions in applied company hierarchy. Both tasks concern management of information assurance network while detailed knowledge of individual information processes and their claims is an assumption to its proper activity. In this process skills and abilities of employees in the area of work with information technologies play an important role.

A new way how to make investment more effective is consolidation of existing information technologies used to building of information system infrastructure. Such solution enables utilization of unused capacity in a company, while network access and virtualization of working premises allow its management from a server. It presents a possibility of more effective work and a user does not have to be informed about the particular infrastructure he actually uses. Such solutions increase management effects, decrease company costs and present a tool for unification of information area. To apply such solution it is needed to know real enterprise information requirements.

3. Management of communication processes and social network theory

Determination of the concept of information demands, their tactics, methods, tools, rules as well as decisions how to use ICT more effectively are the basic points of information process analysis. We focussed our attention to monitor actually applied rules and tactics and according to them we should provide the answer to processes and activities used in the analysed enterprise.

Consequently it is necessary to prepare not only data evaluation but evaluation of all used communication and social sites elements of the enterprise. As we have appointed before for all that it is necessary to manage social networks effectively to gain access to the proper pieces of information. The result of such analysis gives more possibilities to collect information demands to be answered due to all processes inside and in outside the enterprise. It provides more possibilities as well as determination of the rules and activity sequences that are unique, minimal, and consistent and follow the areas and aims they were aimed at. In this context understanding of determination, development and utilization of social network becomes more important. Therefore we have to focus our attention to social network theory.

A social network is a set of people (or organizations or other social entities) connected by a set of social relationships, such as friendship, co-working or information exchange. At their work they often utilize an information network. Researchers working at the intersection of information systems, sociology and mathematics are interested in information networks as well. They study the uses of social networks and the ways in which they are mediated in a society and at workplaces through ICT such as Intranet or some other networks (LAN, MAN, WAN) or the Internet.

The power of social network theory results from its difference from traditional sociological studies, which assume that it is the attributes of individual actors - whether they are friendly or unfriendly, smart or dumb, etc. – that's matter. Social network theory produces an alternative view, where the attributes of individuals are less important than their relationships and ties with other actors/participants within the network. This approach has turned out to be useful for explaining many real - world phenomena, but provides less space for individual agency, the ability of individuals to influence their success which depends on a particular structure of their network (Singh, 2007). Such process strongly depends on employees' relations, entrepreneurial objectives, as well as on employees' loyalty.

In SME there is a specific situation because most of employees at top positions are family members. They have high-ranking management competences due to their specific position, but they do not always have a topic and actual information. They often gather it from own employees who sometimes don't dispose with required tools needed required to obtain such information (often obtained as a result of specific data analyses or from ulterior information sources). But it is important to invest finances to such tools as well as people skills. The real challenge is to develop a member of intelligence analysts who are encouraged to "think creatively" and to acquire intellectual capital in the form of substantive expertise on a broad range of topics. The need for creative thinking runs directly into the need to reform secrecy and compartmentalization of information. A better balance is needed between investments in the emerging collection systems and enhanced forms of analytical capability. The latter means a greatly expanded investment in high quality personnel and new technologies that help analysts, instead of overwhelming them. To say it in a simple way - huge amounts of collected but unprocessed and unanalyzed data are useless for any policymaker – accordingly for SME.

Network theory is similar to system theory and complexity theory. Social networks are also characterized by a distinctive methodology encompassing techniques for collecting data, statistic analysis, visual representation, etc. We can use many different methods and models to analyse such properties of information network and its data flows used as a support of enterprise communication system. Great mass data processing methods based on exploitation of common IT and visualisation provide modelling of precision final solutions by means of acceptation of real or expected conditions. But just in SME it is necessary to estimate whether it is more needful to invest to ICT or into analysis tools to make information and communication system more effective. The most important question to consider is which type of membership activity and where most affects the information and communication network? As we have appointed before enterprises must also monitor the organization environment and promptly react to its changes. It is possible if they better know both advantages and disadvantages of their communication system. To do it, we can apply the analyses which give more opportunities to set up if this network operates effectively or if financial resources or people potential are exploited efficiently.

4. Properties of social network analysis

The purpose of social network analysis is to identify important actors, crucial links, subgroups, roles, network characteristics, answer substantive questions about its structure, etc.

There are three main levels of interest: element, group and network level. As to element level, one is interested in properties (both absolute and relative) of individual actors, links or incidences. An example of this type of analysis is bottleneck identification and structural ranking of network items. On his group level, one is interested in classification of the elements of a network and properties of sub-networks. Examples are - actor equivalence classes and cluster identification. Finally, on the network level, one is interested in properties of the overall network such as connectivity or balance.

If we want to make a network analysis we must study social relations among a set of actors. Network researchers have developed a set of distinctive theoretical perspectives as well. Some of the points of these perspectives are:

- focus on relationships between actors rather than attributes of actors,

- sense of interdependence: global rather atomistic view,
- structure affects substantive outcomes,
- emergency effects.

Social relations can be thought of as dyadic attributes. Whereas mainstream social science is concerned with monadic attributes (e.g. income, age, sex, etc.), network analysis is concerned with attributes of pairs of individuals, of which binary relations are the main kind.

Some examples of dyadic attribute (Richards, 2006):

- Social roles: a boss of, a teacher of, a friend of, etc.
- Affective: likes, respects, hates,
- Cognitive: knows, views as similar,
- Actions: talks to, has lunch with, attacks,
- Distance: number of person between,
- Co-occurrence: is in the same position as, has the same relation as…,
- Mathematical: is two links removed from

If we study network properties we have to analyse parameters like:

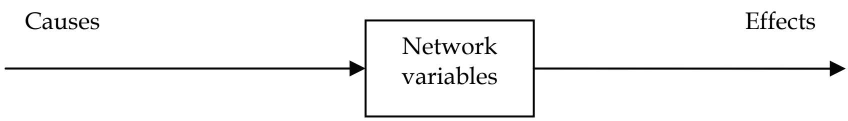

Fig. 1. Network variables

1. Substantive effects of social network variables
- Attributes of ego network → access to resources, mental/physical health
- Network closeness → influence, diffusion
- Similarity of position → similarity of risks, opportunities, outcomes
2. Substantive determinants of social network variables
- Personality → centrality?
- Similarity → friendship ties? (homophily)
- Reduction of cognitive dissonance → transitivity?
- Strategic "networking"
3. Network determinants of network variables
- Relationship between density and centrality.

If we want to make an ego network analysis, it can be done in the context of traditional surveys. Each respondent is asked about the people he/she interacts with and about the relationships among these people.

Ego network analysis is extremely convenient because it can be used in conjunction with random sampling, which enables classical statistical techniques to be used to test hypotheses.

We speak about a complete network analysis in situations where we try to get all the relationships among a set of respondents, such as all the friendships among employees of a given company. Most of rhetoric surrounding network analysis is based on complete network. All the techniques such as subgroup analysis, equivalence analysis and measures like centrality require complete network.

Network analysis is conventionally criticized for being too much methodological and too little theoretical. Critics say that there are few truly network theories of substantive phenomena. This is not a well-considered argument, however, because when examples of network theories are presented, critics say “that's not really a network theory”. This is natural because theories that account for, say, psychological phenomena, tend to have a lot of psychological content. Theories that account for sociological phenomena have sociological independent variables. Only theories that explain network phenomena tend to have a lot of network content (Chung et al., 2007).

5. Utilization of social network analysis and settings of its properties by small enterprise

In spite of all expectations communication system is often strongly dependent on its elements that bring up unexpected situations or processes. Such elements are people and their activities. Hence it is essential to know that the social network theory can be also used to examine how company’s members interact with each other, characterize many informal connections that link executives together, as well as associations and connections between individual employees of different departments. Such analysis tools provide the proper ways for companies to gather, reject or achieve information about competition and also about any unexpected collusions occurred in business activities.

A social network theory is interpreted as a network with nodes (often referred to as actors), i.e. entities such as persons, organizations, or simply objects that are linked by binary relations such as social relations, dependencies or exchange.

To express the structure of such net a net model may be used in which any node (a group of nodes) may have optional links (relations) to another optional node (a group of nodes). The links between nodes present existing social links of a system of communication in a company - both formally and informally.

Its advantage is a chance to simulate difficult tasks such as decision makings in a short time interval, where it is necessary to recognize the importance of a particular node from the point of view of announced information and their impact on a way of decisive problems solution. This model was developed from the hierarchical model, so the hierarchical model is a special case of a net model – it is its subset. Net model consists of sets of arranged couples of nodes where one element is called an owner and the second one is a member (Fig. 2.).

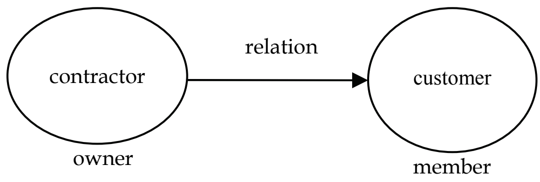

Fig. 2. Enterprises ties

The superior node (e.g. supplier) may have an optional number of subordinate nodes – records (e.g. customers), which can be mutually chained. The rule in this model is that if we miss or add some records links within data base are not disrupted.

Both nodes and links may have additional attributes of any type, and numerical link attributes may strengthen or weaken the tie between two nodes. In its most simple form we can use a social network diagram as a map of all of the relevant ties between the nodes which are being studied.

Such network theory and its model can also be used to determine the social capital of individual actors. It is used to illustrate the data continuity analysis process. Each node in this network represents a person that works in a particular knowledge domain. Nodes often present the individual actors within the networks, and ties are the relationships between the actors. Such network has oriented ties due to character of enterprise relationships.
To understand properties of such analysis we analysed the small enterprise in its social network diagram, where nodes (Y_i) are the points and ties are the lines. People are displayed as nodes Y_i and their social relationships are ties $X_{i,j}$.
The social network diagram has the following structure (Fig. 3.):

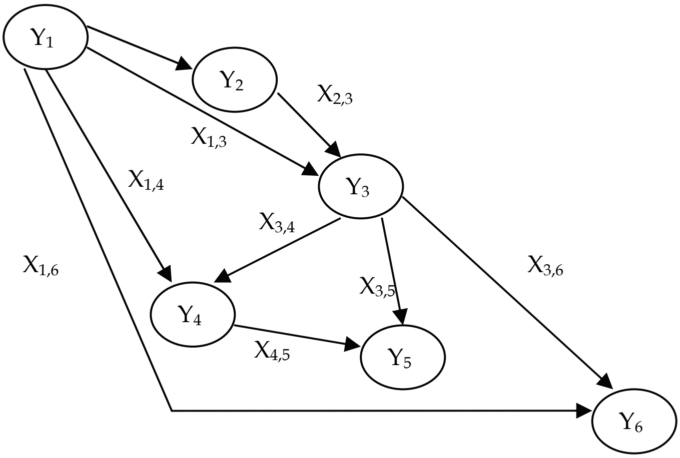

Fig. 3. Social network diagram

The Y_1 is a chief, Y_2 is his wife and Y_3 is a sale and marketing manager, Y_4 is an accountant and other two are regular enterprise members. People have cumulative work duties according to this small business where it is necessary to do it in this way. Neither of people have different knowledge than the others so there can be many kinds of ties between the nodes. So we can easily analyse the structure of network as well as closed points of such social network.
Next in that social network we must know the most significant nodes and their properties – centralities. One of the ways to understand social network needs includes accounts of centrality and of one node's relationship to other nodes in a network. That is why Linton C. Freeman's article concerning centrality in social networks is important (Freeman, 1978). He explored how "graph centralization" is based on differences in point centralities. He also outlined three competing theories regarding the definition of centrality based on degree of a point, control and independence. Because social networks are fundamentally social tools in which people are constantly monitoring and growing their social network, most social network media depict growth using the degree of point definition.
However, control and independence can be more useful definitions. As we have mentioned above, a person who controls information flows is more important than one who is on the topic position or may have more friends in the network. Such person may have better information to eliminate the risk of common business activities. But the importance of this

position is not as high as it should be. Holder of the position is often responsible for finding out such points and their relationships - it's the key to a successful business deal.
Therefore in the next we calculate - for analysed network`s nodes - such properties as local measures of degrees and distance centralities. It helps us to decide better about centralities of such network.
Degree centrality is defined as the number of links incident upon a node (i.e. the number of ties that a node has). In an enterprise network this means counting the number of informed people it has in a social network. The more people are connected to a given node, the more important the node is.
Degree centrality can also indicate which members are the most useful or well connected and therefore the best information resources. It is often interpreted in terms of the immediate risk of node for catching whatever is flowing through the network. The greater a person's degree, the greater the chance that he will catch whatever is flowing through the network, whether it is good or bad. Nodes with degree centrality are not only more viewable and controllable but the network better obtains any information which may effectively exploit in the competition process. In a better way they gather new innovation and knowledge. In general, the greater a person's degree, the more potential influence the network has and vice-versa. For example, in the enterprise network, a person who has more connections can spread information more quickly, and is also be more likely to hear more information. It is so in our enterprise where the marketing manager (node Y_3) has always better information about sales promotion so he can better plane purchase orders than his chief who prepares plans for firm`s stock-in-trade as well as enterprise strategy. Also a lot of research points say that organisations gather better more information incidentally or through fellowship dialogs than through official reports.
Due to fact that an enterprise communication network is usually directed network we also set measures of prestige measures. Such measures are computed for directed networks only, since for those measures the direction is important property of the relation (Wasserman & Faust, 1994). In a directed graph prestige is the term used to describe a node's centrality.
Next we will also analyse distance centralities to obtain better information about weaknesses as well as about opportunities of a communication network. We outline the betweennes centrality based on a counting rate of information ties as well as distance and density centralities computing. There we use a graph-analysis methodology combined with a correlation matrix analysis (Balog & Straka, 2005) to optimize such network properties.

5.1 Setting of local measures of centralities by using a graph-analysis methodology

If we constructed a social network diagram we could analyse point's properties, set hierarchy levels of communication network as well as its density. To do it correctly we configured a matrix model which corresponds with a communication network diagram by Fig. 3.
That correlation matrix corresponds with information flow's relations of the analysed network's subjects described above.
Let this matrix be a compact model of information graph. In the social network there is a time delay of information flows between input and output data according to their background processing in the analysed social network. Let these elements of social network mark as subjects of that system - Y_i. Some relations between these subjects described as oriented paths are variable $X_{i,j}$ those can be even 1, if there is a relation from node Y_i to Y_j node, and $X_{i,j}$ can be even zero, if this relation does not occur. We get an information matrix (matrix of relations between a manager and his employees - see Table 1.):

M 1=

	Y1	Y2	Y3	Y4	Y5	Y6
Y1	0	1	1	1	0	1
Y2	0	0	1	0	0	0
Y3	0	0	0	1	1	1
Y4	0	0	0	0	1	0
Y5	0	0	0	0	0	0
Y6	0	0	0	0	0	0
∑	0	1	2	2	2	2

Table 1. Correlation matrix of information relation network

In the next step we summarized the values in the columns to set hierarchy levels of communication network. If the sum in the columns is zero, these points are integrated to the same hierarchy levels. As we can see from the Fig. 3., the node Y_1 has the highest degree position. Such position we identify as a "Status prestige". It corresponded to the chief position of analysed enterprise network.

To obtain next levels we calculated series of matrix n-exponentiation and consequently we again summarized the values of the columns answered to particular nodes. We repeated that process until we obtained a zero-matrix.

The number of exponentiation corresponded with the number of hierarchy levels. We must exponent our matrix 5-times to obtain a zero-matrix – so our network has five hierarchy levels. Gradually we determined distribution of nodes to several levels and assigned to nodes relevant information flows to the nodes according to existing ties of communication system.

This model monitors the analysed network more transparently because of more visible hierarchy levels and ties and it simplifies the above mentioned graph diagram (Fig. 3.). Our network was simpler, but if we could analyse a bigger social network we could obtain a structure of hierarchy levels more transparently – even it seemed to be complicated at the first sight in the first graph diagram of such network.

Next, if the network is directed (meaning that ties have their direction), then we must usually define two separate measures of degree centrality, namely indegree and outdegree. An indegree is the number of ties directed to the node, and outdegree is the number of ties that the node directs to the others. For positive relations such as friendship or consultancy, we normally interpreted indegree as a form of popularity, and outdegree can be seen as indicating gregariousness (Chung et al., 2007).

So we obtained a new graph model of information network corresponding to existing information hierarchy levels (Fig. 4.).

Next we could decide who has a better control in the communication network. We can use graph-analysis method that also gives information about control centrality. The **control** refers to the extent to which nodes depend on one specific node to communicate with other ones. For example, if more employees are connected to each other only when that node serves as the bridge connecting them, then its centrality is high. It is the node that controls the communication flows. There it is a node Y_3. If such a worker absents information flows from Y_2 to Y_4, Y_5 and Y_6 absent. The worst situation is when Y_1 also doesn't work. Such situation we called as "Social cohesion". It is the minimum number of members who, if removed from a group, would disconnect the group. By our network is minimum equal to 2, it is node Y_1 or Y_3.

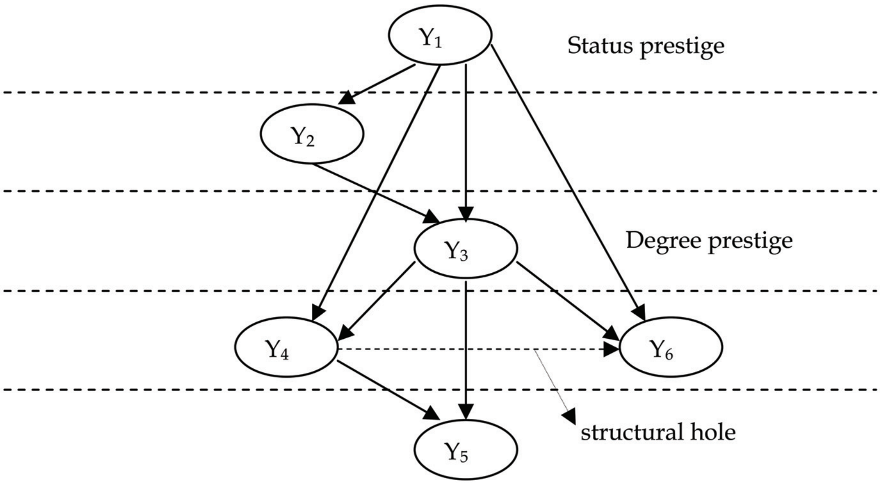

Fig. 4. Graph presentation of hierarchy model

Next we can calculate a measure of centralities in our network. First one is a degree centrality.

- **degree** centrality has the node Y_3 because the most outstar and instar paths connect other nodes to it (Fig. 4.).

We calculate degree centrality as:

$$C_E(v) = \Sigma \ \omega(e) \tag{1}$$

where e is a count of all instars and outstars paths. As we have counted a degree centrality of network by Fig. 4.:

$C_E(v)$ for node Y_3 is even 5.

We can name such centrality as a "Degree Prestige" because this node is prominent due to a lot of other adjacent nodes is linked to this node.
Next we want to set local measures of centralities. We compute

- **outdegree** centrality as:

$$C_E(v) = \sum_{e \in outstar(v)} \omega(e). \tag{2}$$

We can say the node Y_1 has the highest outdegree centrality because its $C_E(v)$ is equal to 4. Next it is Y_3, but not Y_2 as we could gather from hierarchy model (wife of chief) of enterprise structure.
Next centrality is

- **independence** centrality:

means that a node is closely related to all the nodes considered – so that it is minimally dependent on any single node and it isn't a subject to control. This means it can "reach" the maximum number of people through the shortest number of links, without being dependent on a few particular nodes (Y_1). It is normal because the boss of the firm has such position in the firm. He may and have to control all employees' activities.

Vice-versa the point Y_3 is strongly dependent on other nodes so its activities are more visible. It can put stress to its work duty beneath criticism.
On the other side we can decide which of all nodes is well informed – it has relatively the highest level of control in such network.
We can compute it from a graph theory as a:

- **closeness** centrality is a centrality measure of a node within a graph.

Nodes that are "shallow" to other nodes (it means, the nodes that tend to have short distances to other nodes with in the graph) have higher closeness. In the network theory, closeness is a sophisticated measure of centrality. It is defined as the mean shortest path between a node and all other nodes reachable from it.
If we computed this centrality for all nodes as:

$$C_E(v) = \frac{1}{\sum_{t \in V(G)} \delta(v,t)} \tag{3}$$

we obtained that closeness centrality has the node Y_3. We deduced that in such network node Y_3 is the most important one, it means such employee is more important person in the enterprise even if it does not seem like that at first sight. So a successful business deal of all enterprise will depend on his activities.
If chief of enterprise can achieve a better control of all activities he can link to two people who are not linked. He can control their communication. If he fills a structural hole the "static hole" can be strategically filled by connecting one or more links to link together other points (Fig. 4.). It is linked to ideas of social capital of network. Chief who prepares planning of stock-in-trade can obtain better information about real situation when he controls communication activities between Y_4 and Y_6. Y_4 is an accountant manager who gathers information from regular enterprise members.

5.2 Analysis measures of distance centralities and redundancy

Furthermore we can decide about the position of Y_3 when we compute measure of distance centrality:

- **betweenness** centrality

It is a distant measure of nodes within a graph. The nodes that occur on many shortest paths between the other nodes have higher betweenness than those that do not.
The highest betweenness centrality has Y_3 and it serves as the bridge between the most nodes and controls the information flows.
The **betweenness** centrality for node v is:

$$C_E(v) = \sum_{s \neq v \neq t \in V(G)} \frac{\delta st(v)}{\delta st} \tag{4}$$

where:
δst (v) - is the number of the shortest paths from the node s to t that pass through v,
δst - is the total number of the shortest paths from the node s to t.
Betweenness centrality has node Y_3. Its measure is equal to 1/4. The distance measure is the shortest for the node Y_3, where a path to the node Y_5 is the shortest of all through the node Y_3 (but not through the node Y_4). As we can see the analysis through a network graph in the Fig. 3. is more frosted than one in the Fig. 4. because we can't set the shortest way so exactly

because were not aware of hierarchy levels distribution of all nodes. It confirmed our findings that Y_3 is the well important node in such communication network. It is necessary to pay attention to such point because we have to be aware of information security violation. On the other hand, when we analyse an existing network it is necessary **to decide** about **information redundancy,** if it is needful or needless. It is necessary to balance the positives and negatives of size and communication activity.
If we would analyze redundancy we can also use a correlation-matrix model. There we must configure matrix of ties counting rate. The number of ties indicates the number of information redundancies of network nodes (Table 2.):

	Y1	Y2	Y3	Y4	Y5	Y6
Y1	0	1	2	2	2	2
Y2	0	0	1	1	2	1
Y3	0	0	0	1	2	1
Y4	0	0	0	0	1	0
Y5	0	0	0	0	0	0
Y6	0	0	0	0	0	0

Table 2. Matrix of counting rate information ties

As we can see the information redundancy have the nodes Y_3,Y_4,Y_5 and Y_6. If we summarize rather obtained findings (chapter 5.1) we can say the information redundancy for node Y_3 is needful but the other nodes redundancy is needles.
The main shortage of the model is its difficulty concerning a display of links between nodes and also from the point of view of a need of data manipulation – from the point of view difficulty of expression of input and output flow of data in mutual relations in a described company structure of activities or processes. Its advantage is its similarity to physical structures of stored data which enables making company management more transparent, specification of importance of individual nodes in a network, what is very complicated in this open structure, where sometimes workers at lower positions possess important information from the point of view of company priorities.

5.3 Network analysis by using Visone

Nowadays we can use an analysis tool that facilitates the visual exploration of social networks by using Visone programme. It may be used if we have a large network with many nodes and ties, where it is more simply to research its properties through models and build algorithms which integrate and advance the analysis and visualization of social networks (Brandes & Wagner, 2007).
It includes counting of many above described centralities.
Such tool enables a social network analysis by using graph-theoretic concepts - to describe, understand and explain social structure. The Visone software is an attempt to integrate analysis and visualization of social networks and is intended to be used in research of complicated social networks. It attempts to make complicated types of analysis and data handling transparent, intuitive and more readily accessible. Nevertheless we recommend using such tools for SME enterprises if they need to analyse their network. Software Visone is free for research purposes, but not for commercial use. It can be downloaded from http://visone.info/download/.

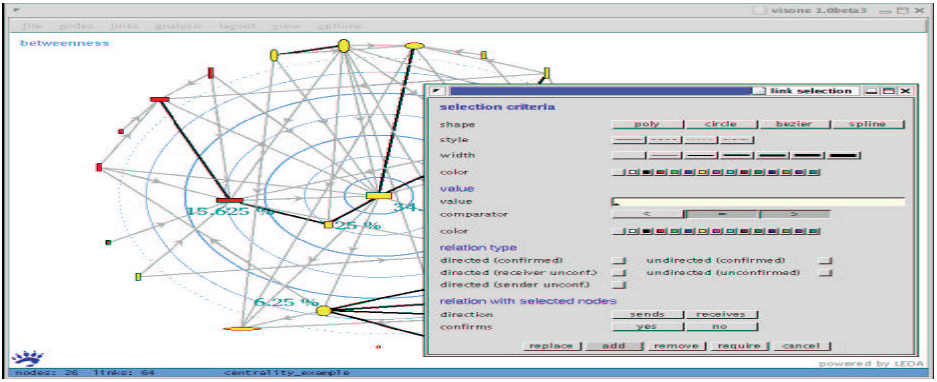

Fig. 5. Visone model analysis

6. Model of company communication network process management

In the previous part we have introduced the model which may be applied to manage a communication network in a company – from the point of view of determination of importance of individual members (nodes) in this network. If we wanted to develop a model the role of which would be to make management of activities concerning required materials processing and basic documents concerning information assurance of economic activities in a company more effective, it would be necessary to know in details all the activities connected with the process. It means that it is vital to carry out a process analysis of performed activities related with provision of corresponding information needs, define needed processes, their consequence and also people responsible for their execution.

Based on it is possible to determine a map of processes and corresponding information flows in a form of related documents. For designing a map of an adequate processes and individual nodes structure which present employees responsible for their execution may be used (Pomffyová, 2008). Based on the processes map – next it is possible to make analysis of repetitive activities at execution of economic operations of a particular company and find out if some activities do not repeat or if they are not executed uselessly. It allows making related processes more transparent and minimizing them so that all activities and processes which are carried out ineffectively or are redundant - are eliminated. Based on it is possible to make not only decisions of operative character but also strategic decisions which concern for example a change of organizational structure, its form, even cancellation or initiating creation of a new working position – based on actual company needs, what is often a narrow place and an obstacle the impact of which may negatively influence company operation and success of business as well.

The advantage of this model is that if processes and responsibilities for their execution are transparent – also partial elimination of human factors influence - resulting from impossibility to carry out particular changes due to superior position of a member of team, or due to underestimation of expert abilities and knowledge of lower range experts – is possible.

As it was already mentioned – if the map of processes and responsible people exists, we can start with optimization of their activities and the criteria which is measurable is monitoring of a length of a cycle of individual documents processing, i.e. we will try to optimize periods

of distribution flows execution – flows related to processing of required documents and length of intervals of idles related to their technological processing.
Based on the results of monitoring and period analysis we may create a matrix in which we record all required intervals. In this way we will get a matrix which clearly depicts a flow of documents between individual nodes. To analyse documents flow a method of matrix of transport model will be used (Balog & Straka, 2005).
As criteria of optimization a sum of multiplication of documents transmission in the direction of their flow is selected:

$$Tc = \sum_{j=1}^{S}\sum_{i=n}^{n}(t_{i,j} + tm_{i,j}) \tag{5}$$

where:
T_c is a total length of a cycle of documents processing (e.g. project documentation),
n - number of positions,
S - number of searched documents,
$t_{i,j}$ - time of duration of technological operations required to process a document of its i-position, including document receiving, document processing and circulation of processed document through all j-positions,
$tm_{i,j}$ - time of stoppage of i-position document at j-position of work place (time during which we do not work with particular documents).
At optimization the time of total cycle of documents transmission must be minimal. Matrix can be created in a form of a Table 3.

transport matrix		work place seq. number					
		P_1	P_2	P_3	...	Pn	SUM
document seq. number	D_1	$tm_{1,1}$ $t_{1,1}$	$tm_{1,2}$ $t_{1,2}$	$tm_{1,3}$ $t_{1,3}$	... ...	$tm_{1,n}$ $t_{1,n}$	TD_1 0
	D_2	$tm_{2,1}$ $t_{2,1}$	$tm_{2,2}$ $t_{2,2}$	$tm_{2,3}$ $t_{2,3}$	... ...	$tm_{2,n}$ $t_{2,n}$	TD_2 0
	D_3	$tm_{3,1}$ $t_{3,1}$	$tm_{3,2}$ $t_{3,2}$	$tm_{3,3}$ $t_{3,3}$	... ...	$tm_{3,n}$ $t_{3,n}$	TD_3 0
	...	...	...	...		...	
	Dn	$tm_{s,1}$ $t_{s,1}$	$tm_{s,2}$ $t_{s,2}$	$tm_{s,3}$ $t_{s,3}$	... ...	$tm_{s,n}$ $t_{s,n}$	TDs 0
	SUM	TP_1	TP_2	TP_3		TPn	ΣTcD = ΣTcP
		0	0	0	0	0	

Table 3. Matrix of transport model

The matrix of transport model allows researching times of individual documents processing $t_{s,n}$ times of stoppages of individual documents $tm_{s,n}$ time necessary to process individual documents at particular work places TDs and time which work places need to process individual documents TPn.
It is important to find such values of TDs and TPn, so that the sum of their times is minimum. Mathematic record of traced equality:

$$\sum TcD = \sum TcP \tag{6}$$

expresses that total sum of times of individual documents at individual work places must be equal to total sum of times work places need to process individual documents. Through minimization of times of total transmission of documents - times of technological processing and stoppages of documents are optimized and we get a tool to model documents movement and analysis of corresponding processes. Through analysis of times provided in individual lines and columns we get a tool for shortages elimination in corresponding processes and it enables to find out narrow places in a company structure. It improves not only management of existing documents movement but also makes managements of processes and activities connected with management of relations in the company more transparent – since this is often the main problem in most companies.

From the point of view of optimization of information flows in companies we have a high quality mathematic apparatus which may be utilized for management of processes connected with creation and processing of company internal documentation or management of distribution of expert, special and project documentation, the delivery of which by e.g. electronic post may bring problems due to a huge capacity of data (e-mails boxes are overload).

7. Assessment of possibilities of individual models of communication network management

Searching and setting of centralities in the social network gives more possibilities to manage the network, supports data management, etc. It is executed by implementation of social network analysis. Social network in enterprises has unique properties and due to them it is a socio-technical system that is created by people with their specific characters but not only by exploitation of technical components and other communication tools.

Separation of weaknesses and some limitations of managed network provide better utilization of communication network in business processes, in negotiations or in decision - making processes. It is possible to eliminate treatments of network nodes that may evoke some failures by more important dealings or statements. Setting of their centralities may eliminate constraints and threats which may occur by using such network to predict partner behaviour and identify new business opportunities mostly when doing business on foreign markets. Definitely, they need enough proper information about possible ways and available support when they carry out business activities with their partners.

8. Conclusion

Applications of such theory in different ways described in this paper provide variable tools to analyse various networks. We presented an extension of graph-analysis methodology combined with correlation matrix analysis which simplifies relationships management in the enterprise communication network. The correlation matrix modelling is described by a functional analysis which includes the graph-analysis of our network. The computing of centralities offers a precise tool to determine centralities of such network. In this way, the discontinuity or darkness points can be eliminated. In the tests of the method in a simple system we assigned the advantages of such analysis that helps us to determinate seclusions, menaces as well as opportunities of analysed enterprise system occurred in such business segment. If we optimise a network by using such tools we can precisely analyse also the network which seemed to be complicated at the first side. It is due to necessity of the top subject matter experts – SME – they must search information, use both direct and indirect links – hierarchical as well as informal communication paths. Therefore SME can apply the above described network measure metrics of centralities as well as distance centralities. According to them they can better decide about the size of investment which company needs to improve its management through higher quality communication processes. It is especially necessary for SME due to incorrect leverage that could weaken or even end all their business activities.

Proposed models of net structure management, from the points of view of determination of importance of work positions through a method of social networks and analysis of communication processes and periods of their duration through a matrix of transport model bring benefits for the company because information strategy conforms to the requirements of company management and its activities. The advantage of the models we propose is that they are suitable for management of complicated social–economic system of any company at different levels of management, while at the same time they eliminate as much as possible the influence of human factor. They also allow analysis of its interactivity with other systems and when the map of processes is created negative impacts resulting from superior positions of some employees are not considered. The system also allows management of a system of rapid changes - especially thank to transparency and specification of processes, and brings the possibility to model various situations and possibility of what-if analysis and its impact on total operation in a company, etc. The above mentioned models make possible to analyse complicated internal relations in a company and it is possible to detect often hidden characteristics of network nodes and operations carried out with them – which may positively or negatively influence the way of doing business and total success of a company on the market. A company obtains a tool through which it can get a view concerning situation in the company and make strategically important decisions, i.e. strategically manage development in a particular company. Based on it - it is possible to eliminate narrow places in company work organization, while if all necessary measures are carried out we get a tool which changes strategy of company’s management and it is based on a principle of IT utilization – as a part of information strategy of the company. What is not good? It is situation when managers as well as employees do not want to cooperate by preparing of such communication and information processes analysis. In the next we will pay attention to better specification of all processes occurred in enterprise communication and information network to do such analysis more exactly, then that needs to be defined as well.

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10. References

Balog, M. & Straka, M. (2005). *Logistické informačné systémy*. Epos, ISBN 80-8057-660-2, Košice

Brandes, U. & Wagner, D. (2007). *Visone - Analysis and Visualization of Social Networks.* [online], [cit. 2007-12-01] http://i11www.iti.uni-karlsruhe.de/algo/people/dwagner/papers/bw-vavsn-03.pdf

Freeman, L. C. (1979). Centrality in Social Networks: Conceptual Clarification, *Social Networks*, Vol. 1, No. 3., (1979), pp. 215-239, ISSN 0378-8733

Chung, K. ; Hossain, L. & Davis, J. (2007). *Exploring Sociocentric and Egocentric Approaches for Social Network Analysis.* [online], [cit. 2007-06-10]. http://www.cs.usyd.edu.au

Lohnert, M. *Unified communications.* (2008). [online], [cit. 2008-03-20] www.efocus.sk/images/ archiv/file_1077_23.pdf

Pettey, CH. (2009). Gartner Identifies the Top 10 Strategic Technologies for 2010. [online], [cit. 2009-11-12] http://www.gartner.com/it/page.jsp?id=1210613

Pomffyová, M. (2008). Možnosti diagnostiky tokov informácií v podniku. *Proceedings of IV. international scientific conference "Diagnostika podniku, controlling a logistika"in Žilina.* ISBN 978-80-8070-819-1, April, 2008, ŽU, Žilina

Richards, D. A. (2006). *What Is Social Network Analysis?* [online], [cit. 2007-07-29] http://www.analytictech.com /networks/whatis.htm

Singh, S. (2007). Social Networks and Group Formation. *Theoretical Concepts to Leverage* [online],[cit. 2007-09-06]. http://www.boxesandarrows.com/view/social-networks

Wasserman, S. & Faust, K. (1994). *Social Network Analysis*. Cambridge University Press, ISBN 0521 38707 8, Cambridge

10

Virtual Work Group Collaboration in a Manufacturing Process

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1. Introduction

People work together, and groups make most of the complex decisions in organizations. Managers and staff continuously make decisions, design and manufacture products, develop policies and strategies, design software and so on. Even in hierarchical organizations, decision making is usually a shared process. A group may be involved in a decision or in a decision related task. However, work group may have both potential benefits (process gains) and potential drawbacks (process losses). When people work in teams, especially when members are in different locations and may be working at different times, they need to communicate and collaborate and access a diverse set of information sources in multiple formats. Thus, supporting work group emphasizes the important aspects of communications, computer technologies and work methodologies. Other reasons for support are cost savings, expedited decision speed, the need to support virtual teams, the need for external experts, and improving the decision making process. Almost all organizations, small and large, are using some computer-based communication and collaboration methods and tools to support people working in teams or groups (Turban et al., 2007). Moreover, the importance for businesses have been increased in such level, that collaboration technology (CT) has been hailed as the hallmark of an empowering organization, as it goes beyond the scope of traditional e-mail systems to allow people to collaborate electronically, fostering creativity, and teamwork in the process (Regan & O'Connor, 2002).
Working with teams and groups it is a complicated process, even for the clear advantages that can be obtained, there is a great chance for process losses. Therefore, a multidisciplinary approach is usually required for the multiple and diverse aspects that have to be considered for a successful implantation of the appropriate technologies, where some of these aspects are related to personal behaviour and work styles, group's functionality and dynamics, organizational culture and learning, knowledge sharing and conversion, technical skills and expertise (Wallace, 1997; Nakayama & D´ávila, 2003; Samarah et al., 2007). Since CT belongs and represents a paradigm shift for computer science, one in which human-human rather than human-machine communication, coordination, and problem solving are emphasized (Baecker, 1993). Then, it is important to realize how this technology can enable and improve the group work performance through a successful selection and implementation of the right

infrastructure, allowing an effective technology appropriation and user acceptance (Youngjin, 2003). In this context, virtual teams require the use of information technology (IT) to exist, little is known about how the technology can be configured to optimize work group performance (Hacker & Kleiner, 1996).
Although some of these aspects and concerns have been discussed before, in previous research works, more and diverse cases are need to support, design and establish a framework for best practices and lessons learned, that if the case, serve as a baseline to look for models, explore and develop standards based in a common standard-based foundation (Tomek, 2003), that in consequence will address common efforts of researches, developers, and practitioners dedicated to all different and diverse aspects of collaboration.
In this chapter, discussion and topics of virtual work group collaboration are explored within a real and practical case of a selection and implementation of an integrated web-based IT infrastructure for a manufacturing process.

2. Virtual work group collaboration

2.1 Work group collaboration

Just as societies are collections of individuals, collaborative computing is the collection of existing and new hardware and software that enables people to communicate, share information, and work together. Collaboration can happen no matter where people are physically located and no matter whether they interact in real time or asynchronously (Woodcock, 1997).
The web supports intra- and inter-organizational collaborative decision making through collaboration tools and access to data, information, and knowledge from inside and outside the organization. Groupware tools can support decision making directly or indirectly, and they provides a mechanism for team members to share opinions, data, information, knowledge, and other resources. Different computing technologies support groupwork in different ways, depending on the purpose of the group, the task, and the time/place category in which the work occurs (Turban et al., 2007).
Groupware tools go by a variety of names, including group support systems (GSSs), group decision support systems (GDSSs), computer support for collaborative work (CSCW), electronic meeting systems (EMSs), collaborative systems, or simply teamware. Groupware products can be organized by their complexity and the length of the time they have been in the market. Level 1, groupware products support communications. Level 2, systems include software tools with statistical features designed to help groups solve complex, unstructured, problems. Level 3, systems in various stages of development, are behind the scenes software agents that can operate to keep projects on track as a virtual team member or serve to facilitate information gathering needs of group members (Regan & O'Connor, 2002).
The effectiveness of a collaborative technology depends on the location of the group members and on the time that shared information is sent and received. DeSantics and Gallupe (1987) proposed a framework for classifying IT communication support technologies. In this framework, communication is divided into four cells that are organized along the two dimensions time and place. Groups, groupwork and teamwork in organizations are proliferating. Consequently, groupware continues to evolve to support effective groupwork, mostly for communication and collaboration. Modern web-based ITs provide an inexpensive, fast, capable, and reliable means for supporting communications. But computers cannot support all communication areas. Networked computer systems, such

as the Internet, intranets, extranets, and proprietary private networks, are the enabling platforms that support communication (Turban et al., 2007).

2.2 Virtual collaboration

The leadership traits and skills needed with virtual teams are not different from those used with collocated teams (Siakas et al., 2005). The difference is in the way they are exerted to create the desired results. Collaboration has three facets (Balstrup, 2004), namely:

- Collaboration within each collocated group
- Collaboration between dispersed group of the virtual team
- Collaboration between the groups and the leader

A potential conflict arises when the team consists of members from different organizational units, because the team does not know where to place its loyalty. In virtual environment this is amplified, because informal communication is reduced (members seldom meet face-to-face). Lewis (2006) stated that Language is a poor communication tool unless each word or phrase is seen in its original cultural context. Therefore, a successful leader of a virtual team must excel in applying the right choice of communication means along with a profound knowledge of the effect of applying it (Siakas et al., 2005).

Teamwork is in essence a result of human interaction, but, in an environment where organizations formulate strategies for becoming global, working in a common place becomes less common. Two important factors for supporting collaboration are loyalty and commitment. The individuals of the virtual team and the leader must build a cohesive team committed to the common goal and through interdependent interaction generate group identity and create the feeling of belonging to the "we" group (Balstrup, 2004). Creation of cohesion is fragile and requires effective interpersonal leadership. The cultural dimension divides the teams into culturally homogeneous and heterogeneous teams. Culture is the most difficult to assess as it embraces facets like language, tradition, values, core beliefs, humor and many more. The virtual leader must posses a profound understanding of the cultural differences within the team (Siakas et al., 2005).

2.3 Virtual teams

Today, technology, speed, globalization, and complexity are rearranging the root premise of work design. Two things happen: Distance and time become problems to solve, and organizational issues develop within rigid hierarchy-bureaucracies. To deal with the demands of competition that force cross-boundary work, organizations create virtual teams. A virtual team is a group of people who work interdependently with a shared purpose across space, time, and organization boundaries using technology. Electronic media together with computers enable the creation of new kinds of spaces. They are real to the groups that inhabit them, yet are not the same as physical locations. However, successful collaborative work requires 90 percent people and 10 percent technology. What works can be boiled down to one word: trust. Technology and resources alone do not enable success; people do. Relationships—technological and human—drive the reorganization of work. Four words capture the essence of virtual teams: people, purpose, links, and time. We are learning new, more horizontally connected, participatory ways of achieving higher levels of small-group performance. We are rediscovering ancient small-group, face-to-face knowledge. At the same time, we're inventing some brand-new skills for the geographically diffuse groups of

the future. Teams with trust converge more easily, organize their work more quickly, and manage themselves better. Trust builds with the recognition of the contribution that everyone makes. This "matter of faith" comes from past experience, however brief or extensive. The importance of trust cuts across a team's life cycle (Lipnack & Stamps, 2000).
A virtual team is first at all a team, they see each other like a team more than anything else, and it is characterized by interdependence, shared values, and common goals. Additionally, it is characterized by members who are geographically separated from one another, who communicate mostly through electronic means, and whose boundaries maybe stretched by the inclusion of core and peripheral members, members from multiple departments, and smaller teams subsumed by larger teams (Nemiro, 2004).
Duarte and Snyder (2006) refer about the factors for virtual teams that affect the probability of their success:

- Human resource policies
- Training and on-the-job education and development
- Standard organizational and team processes
- Use of electronic collaboration and communication technology
- Organizational culture
- Leadership support of virtual teams
- Team leader and team member competencies

In addition, they mention that there are different kinds of virtual teams as described:

- Networked teams
- Parallel teams
- Project or product development teams
- Work, functional, or production teams
- Service teams
- Management teams
- Action teams

Nakayama and D´ávila (2003) explain the advantages, benefits, and needs of virtual teams: As for the advantages of virtual teams, we verified that they comprehend both employees and employers. Employees are benefited because they save time that was once spent going to other company units to take part of meetings, and thus they have more time to dedicate to work. Projects can be developed using communication technologies extremely agile and fast, such as e-mail and videoconference. Participants of virtual teams may have in a videoconference the same level of understanding they have in a traditional meeting, besides receiving the information at the same moment. Besides, there is the possibility that members of these teams count on the participation of people from anywhere in the world, or from the company. The organization may also benefit from this practice reducing costs on physical spaces, travel expenditures and other operational expenses. However, the organization must be prepared to implement and maintain the technology necessary for the teams work. It is also necessary that the company provides training and all the support in what concerns communication and collaborative technologies. Employees need to have discipline and work in differentiated times, they need to know available tools and must be aware of the difficulties the lack of physical contact may bring: possible communication noises, lack of motivation or even of confidence (Nakayama & D´ávila, 2003).

2.4 Collaborative work systems

Collaborative work systems (CWSs) are those in which conscious efforts have been made to create strategies, policies, and structures as well as to institutionalize values, behaviors, and practices that promote cooperation among different parties in the organization in order to achieve desired business outcomes. While many organizations vocalize support for teamwork and collaboration, CWSs are distinguished by intentional efforts to embed the organization with work processes and cultural mechanisms that enable and reinforce collaboration. New forms of organization continue to emerge with CWSs as an essential facet. Team-based organizations and self-managing organizations represent types of collaborative systems. The computer revolution has made possible network, cellular and spherical forms of organizing, which represent more trans-organizational forms of collaboration. CWSs provide one of the key competency areas that organizations can focus on for building vitality and excellence, including competitive and collaborative advantage (Beyerlein et al., 2004).

Some forms of CWSs are listed below (Beyerlein & Harris, 2004):

Group Level

- Team. A group of people who have interdependent tasks and shared purpose and who are held mutually accountable for shared goals.
- Community of practice. An informal group or network of people who have shared interests, stories, and common language, but are not necessarily held mutually accountable.

Organizational Level

- Team-based organization. Teams are the unit of work, managers are in teams, and the organization is designed to support teams.
- Collaborative organization. Both formal and informal collaboration is supported, teams are used where need, and the organization is designed to support collaboration.

Some reasons for focusing in CWSs are listed below (Beyerlein & Harris, 2004):

- To increase a competitive advantage
- To create a context for team success
- To promote lateral integration and alignment
- To better connect to your environment
- To increase flexibility

The optimal CWS occurs when group members are provided access to information, knowledge and resources that allow them to participate to the design of unit-level methods for accomplishing the work and the construction of environmental support systems and enabling arrangements. The quality of the participation depends on the ability of group members to establish relationships with other individuals and groups so that decision making (formal authorization, empowerment) and accountability (structure) are clearly communicated and mutually understood within the context of support systems and enabling structures (Beyerlein & Harris, 2004).

3. Practical selection and implementation

3.1 Work process

In the manufacturing process of the company where the study was conducted, when a product requires a replacement part, a swapping sub-process is then followed, where different teams or groups of different areas conform a virtual work group (for this particular sub-process), they participate actively in order to obtain the required part in time, following the required processes, fulfilling and even over-passing the objectives established. This is a key and sensitive sub-process, due the product will be on hold until a good part is obtained, replaced, tested and only then, it can returned to the manufacturing process again. The cost for having a product in this condition is high in several and different manners, like storing, waiting, transportation, moving/storing materials/paper-work, that according to the Lean 6-Sigma initiative (George et al., 2005), those are waste in the process and have non-value add (NVA) to customers. In addition, the materials' handling increases the possibility of damage in the product, and also impacts the cost. Thus, the different teams that participate require to be focused and have an effective communication and collaboration mechanism.

This is the main reason why we decided to built a system that supports this virtual work group and established the following research question: How an integrated and web-based IT infrastructure conformed by dashboards, workflow and a part's tracking system, can provide of a mechanism for an effective communication and collaboration for a virtual work group in a manufacturing process?. Other objectives for this initiative and project are: improve the compromise and responsibility between participants, and collect historic information to perform further analysis.

3.2 Issue description

Before the prototype was used, the sub-process followed, mainly used the e-mail as a groupware tool, where in every shift (almost at the end), it was prepared a report with the summary of parts pending for replacement, and then it was sent to all teams involved. At the beginning of the following shift, a revision was conducted in order to know which parts will be available during the shift or still will be waiting for a further period of time. However, if a product (that it was waiting for parts), is considered critical or in a high priority, then the communication by e-mail was increased and this also increased the possibility of errors and mistakes, miscommunication, and then process losses. In fact, when there was a high demand of parts, it could happen that the participants look for other communication channels like phone calls, instant messaging (IM), and others, in order to fulfill quickly their needs, where sometimes not all participants and teams were informed or included in the agreements. In addition, this process has implicit many considerations like cycle-time consumption, performance losses, lack of real-time information, workload, lacks of level of detail, less reliable information, deficient historic data for quality analysis as others. All aspects mentioned before, for this particular sub-process.

3.3 Selection of the integrated IT infrastructure

We collected information from all participants of the four different teams, in order to have the best approach of their needs, followed the selection process described below, and built a minimal system in order to put as soon as possible a prototype in production to see if the benefits of the technology after six months of being used, could fulfill the work group needs, the objectives of the process, and the interest of the company. Therefore, the intention of this study is to describe in detail how those objectives could be met successfully.

The mission statement and concept generation, user needs and requirements were followed according to the models and suggested practices presented in the work, Product Design and Development (Ulrich & Eppinger, 2004), and additional references like: IEEE Recommended Practice for Software Requirements and Specifications (IEEE Std. 830-1998), IEEE Guide for

Developing System Requirements Specifications (IEEE Std. 1233-1998), and IEEE Recommended Practice for Software Design Descriptions (IEEE Std. 1016- 1998).
The customization of the selection process includes the following steps: mission statement, gathering information from users, interpret information in terms of user needs, concept generation, establishing requirements, evaluation and selection of the collaborative tools. We adapted and followed up this six step process where allowed us to be focused and keep consistency, where we could have the requirements as objectives for this project that finally, give us the direction for the evaluation and selection of the integrated IT infrastructure.

3.3.1 Mission statement

The mission statement presented below (Table 1), summarizes the direction followed by the project team, and includes some of all of the following information: the product vision or brief description of the product, key business goals, target market for the product, assumptions and constrains, that guides the development effort from the stakeholders. The mission statement belongs more to the product planning phases, but is presented here as a base and initial phase for the selection process.

Mission Statement: Selection and Implementation of an Integrated Web-based IT Infrastructure for a virtual work group collaboration in a manufacturing process.	
Product Description	Integrated and web-based collaborative IT infrastructure using dashboard's functionality (cycle time, aging, and product inventory's levels on hold), with workflow management, and parts' tracking operations.
Key Business Goals	Provide an effective communication and collaboration. Improve the compromise and responsibility between participants. Collect historic information to perform further analysis.
Primary Market	Current manufacturing process for the company of this study.
Secondary Markets	Free open source worldwide community.
Assumptions and Constraints	The system will be accessed by a web browser where in same window the user will interact with all different functionalities required to follow up tasks and parts during the process. Have coordination between participants of the different groups. Execute all steps of the replacement process. And monitor the levels of the Key Process Indicators (KPIs).
Stakeholders/Teams	Warehouse. Test. Quality. Material's planning.

Table 1. Mission statement

3.3.2 Gathering information from users

The gathering information was performed having contact with users and participants through interviews, brainstorming sessions, and observing the areas where the system will be used. Also, the project team belongs to those areas, and this help to understand and identify better the different teams' needs.

3.3.3 Interpret information in terms of user needs

The information is organized regarding to the participant's comments and user's feedbacks, then the information is interpreted in terms of user needs. In this sense, user needs are expressed as written statements and are the result of interpreting the need underlying the raw data gathered from the users.

3.3.4 Concept generation

A product concept is an approximate description of the technology, working principles, and form of the product. It is a concise description of how the product will satisfy the customer needs. The degree, to which a product satisfies customers and can be successfully commercialized, depends to a large measure on the quality of the underlying concept. Good concept generation leaves the team with confidence that the full space of alternatives has been explored (Ulrich & Eppinger, 2004). For the concept generation of this project, it was developed four steps fully explored, that are described as follows: mission statement (as input), technological review, market (business unit) analysis, and generating the concept (in an iterative and spiral approach).

3.3.5 Establishing requirements

Establishing requirements takes an additional importance and is substantially more challenging when developing a high complex product, consisting of multiple subsystems designed by multiple development teams. In such context, specifications are used to define the development objectives of each of the subsystems, as well as the product as a whole (Ulrich & Eppinger, 2004). This step allowed us reflecting user needs and concept generation in terms of product requirements.

3.3.6 Evaluation and selection of the collaborative tools

Evaluating the collaborative tools depends on many factors (Brown et al., 2007), where previous research works have been discussed the need to consider all different aspects that impacts the virtual teams performance (Hacker & Kleiner 1996; Wallace 1997; Nakayama & D´ávila, 2003). For our case and due the nature characteristics and needs of the virtual teams, the manufacturing process itself, the project's objectives, the current capabilities, and the intention to measure all steps in the process in order to look for the continuous process improvement. The workflow, dashboards, and parts' tracking system, were the most appropriate tools to use and integrated in the infrastructure.

3.4 Virtual work group characteristics

The virtual work group of this study is conformed by four different teams or areas as: test, warehouse, quality, material's planning. All teams work for same company but are located at different places and all of them never get together through the process at once. In this sense, some of these different and diverse participants integrated in those different teams;

work at different locations into the company. In addition, there are three different production shifts and one administrative shift, where the process flows and participants communicate and collaborate together as a virtual work group. Therefore and according to the time/place communication framework (Turban et al., 2007), the technology proposed is featured as different time/place. Another classification for this virtual team is for its kind, where and according to Duarte and Snyder (2006), this virtual work team can be considered as for work, functional, or production team.

3.5 Methodology

For the software development process, we decided to follow a composite model from two different approaches. The iterative life cycle model that has become a standard in the software industry lead by Rational Unified Process (RUP), where on behalf the waterfall process, the iterative approach is superior providing a mature, rigorous, and flexible software engineering process (Kruchten, 2000). On the other hand, the requirements prototyping model aims to build a partial implementation of a the system, where the main focus is to express purpose of learning about the system's requirements and capture what was learned when working with the prototype and then use it in documenting the actual requirements' specifications for the real system development (Thayer, 2000). Both models allowed us to construct a prototype in few weeks (four weeks in total).

3.6 Architecture

The diagram presented in the fig. 1, describes the system's architecture with all of its subsystems included. The Web Access to Views/Tabs of System represents the main access' channel; this access can be performed using any Internet browser. In addition, with the back-end application that runs the system. Users and groups' participants defined by category and profile are the users that are only able to access. The Web Services' module makes available the system through the web. The Coordinator Module is the system's core where organizes all in-out operations in an overall perspective. The Management and Security module controls every operation within a security scope, and also manages and coordinates the different collaborative modules/subsystems of the infrastructure. The

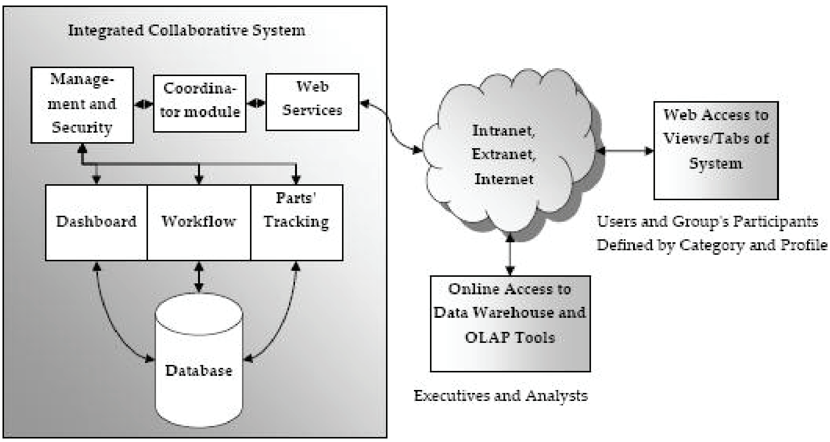

Fig. 1. Architecture. Adapted from González-Trujillo, 2009

Dashboard, Workflow, and Part's Tracking are the integrated collaborative subsystems. The Database is a common repository of all records that are being uploaded to the system. The Online Access to Data Warehouse (DWH) and OLAP Tools module is a complementary subsystem that performs information retrieval (IR), historic analysis, and knowledge discovery for Executives and Analysis usually, but not restrictively.

3.7 Data acquisition and data analysis

In order to retrieve, collect and manage with a proper mechanism the system's data recorded and historic information (around 2,946 records in the table of parts, and 11,474 records in the table of changes), during the period where the prototype was used (six months from March to August of 2008), we built a data-mart (fig. 2), following a multidimensional database model and star-like schema design, where using a DWH and OLAP technology allowed us to acquire all information using pivot tables as visual tool for the Knowledge Discovery Process (fig. 3). This subsystem is considered a complement of the system's proposed.

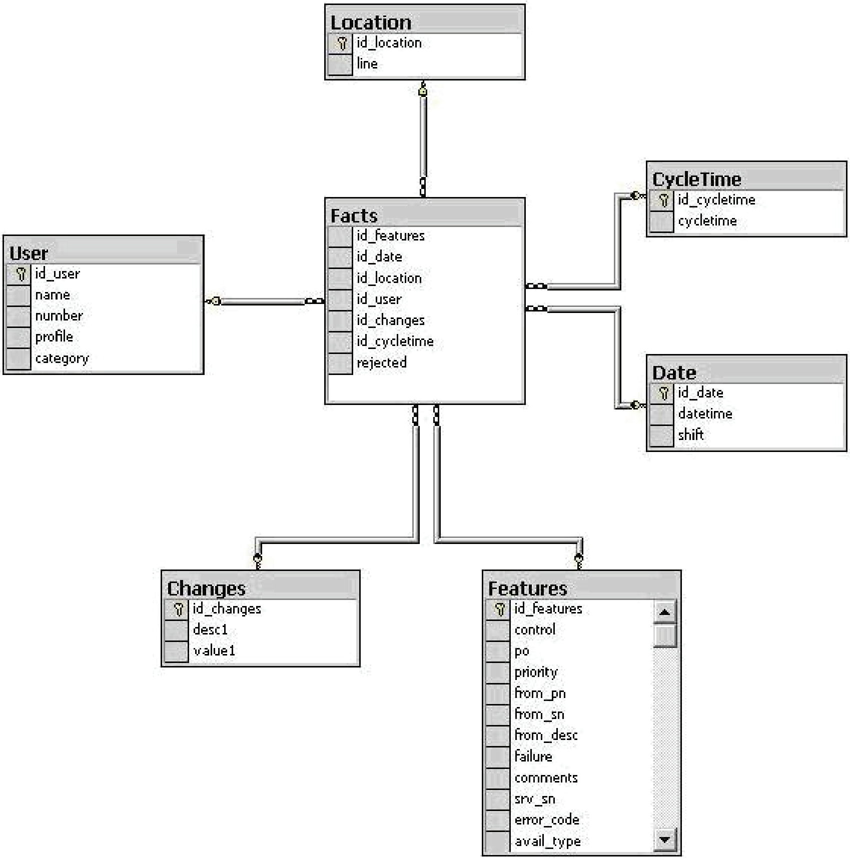

Fig. 2. Data-mart, multidimensional database model, star-like schema design

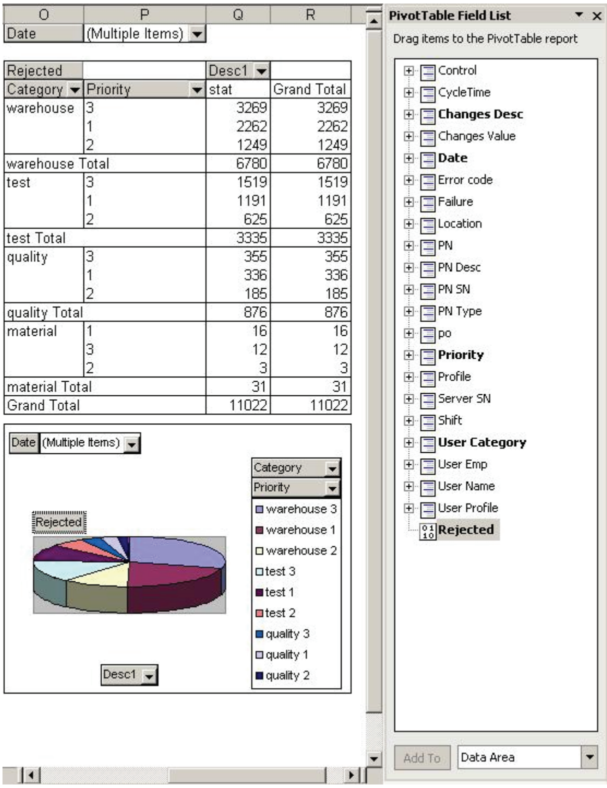

Fig. 3. Pivot table for the Knowledge Discovery Process

Additional comments and suggestions from participant's experience were collected conducting a survey by a questionnaire with open-ended questions, where 22 virtual team members participated from 27 users that worked with the prototype during the six moths of period for this study, representing 81.5 % of total.

3.8 Functionality and operation

The system has different tabs for the same window in the Web browser that constituted all the dashboards required. The first of them is the control panel, followed by the priority, after the detailed tasks' list, and the tasks' capture. Every user in the system is being configured and must be part of a category and profile. Each user's category can participate and work with one or more state changes in the workflow process and which is showed in control panel. Each user's profile represents an administration level in the system, where users of read-only level, can login but not change the process' states, the users of basic level, can change the state and the tasks' features, meanwhile users with admin level, can do all before but add new users. Finally, the user of higher level (root user) also can do all before but add new admin users.

Each task has a state and a group of features (fig. 4). The state' indicators can be configured with different colors or can use a neutral color, and also can select a particular figure for a better identification. When a state is changed by user, the system requests an acknowledgement for security and process' control purposes, and only is accepted if the user belongs to the category and profile required by this particular state that was previously configured. In a sense that users for a category and profile specified are able to change only this state and others with the same characteristics per configuration at the workflow. The same behavior occurs for every feature of each specific task.

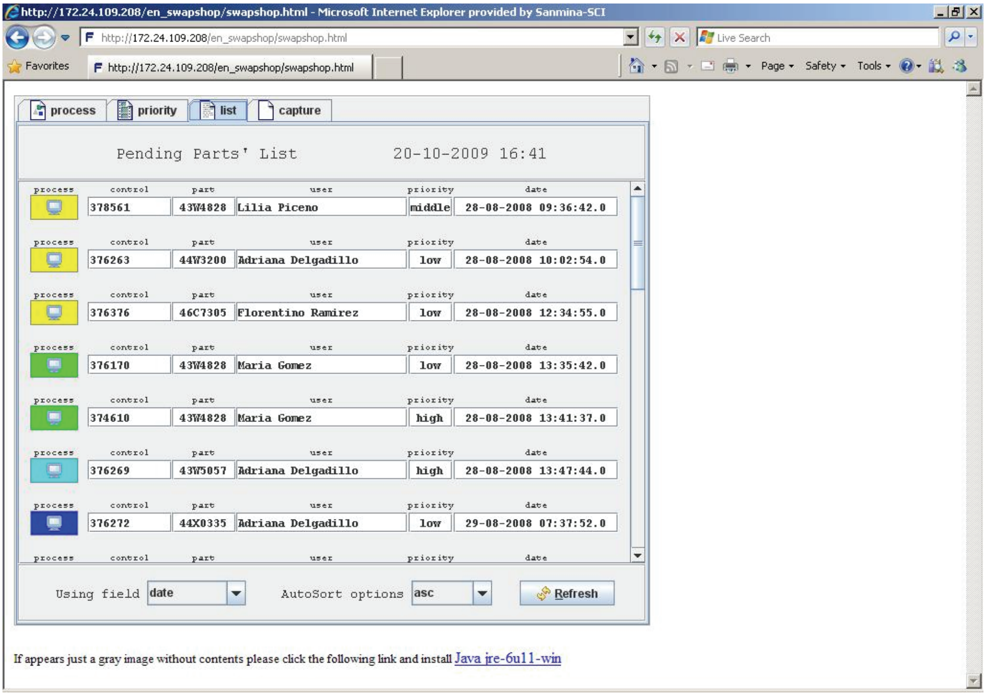

Fig. 4. States of tasks with key features

When a task has concluded the overall process at the workflow, the last operation that is being executed changes the state to historic mode, then the task disappears immediately from all views in the system, giving the impression of not longer exist, but still being available to be acquired through an IR process, with the intention to perform further analysis.

In order to capture the hidden needs and specific knowledge about tasks and parts, we included a box for comments as an additional feature for every task, where users (if they require), can add any comment or extra information required to follow up a particular task through the workflow process. With this, we expect to acquire some knowledge about additional features required for tasks and parts that need to be included but are not in the prototype or in the current production version of the system, even some specific knowledge like detractors, errors and issues found during the process, and being identified by users. After, these comments can be retrieved by other system's mechanisms like IR, for a further support and exchange between participants as knowledge sharing.

4. Findings

4.1 Collaboration results

For this exploratory study, the test team has the most quantity of participants with 74.07%, quality with 14.81%, warehouse 7.40%, and materials' planning with 3.70%. However, the most active collaboration is for the warehouse team with 61.83 %, test with 30.54 %, quality with 7.35 % and material's planning with 0.26 %. This access and collaboration's level is expected due the process' workflow. In this sense, while most changes are performed by warehouse with 50 %, test 25 %, while quality has lesser participation with 12.5 %, and. materials' planning has a maximum of 12.5%, because its collaboration is required just in some cases, therefore is not mandatory (Table 2).

Virtual Work Groups	Collaboration Required	Collaboration Registered	Collaboration Percentage	Partici -pants	Participants Percentage
Warehouse	50 %	6,780	61.51 %	2	7.40 %
Test	25 %	3,335	30.26 %	20	74.07 %
Quality	12.5 %	876	7.95 %	4	14.81 %
Material's Planning	0-12.5 %	31	0.28 %	1	3.70 %

Table 2. Analysis about collaboration

4.2 Communication results

We collected hidden needs and specific knowledge about tasks and parts from the box of comments located in each task, where users could add comments and extra information as knowledge required to follow up the tasks and parts through the process. During the six months of period where the prototype was used, the system registered 440 comments from the different tasks and found that those comments are related with: substitute parts, parts' inventory, part's availability, information sharing, messaging, process related, and blank (Table 3).

Additional comments and suggestions about other benefits from participant's experience were collected conducting a survey by a questionnaire with open-ended questions, where diverse users perceived a cycle time's optimization, system's use simplicity, process' optimization, operation's improvement, better control of tasks and parts, workload's reduction, and acquiring information about operator's performance. We could also have other measurements like cycle time and product inventory's levels on hold, which never before could be collected and analyzed with these levels of detail.

Category	Quantity	Percentage
Substitutes	184	41.82 %
Blank	120	27.27 %
Availability	54	12.27 %
Information	40	9.09 %
Messaging	29	6.59 %
Process	8	1.82 %
Inventory	5	1.14 %

Table 3. Analysis about communication

5. Discussion

Previous research works refer to provide flexible integration of tools for the purpose of business process and workflow process definition (Nagypal et al., 2001). In addition, with integrating individual synchronous tools such as multi-user editors and virtual whiteboards, into a process executed in a workflow management system (Ben-Shaul & Kaiser, 1996). Other works also referred the integration of same technologies like the scalable middleware framework, which can support high-degree decoupling between workflow and groupware (Shaokun, et al., 2008). Our main interest and proposal is focused and dedicated more in the integration of Business Intelligence (BI) using dashboard's functionality (cycle time, aging, and product inventory's levels on hold), with workflow management, and parts' tracking system's operations in a web-based IT infrastructure, to provide of a mechanism for an effective communication and collaboration for a virtual work group in a manufacturing process. The inclusion of dashboard functionality not just allows monitoring the levels of the KPIs in order to keep process' control but for contain in a faster manner issues and within using historical information, optimize the process through analyzing and detecting bottlenecks and repeated patterns of problems that may arise. In addition, it can move forward to keep updating the system with hidden user needs obtained also from the system, and issues found within the information collected, that allows improving the overall system and process together in a continuous process improvement cycle.

A study that has been performed to analyze the current status of cooperative applications in Latin American corporations (where the company of this study is geographically located) referred that e-mail and shared data access are ranked 1/16 and 2/16 respectively, and use both by 96% of the organizations that possess some groupware tool. Meanwhile, collaborative tools are being ranked 9/16 and being use by less than 30 % of the organizations surveyed (Alanis & Diaz-Padilla, 2002). In this same study, the average operative time has been 5 years in tools like electronic mail and information exchange utilities, while the average for collaborative tools have been 3 years. The training time of electronic mail is little more than 1.6 weeks and collaborative tools are little more than 1.2 weeks of training (Alanis & Diaz-Padilla, 2002). Since the gap in both results (especially in popularity and years of use) are for consideration, it gives an idea of what it represents in regarding to the learning curve, knowledge and, experience for this initiative to shift from electronic mail to collaborative tools as proposed, and the insights obtained from this study.

By another hand, there has been reported that collaboration in the manufacturing sector is difficult to implement (Barrat, 2004). It requires the parties involved to make adequate preparation including analysis on various aspects to ensure its readiness to be engaged in such demanding relationship (Ismail & Alina, 2008). In this context, this project exposes a practical case that could help (within other related works), to understand better collaboration in the business segment (EMS: electronic manufacturing services) in order to support and establish a common framework for virtual work group and web-based collaboration.

However, this study don't propose a different approach, or a new foundation for virtual team collaboration, but also it contributes performing a quantitative analysis based in historical information collected during the period of use of the prototype implemented, that it was made possible applying DWH and OLAP technologies, that acquired, integrated and transformed the data stored when using the collaboration system in multidimensional data, that allowed to obtain an overall perspective, valuable information and knowledge, described in the results section. Therefore, it provided of a method to analyze information in a deeper and faster manner from collaboration systems that could serve to obtain further insights for this and other research studies.

6. Limitations and conclusions

This is an exploratory study, therefore the conclusions drawn for this study must be considered in this sense. The study explores the selection and implementation of an integrated and web-based IT infrastructure (dashboard, workflow and parts tracking system) that can provide of a mechanism for an effective communication and collaboration for a virtual work group in a manufacturing process.

Principal benefits describe an active collaboration between groups and participants, where groups like warehouse (61.51% registered from 50% required) and test (30.26% registered from 25% required) overpass their collaboration, quality did in a lower level (7.95%) that corresponds to a 63.60% from the expected level (12.5%), and materials' planning was between the range (0.28% registered from 0-12.5% required) due its collaboration is required just in specific cases and is not mandatory for every task. It's important to mention that the most active collaboration corresponds to groups that their participation are required at most in order to fulfill the needs for this process, due the principal objective is to obtain the replacement parts in the right time and place, and these parts are requested by the test's group and acquired and provided by the warehouse's group.

In addition, the system collected hidden needs and specific knowledge about tasks and parts from the box of comments, where we obtained 440 comments, that 120 comments are blank. Then we have 320 effective comments from 934 parts replaced, that it represents 34.26%, in a sense of having one comment per three parts followed and replaced in the workflow process. Also, it's important to establish that these comments are not mandatory for workflow process; the users place them as their response and contribution. However, we analyzed and categorized those comments into seven groups and found 120 records as blank that it represents 27.27%, but most comments are for substitute parts with 41.82%. Therefore, the participant uses the system also as a communication channel to fulfill the needs of process and teams. With this, we expect to update the system with new features and options to allow managing better this information and collect and share the knowledge during the process that could feedback other users and participants for the improvement and optimization of process and operation. Thus, we can establish a continuous improvement and updating cycle for the process and system altogether.

The use of the system allowed following up the tasks since the beginning to the end of the process with full detail for each record, keeping historic data that could be used for further analysis. Additional benefits were also obtained from the use of dashboards, workflow and parts' tracking while using the different modules visually managed by tabs through the integration of the collaborative tools. Some of these benefits are: cycle time's optimization, system's use simplicity, process' optimization, operation's improvement, better control of tasks and parts, workload's reduction, and acquiring information about operator's performance.

A major compromise and responsibility between participants were also noticed from the impressions of participants. Finally, we could capture, see and understand that the system successfully enhanced the group presence while promoting an effective communication and collaboration. Therefore, the benefits from the selection and implementation of the system answer the research question established.

7. Future research and project

Future research works can be addressed for this project and other replicas used for other business units and processes that can provide further insights for groupware evaluations (Pinelle & Gutwin, 2000), and to support, design and establish a framework for best practices and lessons learned, that if the case, serve as a baseline to look for models, explore and develop standards based in a common standard-based foundation (Tomek, 2003), that in consequence will address common efforts of researches developers and practitioners dedicated to all different and diverse aspects of collaboration.
We expect to complete the implementation of the final release of the system where we can include as new requirements, all the feedback and hidden needs coming from participants as part of the analysis, results and conclusions drawn from this study.
On the other hand, the project was already accepted as a free open source project (Gonzalez, 2009) where we are looking to include additional modules with features that allow reconfiguration and customization, and then have a system available for the free open source worldwide community.

8. References

Alanis, M. & Diaz-Padilla, J. (2003). Groupware effectiveness in large Latin American corporations, *Proceedings of the 36th Annual Hawaii International Conference on System Sciences 2003*, pp. 1-10, ISBN: 0-7695-1874-5, Hawaii, Jan. 2003, IEEE Xplore Digital Library, N. J.

Baecker, R. (1993). *Readings in Groupware and Computer-Supported Cooperative Work: Assisting Human-Human Collaboration*, Morgan Kaufmann Publishers Inc., ISBN: 1-55860-241-0, San Francisco, CA

Balstrup, B. (2004). Leading by Detached Involvement – Success factors enabling leadership of virtual teams. MBA Dissertation, Henley Management College, UK

Barrat, M. (2004). Understanding the meaning of collaboration in the supply chain. *Supply Chain Management: An International Journal*, Vol. 9, No. 1, pp.30-42, ISSN: 1359-8546

Ben-Shaul, I.Z. & Kaiser, G.E. (1996). Integrating groupware activities into workflow management systems, *Proceedings of the Seventh Israeli Conference on Computer Systems and Software Engineering 1996*, pp. 140-149, ISBN: 0-8186-7536-5, Herzliya, Jun. 1996, IEEE Xplore Digital Library, N. J.

Beyerlein, M.M.; Beyerlein S.T. & Barker J. (2004). Preface, In: *Guiding the Journey to Collaborative Work Systems: A Strategic Design Workbook*, Pfeiffer, ISBN: 0-7879-6788-2, San Francisco, CA

Beyerlein, M.M. & Harris, C.L. (2004). *Guiding the Journey to Collaborative Work Systems: A Strategic Design Workbook*, Pfeiffer, ISBN: 0-7879-6788-2, San Francisco, CA

Brown, M.K.; Huettner, B. & James-Tanny, C. (2007). Choosing the Right Tools for Your Virtual Team: Evaluating Wikis, Blogs, and Other Collaborative Tools, *IPCC 2007 IEEE International Professional Communication Conference 2007*, pp. 1-4, ISBN: 978-1-4244-1242-6, Seattle, Oct. 2007, IEEE Xplore Digital Library, N. J.

DeSantics, G. & Gallupe, R.B. (1987). A Foundation for the Study of Group Decision Support Systems, Management Science, Vol. 33, No. 5

Duarte, D. L. & Snyder, N. T. (2006). *Mastering Virtual Teams: strategies, tools and Techniques that succeed*, Jossey-Bass Inc., ISBN: 0-7879-8280-6, San Francisco, CA

George, M.L.; Maxey, J.; Rowlands, D.T. & George, M. (2005). *The Lean Six Sigma Pocket Toolbook: A Quick Reference Guide to Nearly 100 Tools for Improving Process Quality, Speed, and Complexity,* McGraw-Hill, ISBN: 0-0714-41190, N.Y.

Gonzalez, J.L. (2009). http://tlamati.sourceforge.net/, Web dashboard issue task tracking system, Jan. 2009, SourceForge.net is owned and operated by Geeknet, Inc., Mountain View, CA

González-Trujillo, J.L. (2009). Diseño y Construcción de un Sistema Colaborativo Integrado Basado en Web, para un Grupo Virtual de Trabajo, en un Proceso de Manufactura Electrónica, *IADIS Ibero- Americana WWW/Internet 2009*, pp. 27- 34, ISBN: 978–972–8924–90-4, Madrid, Oct. 2009, IADIS Press Publishes Conference Proceedings

Hacker, M.E. & Kleiner, B.M. (1996). Identifying critical factors impacting virtual work group performance, *IEMC 96 Proceedings, International Conference on Engineering and Technology Management 1996,* pp. 196-200, ISBN: 0-7803-3552-X, Vancouver, Aug. 1996, IEEE Xplore Digital Library, N. J.

IEEE Std. 830-1998 (1998). IEEE recommended practice for software requirements specifications, Software Engineering Standards Committee of the IEEE Computer Society, ISBN: 0-7381-0332-2, Oct. 1998, USA

IEEE Std. 1016- 1998 (1998). IEEE recommended practice for software design descriptions, Software Engineering Standards Committee of the IEEE Computer Society, ISBN: 0-7381-1455-3, Dec. 1998, USA

IEEE Std. 1233-1998 (1998). IEEE guide for developing system requirements specifications, Software Engineering Standards Committee of the IEEE Computer Society, ISBN: 0-7381-0337-3, Dec. 1998, USA

Ismail, H.-P.M. & Alina, S. (2008). Understanding collaboration and supply chain process: A critical review, *ICMIT 2008 4th IEEE International Conference on Management of Innovation and Technology 2008*, pp. 1033–1037, ISBN: 978-1-4244-2329-3, Bangkok, Sep. 2008, IEEE Xplore Digital Library, N. J.

Kruchten, P. (2000). *The Rational Unified Process – An Introduction*, Addison-Wesley-Longman, Pearson Education Inc., ISBN: 0-201-70710-1, Boston, MA

Lewis, R.D. (2006). *When cultures collide: leading across cultures*, Nicholas Brealey Publishing, WS Bookwell, ISBN: 1-904838-02-2, Finland

Lipnack, J. & Stamps, J. (2000). *Virtual Teams: People Working Across Boundaries with Technology*, John Wiley & Sons Inc., ISBN: 0-471-38825-4, N. Y.

Nagypal, G.; Fischer, F.; Straub, U.; Weiss, P. & Nikolai, R. (2001). Integrating workflow and groupware functionalities for co-operating small and medium sized enterprises: a case study, *Proceedings Seventh International Workshop on Groupware*, pp. 38-43, ISBN: 0-7695-1351-4, Darmstadt, Sep. 2001, IEEE Xplore Digital Library, N. J.

Nakayama, M.K. & D´ávila, M.M. (2003). Virtual Teams Performance: an Analysis Based on Indicators, *IADIS International Conference e-Society 2003*, pp. 387-391, ISBN: 972-98947-0-1, IADIS Press publishes Conference Proceedings

Nemiro, J.E. (2004). *Creativity in Virtual Teams: Key Components for Success*, Pfeiffer, ISBN: 0-7879-7114-6, San Francisco, CA

Pinelle, D. & Gutwin, C. (2000). A review of groupware evaluations, *(WET ICE 2000) Proceedings IEEE 9th International Workshops on. Enabling Technologies: Infrastructure for Collaborative Enterprises 2000*, pp. 86-91, ISBN: 0-7695-0798-0, Gaithersburg, Jun. 2000, IEEE Xplore Digital Library, N. J.

Regan, E. & O'Connor, B. (2002). *End-User Information Systems: Implementing Individual and Work Group Technologies*, Prentice-Hall, Pearson Education Inc., ISBN: 0-13018-264-8, Upper Saddle River, USA

Samarah, I.; Paul, S. & Tadisina, S. (2007). Collaboration Technology Support for Knowledge Conversion in Virtual Teams: A Theoretical Perspective, HICSS 2007 40th Annual Hawaii International Conference on System Sciences 2007, pp. 1-10, E-ISBN: 0-7695-2755-8, Waikoloa, Jan. 2007, IEEE Xplore Digital Library, N. J.

Shaokun, F.; Daning, H. & Zhao, J.L. (2008). Integrating Workflow and Forum via Event Management, *AMIGE 2008 IEEE Symposium on Advanced Management of Information for Globalized Enterprises 2008*, pp. 1-5, ISBN: 978-1-4244-3694-1, Tianjin, Sep. 2008, IEEE Xplore Digital Library, N. J.

Siakas, K.V.; Balstrup, B.; Georgiadou, E. & Berki, E. (2005). Global Software Development; the Dimension of Culture, IADIS Virtual Multi Conference on Computer Science and Information Systems 2005, pp. 386-391, ISBN: 972-8939-00-0, IADIS Press publishes Conference Proceedings

Thayer, R.H. (2000). *Software Engineering Project Management*, ISBN: 0-8186-8000-8, IEEE Computer Society, Los Alamitos, CA

Tomek, I. (2003). Towards a common foundation for Web-based collaboration, *Proceedings 14th International Workshop on Database and Expert Systems Applications 2003*, pp. 261-265, ISBN: 0-7695-1993-8, Sep. 2003, IEEE Xplore Digital Library, N. J.

Turban, E.; Aronson, J.; E., Liang, T.-P. & Sharda, R. (2007). *Decision Support and Business Intelligence Systems*, Prentice Hall, Pearson Education Inc., ISBN: 0-13-198660-0, Upper Saddle River, N. J.

Ulrich, K.T. & Eppinger, S.D. (2004). *Product Design and Development*, McGraw-Hill/Irwin, ISBN: 0-07-247146-8, N. Y.

Wallace, M. (1997). Groupware: if you build it, they may not come, *IEEE Transactions on Professional Communication*, Vol. 40, No. 1, Mar. 1997, pp. 48-53, ISSN: 0361-1434

Woodcock, J. (1997). *Understanding Groupware in the Enterprise*, Microsoft Press, ISBN: 1-57231-561-X, Redmond, WA

Youngjin, Y. (1998). Predicting groupware usage, *Proceedings of the Thirty-First Hawaii International Conference on System Sciences 1998,* pp. 510-517, ISBN: 0-8186-8255-8, Kohala Coast, Jan. 1998, IEEE Xplore Digital Library, N. J.

11

Integration of BPM Systems

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1. Introduction

New technologies have emerged to support the global economy where for instance suppliers, manufactures and retailers are working together in order to minimise the cost and maximise efficiency. One of the technologies that has become a buzz word for many businesses is business process management or BPM. A business process comprises activities and tasks, the resources required to perform each task, and the business rules linking these activities and tasks. The tasks may be performed by human and/or machine actors. Workflow provides a way of describing the order of execution and the dependent relationships between the constituting activities of short or long running processes. Workflow allows businesses to capture not only the information but also the processes that transform the information - the process asset (Koulopoulos, T. M., 1995). Applications which involve automated, human-centric and collaborative processes across organisations are inherently different from one organisation to another. Even within the same organisation but over time, applications are adapted as ongoing change to the business processes is seen as the norm in today's dynamic business environment. The major difference lies in the specifics of business processes which are changing rapidly in order to match the way in which businesses operate. In this chapter we introduce and discuss Business Process Management (BPM) with a focus on the integration of heterogeneous BPM systems across multiple organisations. We identify the problems and the main challenges not only with regards to technologies but also in the social and cultural context. We also discuss the issues that have arisen in our bid to find the solutions.

2. Background

2.1 The need for integration at different stages

There has been an increasing demand from businesses in different geographical locations to be able set up and share processes such as a number of supplier-chain processes required by many major companies. eLearning and the concept of a virtual university has also become a popular topic for consideration today and it is this example that will be used to explain the need for integration at different stages of BPM. A Networked Virtual University is formed by a number of participating universities of different countries to provide a coherent set of courses. The ideas is that students from all over the world would able to register to study courses. Academics from these universities would need to work together through a shared process such as exam paper setting, coursework marking and so on. One of the main challenges in setting up and managing such processes is to cater for the needs of the individuals in the different organisations involved. One would end up having to use a good array of tools and platforms just to follow a shared business process such as coursework marking initiated by another university. Most of the tools currently available do not recognise the fact that users of different organisations involved in a shared process are often using a different set of tools for modelling, designing and interacting with their processes. For instance, in a Networked Virtual University (NVU), where several universities partner to provide a number of coherent study programmes through a combination of online and traditional means, a unit coordinator of a programme responsible for setting an exam paper would sometimes be required to work with an external examiner for the purpose of quality control. This would require the creation of a cross-domain business process that automatically coordinates the activities carried out by the internal and external parties, monitors the events as activities complete, notifies and/or alerts the interested parties by sending reminders and/or taking escalation actions. Suppose that each institution had a BPM (Business Process Management) system to start with, it is unlikely that they could create and then interact with a system using tools familiar to all parties. If there is a dominant party (i.e. whose business objectives will be satisfied by finishing the process), it's more likely that their BPM system would be used but the other parties will have to adapt to a "foreign" practice, if this is possible, e.g. through a web application interface.

When organisations are working on workflows that cross their organisational boundaries they are likely to need to collaborate at three stages (Fig. 1)

The complexity of each stage is significantly increased by the involvement of multiple participants. The sections below examine each of these stages in more detail.

Stage 1 - Understand and model the workflows

In order to come to a shared understanding of the workflows the participating organisations need to create a model that is understood and agreed by all participants. This will normally involve the use of some diagrammatic modelling notation created using a modelling tool. BPMN is popular as a modelling notation but not every organisation uses it. Some may use simpler generic models such as UML Activity Diagram or alternative BPM modelling notations such as Event-driven process chains (Van der Aalst 1999). Even if all the participants use the same modelling notation they may not use the same modelling tools which gives rise to the need to exchange models between tools.

Stage 2 - Create an executable representation of the workflows for use by a workflow engine

For a workflow model to be automated it needs to be converted into an executable form. Some modelling tools make this very easy whereas with others there is a need to carry out a translation. If the workflows are to be executed in several workflow engines belonging to different participants then there may be the problem of translating the model into several different executable formats suitable for the variety of engines.

Stage 3 - Interact with running workflow instances

When workflows are automated by a workflow engine there is obviously a need for people at the various collaborating organisations to interact with them. This can be the most problematic step. Different organisations may interact with workflows in different ways. For instance one organisation may use a push approach where tasks requiring action are presented to the user in a in-tray or via email whereas another organisation may use a pull approach where the user occasionally checks to see if anything requires their attention. Tasks will be carried out using different applications. For instance in a networked

University one partner my record marks using a spreadsheet whereas another may use a database. Organisations may or may not have their own workflow engines.

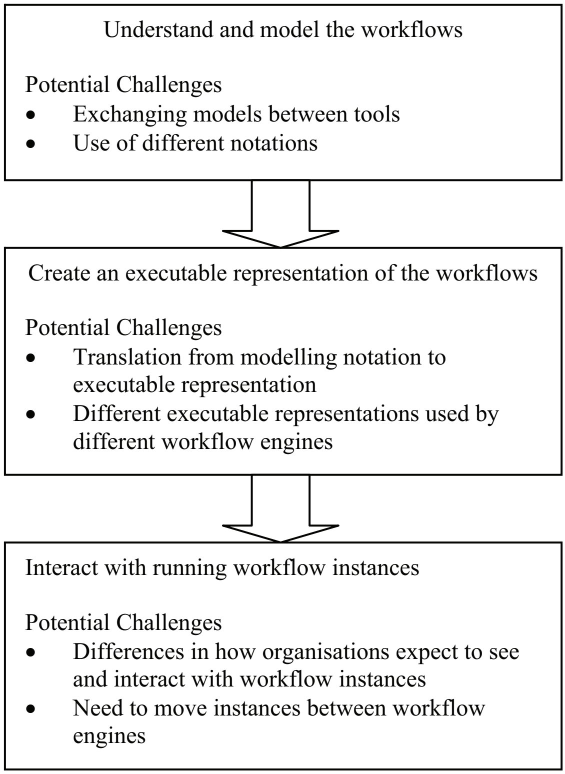

Fig. 1. Potential challenges at each stage of workflow integration
Stage 1 - Understand and model the workflows
Stage 2 - Create an executable representation of the workflows for use by a workflow engine
Stage 3 - Interact with running workflow instances

2.2 Motivation and problem statement

In the UK, higher education institutions often form partnerships to provide the same courses to students residing in the various institutions. In recent years, collaboration with overseas universities/colleges has grown rapidly and in many institutions, workflow automation is now common place. Problems arise when the partner institutions share a process in the collaboration but the partners in the collaboration may change from time to time, such that one partner may decide to leave or a new one may join. For instance a workflow for marking coursework may involve the students submitting the coursework online, the tutors mark them locally at each institution. The marked courseworks are then fed to a moderation procedure in order to ensure the quality of the marking. A lead institution will set up the workflow that all institutions will follow. A number of ways to set up and follow through such a process are possible. One is to ask everyone to follow the process created and maintained by the lead institution. A good reason for doing so is that the objectives of the workflow are defined by the lead institution, and are imposed as requirements to the partner institutions. Another way to set up a shared process may require the use of more than one type of BPM system run by the different institutions. In this case, a shared process has to be agreed by all involved, and the setting up becomes more complex. The former would normally require a Web-based interface for the remote partners. In both cases problems can arise when the staff and students use the system because they are required to deal with an array of unfamiliar interfaces due to the fact that the shared process may bring with it various interfaces and indeed different practices. The research challenge lies in how to find a way to alleviate the users of the BPM systems at all the participating institutions from the burden of having to learn and deal with new interfaces and practices. The less the users have to learn new things unnecessarily the more productive they become. It is also a challenge to the IT department in each of the institutions if setting these processes up requires a lot of work such as project planning, design and programming. In conclusion, a cross-domain business process often comprises activities and/or tasks to be carried out by people and/or system functions residing in different organisations. The main concern about the integration of BPM systems is how to get the workflow engines from the different organisations to work together towards shared business objectives. BPM system integration, however, often stops short once these engines can work together technically. Cultural factors, ROI and user proficiency issues are often not considered. The latter however is vital to the success of such integration. In this research we assume that each organisation defines the business objectives at a high level in terms of use cases and user interactions. They also use their preferred BPM systems and tools for process modelling, design and execution. The employees of these organisations have preferences for the tools they use and different proficiency levels in using them. Culturally speaking, people prefer to use the tools they are already familiar with, and are generally reluctant to adapt to different tools; it may not always be possible to do so in some cases. Furthermore, organisations would generally want to preserve their investment of the various tools that they acquired over time. How can we make integration of information and process from the different organisations easier, i.e. at a higher level of abstraction rather than through lower level programming? This research aims to survey the existing work, the current technologies and related standards, and explore the possible solutions.

3. Existing work and standards of BPM

3.1 Review of BPM Technologies and standards

Business Process Management covers the complete life cycle of process design, modelling, deployment, execution, management, monitoring, optimisation, error prevention etc. in its attempt to automate a sequence of system and human activities required to complete a business process e.g. registering a student to study for a course at a university. Its aim is to enhance and make existing processes more efficient and to design new processes where appropriate. In the early days software tended to be fairly inflexible however this is improving slowly and the industry is now adopting standards to support the different parts of the lifecycle including the human side of the workflow process.

BPM starts with modelling the business domain, capturing workflows and activities in order to analyse and optimise them. This requires an analyst to check for unnecessary manual steps, processes that can be carried out in parallel, establishing responsibilities, removing duplicate effort e.g. entry of data into dual systems etc. The models are typically analysed and implemented through a BPM suite's designer, typically a graphical development tool which puts human tasks, system functions, and business rules together to create an executable solution. This is then deployed into a BPM engine for execution which may trigger real-time notifications of activities, workflow progress and alerts e.g. if a process has failed for some reason.

Numerous tools and standards from various bodies such as W3C (W3C 2009) and OASIS (Oasis 1993) have been developed to support this process and in this section we will provide an overview of the current technologies and standards used in Business Process Management.

3.2 Service Oriented Architectures (SOA)

It would not be appropriate to comment on BPM without also talking about SOA (Service Oriented Architectures) due to the close coupling between the two and its dominance in industry today. Service oriented architectures have been around for a long time however, when referring to them these days, they imply the implementation of systems using web services technology. A web service is a standard approach to making a reusable component (a piece of software functionality) available and accessible across the web and can be thought of as a repeatable business task such as checking a credit balance, determining if a product is available or booking a holiday. Web services are typically the way in which a business process is implemented. BPM is about providing a workflow layer to orchestrate the web services. It provides the context to SOA essentially managing the dynamic execution of services and allows business users to interact with them as appropriate.

SOA can be thought of as an architectural style which formally separates services (the business functionality) from the consumers (other business systems). Separation is achieved through a service contract between the consumer and producer of the service. This contract should address issues such as availability, version control, security, performance etc. Having said this many web services are freely available over the internet but use of them is risky without a service level agreement as they may not exist in future however, this may not be an issue if similar alternate web services are available for use. In addition to a service contract there must be a way for providers to publish service contracts and for consumers to locate service contracts. These typically occur through standards such as the Universal Description, Discovery and Integration (UDDI 1993) which is an XML (XML 2003) based markup language from W3C that enables businesses to publish details of services available on the internet. The Web Services Description Language (WSDL 2007) provides a way of describing web services in an XML format. Note that WSDL tells you how to interact with the web service but says nothing about how it actually works behind the interface. The standard for communication is via SOAP (Simple Object Access Protocol) (SOAP 2007) which is a specification for exchanging information in web services. These standards are not described in detail here as information about them is commonly available so the reader is referred elsewhere for further information. The important issue to understand about SOA in this context, is that it separates the contract from the implementation of that contract thus producing an architecture which is loosely coupled resulting in easily reconfigurable systems, which can adapt to changes in business processes easily.

There has been a convergence in recent times towards integrating various approaches such as SOA with SaaS (Software as a Service) (Bennett et al., 2000) and the Web with much talk about Web Oriented Architectures (WOA) [ref]. This approach extends SOA to web-based applications in order allow businesses to open up relevant parts of their IT systems to customers, vendors etc. as appropriate. This has now become a necessity in order to address

competitive advantage. WOA (Hinchcliffe 2006) is often considered to be a light-weight version of SOA using RESTful Web services, open APIs and integration approaches such as mashups.
In order to manage the lifecycle of business processes in an SOA architecture, software is needed that will enable you to, for example: expose services without the need for programming, compose services from other services, deploy services on any platform (hardware and operating system), maintain security and usage policies, orchestrate services i.e. centrally coordinate the invocation of multiple web services, automatically generate the WSDL; provide a graphical design tool, a distributable runtime engine and service monitoring capabilities, have the ability to graphically design transformations to and from non-XML formats. These are all typical functions provided by SOA middleware along with a runtime environment which should include e.g. event detection, service hosting, intelligent routing, message transformation processing, security capabilities, synchronous and asynchronous message delivery. Often these functions will be divided into several products. An enterprise service bus (ESB) is typically at the core of a SOA tool providing an event-driven, standards based messaging engine.

3.3 BPEL and associated standards

Individual services must be composed into a sequence of steps i.e. the workflow, failure and exceptional cases associated with each service must be dealt with. Note that the latter may require one or more service activities to be 'undone' and control passed back to the user. Workflow design involves analysing existing or planned business processes to understand the different stages of these processes; representing the process being designed in a workflow design notation and converting the final design into an executable program. This could be done by writing in a language such as Java or C# however the standard that has emerged to do this is WS-BPEL (Web Services Business Process Execution Language), known as BPEL (2006) for short and is an OASIS standard for specifying how web services interact. BPEL is a XML-based language which Business analysts can use to specify the orchestration of the web services for execution by BPEL. The BPEL process produced is itself a web service, and exposes itself via a WSDL description. A BPEL engine can then execute the process description. Fig. 2 shows a possible BPEL representation of the exam setting case study. Each human task has to be wrapped in web services and invoked as a web service.
BPEL has three basic components to it

- The programming logic i.e. the BPEL execution code. This contains commands to e.g. invoke a web service, reply to a message received, execute activities in sequence or in parallel in addition to standard programming constructs of loops, selection and variable assignment.
- Data types which are defined using XSD (XML Schema 2006) which is W3C standard for describing the structure of an XML Schema Document.
- Input/Output (I/O) which is achieved through the WSDL (Web Services Description Language) standard.

WS-BPEL has a number of other associated standards, too many to list here but key standards or emerging standards are:

- WS-CDL (Choreography Description Language) (WS-CDL 2007). This is currently a candidate standard for W3C and is an XML-based language that describes the semantics of peer-to-peer collaborations of Web Services across organisations. It is generally used to provide common rules about how companies will participate within a collaboration across multiple organisations.

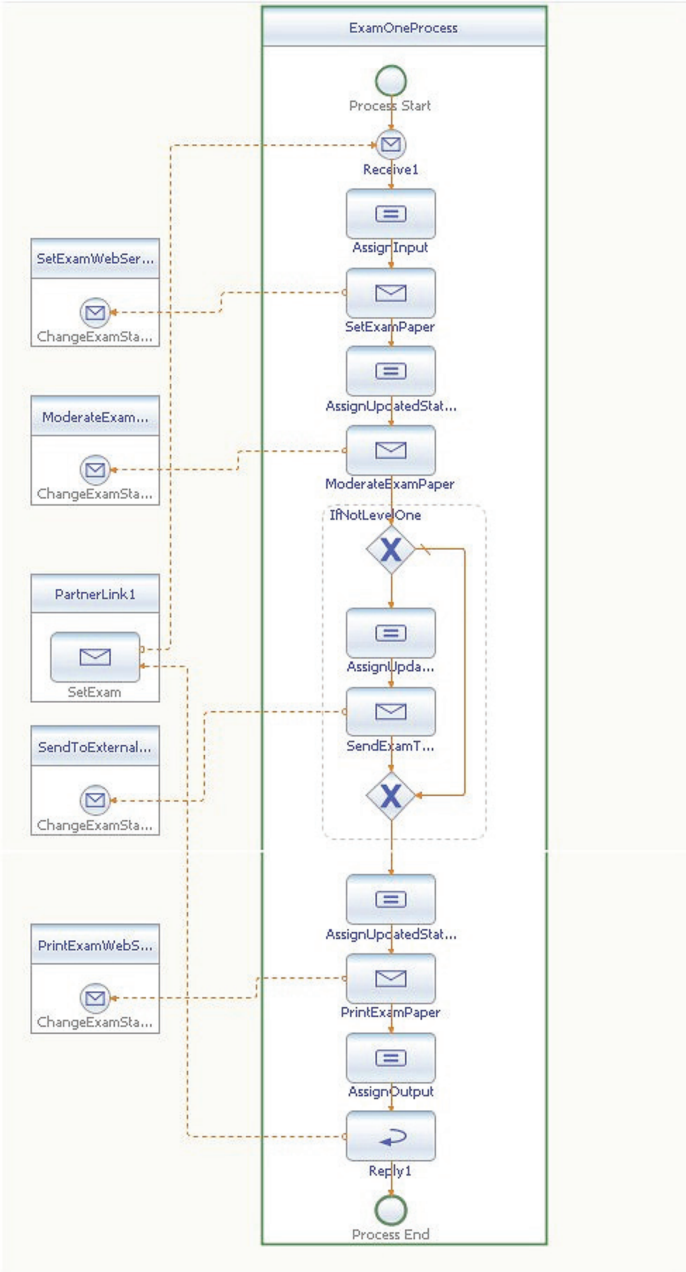

Fig. 2. A BPEL representation of an exam setting process

- WS-Coordination is an OASIS standard (WS-Coordination 2009) and is an extensible framework for coordinating activities and providing protocols that coordinate the actions of distributed applications. For example it might be used in several applications spanning multiple organisations that need to reach an agreement on the outcome of a distributed transaction.
- BPEL4People is the WS-BPEL Extension for People standard by OASIS [BPEL4People 2005]. The WS-BPEL standard only deals with web services, it does not address the need for human interaction in workflow which many real-world business processes require in order to complete. The BPEL4People standard is an extension of WS-BPEL to include interaction with humans.

There are many other standards, particularly from OASIS which cover areas such as transactions, security, trust etc. however their details are beyond the scope of this chapter and the reader is referred to the standards bodies websites for further details.

3.4 Business Process Modelling Notation (BPMN)

BPMN is a business process language and is an OMG (BPMN 2006) standard. It essentially provides a graphical notation to help visualise WS-BPEL code and is designed to be understood by business users and technical developers alike, thus trying to help bridge the communication divide between the two that is so often talked about. The standard specifies a BPD (Business Process Diagram) which is based on a flowcharting technique and contains the following key elements:

- Flow Objects – these include Events (something than happens), Activities (a process that is done) and Gateways which show how paths merge and fork.
- Connecting Objects – include sequence Flow (which show the order in which activities will be performed), message flows (which show the messages that flow across organisational boundaries), and associations (these associate an Artifact or text to a Flow Object).
- Swimlanes are used to help partition and organise activities. A “Pool” represents a participant in a process and a “Lane” is used to organise activities within a pool.
- Artifacts (Artefacts) are essentially additional information you might need to show on the diagram. There are three types of artifacts: a Data Object which could, for example, be the data associated with a message e.g. an invoice, Groups which are often used to highlight particular logical areas of the diagram e.g. the parts of a diagram associated with the registration of a student at University; and Text Annotations which allow additional detail to be provided on the diagram where appropriate.

It should be noted that BPMN is significantly different to other common standards for providing views on a system such as UML. Whilst they both provide a graphical notation of business processes in some form, UML takes an object-oriented view of the system and is not easily understandable by business users whereas BPNM takes a process-oriented view of the system and is more intuitively understood without formal training in the notation. The two approaches are not in competition, they serve different purposes, providing different views of the system processes and are complementary.

3.5 XML Process Definition Language (XPDL)

XPDL is a Workflow Management Coalition (XPDL 2005) standard and defines how Business Process Definitions can be exchanged between different workflow products and engines. It is designed to enable the complete reconstruction of a workflow diagram including all the semantics, the X and Y coordinates of the diagram elements and how the nodes are linked etc. XPDL is currently the best format for exchanging BPNM diagrams. Note that BPEL does not contain graphical information its focus is purely on the execution of the processes hence the application to BPNM not BPEL.

3.6 Business Process Definition Metamodel (BPDM)

BPDM is a standard from the OMG (BPDM 2008) which extends BPMN and BPEL to support the exchange of business processes definitions between tools and execution environments. It is similar to XPDL for process interchange but offers some additional features to try and provide a common metamodel to unify many existing notations to business process definition notations. It also aims integrate the approach with UML and other industry standards to provide a consistent and complete approach to lifecycle development. OMG aims to reconcile BPMN and BPDM into a consistent language.

3.7 Wf-XML

Wf-XML is a BPM standard (Wf-XML 2006) developed by the Workflow Management Coalition and is an extension to the OASIS Asynchronous Service Access Protocol (ASAP 2005) which is itself an extension to SOAP. ASAP provides support for starting and monitoring services in other workflow engines that might take a long time to complete. Wf-XML extends this functionality providing additional web service operations to send and retrieve process definitions of a service thus providing a standard way for design tools and execution engines to communicate. Wf-XML 2.0 is defined using WSDL and is therefore provided as a web service.

3.8 BPM engines

There are many BPM engines on the market e.g. eClarus software (eClarus 2009) and Singularity's Business Process Management (BPM) Suite [Singularity 2009]. Most, if not all, use the standards described above as core in their delivery. The standards for BPM execution, management, information interchange etc. are however constantly evolving and being regularly updated. For example, the prospposed standards for open services grid architecture (OGSA2006) from the Open Grid Forum are based on existing standards although not a standard itself at the time of writing.

BPM engines can be stand alone products or embedded into other products such as Oracle's Business Process Management solution (Oracle 2009). It should be noted that BPM tools are not often a solution in themselves; they are generally only part of a solution. Many other tools and techniques are needed to help solve the complexity of managing workflow which often requires human input and the need to address issues across organisational boundaries. For example, Business Analysis tools (BPA), Business Activity monitoring (BAM), Business rules engines (BRE) and Business process management suites (BPMS) which according to Gartner will be among the fastest growing software markets in 2011 (Gartner 2009).

3.9 Review of related research

Jung et al., (2006) propose an approach to BPM integration which they refer to as "multi-phase process composition". The essence of this approach is that organisations have private workflows which are linked at various points into a collaborative workflow. This approach

can be implemented in various ways. Jung et al. have developed a prototype where each partner organisation has its own internal workflow or BPM engine running its private processes. In addition there is a BPM engine that runs a shared process which co-ordinates the collaborative workflow. XPDL is used to describe the private workflows and BPEL for the shared collaborative workflow. Communication between the engines is via Wf-XML.
There are several advantages to the approach proposed by Jung et al. Organisations are able to use their familiar workflow engines and retain control of their private workflows. If there are three collaborating partners then each only has to link into the shared BPM engine rather than link to each of the other partners' engines. As the number of partners grows (as may be the case in a virtual enterprise) this provides a significant advantage in terms of maintainability. A disadvantage of the approach is that it is quite complex to set up. Also, in order to see the status of a workflow it may be necessary to interact with several work flow engines.
Meng et al., (2006) describes Dynamic Workflow Model (DWM) and an implementation Dynaflow that is based on DWM. It tries to solve problems in virtual enterprises which are similar to those in virtual university: namely how to model and manage inter-organisation workflow for businesses that need to be more agile and flexible, and to maximise the use of their existing recourses. DWM provides support for creating and running dynamic workflows across organisational boundaries. DWM extends the WfMC's WPDL with new modelling construct such as connectors, and events, triggers and rules. It also encapsulates activities definitions and allows web service requests to be part of the activity specification. DynaFlow then makes use of Event-Triggers-Rules (ETR) server to trigger business rules during an enactment of a process thus rules are enforced or the process model is modified at run-time. Their approach is based on web services enhanced with asynchronous events. It combines workflow engine and middleware services to form an enterprise infrastructure. The main drawback of the work is that each organisation will have to install the same set of servers including the event server, the ETR server, and the Workflow server and so on, in order to manage inter-organisational processes.

3.10 Some related work in progress

Most current approaches to the computer assisted management of business activities focus on the automation of tasks in a way that the computer systems assist and direct the business processes according to the predefined business process definition. Work done by the Artificial Intelligence (AI) group at the University of Greenwich (Kapetanakis 2009) investigates the use of AI for the intelligent monitoring of business activities. The approach proposed is inspired by the way human managers interact with and manipulate processes in an agile way to deal with unforeseen circumstances and with the uncertainty stemming from the limitations that most systems have in capturing every detail of business workflows, especially at the interface level between systems and human actors.
Modern enterprise systems are able to separate the definition of workflow based business processes from the software implementing the operation of these workflows, offering much more flexibility and agility than was possible in older systems. This allows enterprise computer systems to monitor and control business processes and workflows within an organisation. Additionally, this allows for the agile change of workflows to adapt to the changing business needs of an organisation.
Case Based Reasoning (CBR) (Kolodner 1993) has been proposed as a natural approach to the recall, reuse and adaptation of workflows and knowledge associated with their

structure. Minor et al., [Minor 2007] proposed a CBR approach to the reuse and adaptation of agile workflows based on a graph representation of workflows and structural similarity measures. The definition of similarity measures for structured representations of cases in CBR has been proposed (Bunke 1994) and applied to many real life applications requiring reuse of domain knowledge associated with rich structure based cases (Mileman 2002; Wolf 2008).

A key issue associated with the monitoring and control of workflows is that these are very often adapted and overridden to deal with unanticipated problems and changes in the operating environment. This is particularly the case in the aspects of workflows that directly interact with human roles. Most business process management systems have override options allowing managers to bypass or adapt workflows to deal with operational problems and priorities. Additionally, workflows are liable to change as the business requirements change and in many case workflows involving processes from different parts of an organisation, or between collaborating organisations can "tangle", requiring the need for synchronisation and mutual adaptation to allow for compatible synergy.

The flexibility and adaptability of workflows provides challenges in the effective monitoring of a business process. Typically, workflow management systems provide outputs in terms of event logs of actions occurring during the execution of a workflow. These could refer to an action (such as a sign-off action or uploading a document), or a communication (such as a transaction initiation or email being initiated and sent). The challenge in monitoring workflows using event information is that even where the workflow structure is well defined and understood, the trace of events/actions does not usually contain the context behind any decisions that caused these events/actions to occur. Additionally, there are often a lot of contextual information and communications that are not captured by the system. For example, some actions can be performed manually and informal communications/meetings between workflow workers may not be captured by the system. Knowledge of the workflow structure and orchestration of workflows does not necessarily define uniquely the choreography and operation of the workflows. The effective monitoring of workflows is therefore required to deal with uncertainty stemming from these issues (Kapetanakis 2009).

The overall exam moderation workflow process is formally defined and constrained by the system operation as seen in Fig. 3. There are also some limited facilities for manual override by the system administrator. However, the overall process in conjunction with the actions and communications audit trail do not uniquely explain the exact cause of individual actions and cannot predict reliably what the next event/action will be and when this is likely to occur. Most of the uncertainty stems from the problem that a significant part of the workflow occurs in isolation from the system. The system does not capture all of the contextual knowledge associated with workflows. A lot of the communications between workflow stakeholders can occur outside the system e.g. direct emails, physical meetings and phone calls adding to the uncertainty associated with past or anticipated events and the clear definition of the current state.

Discussions with workflow monitoring managers showed that patterns of events indicated, but did not define uniquely, the current context and state of a workflow. Managers were able to guess from looking at the workflow events and communications audit what the context and current state of a workflow was and point to possible problems. Most problems occur due to human misunderstanding of the current state and confusion with roles and responsibilities and usually result in the workflow stalling. Managers will then try to restart

the process by adding comments to the system, or initiate new actions and communications. However, this depends on managers realising that such a problem has occurred.
A typical problem series of event could be one where a stakeholder has missed reading an email requiring an action. In that case, the workflow would stall until a manager or another stakeholder spots the problem and produces a manual action (such as sending an email) to get the workflow moving again. For example, using our assessment scenario, a module coordinator upload notification may have been missed by a moderator who would then not read the new version and either approve or try to amend by a new upload as s/he needs to do. In that case, the coordinator may take no further action and other stakeholders will not act expecting an action from the moderator to occur.

The CBR Workflow Monitoring System

The aim of the CBR Workflow Intelligent Monitoring System (CBR-WIMS) is to provide an automatic monitoring system that will notify managers and stakeholders of potential problems with the workflow and provide advice on actions that can remedy a perceived problem.
The monitoring system is designed to work based on experience of past event/action temporal sequences and the associated contextual knowledge and classification in a Case-Based Reasoning system. Similarity measures allow the retrieval of close matches and their associated workflow knowledge. This allows the classification of a sequence as a particular type of problem that needs to be reported to the monitoring system. Additionally, it is intended that any associated knowledge or plan of action can be retrieved, adapted and reused in terms of a recommendation for remedial action on the workflow.

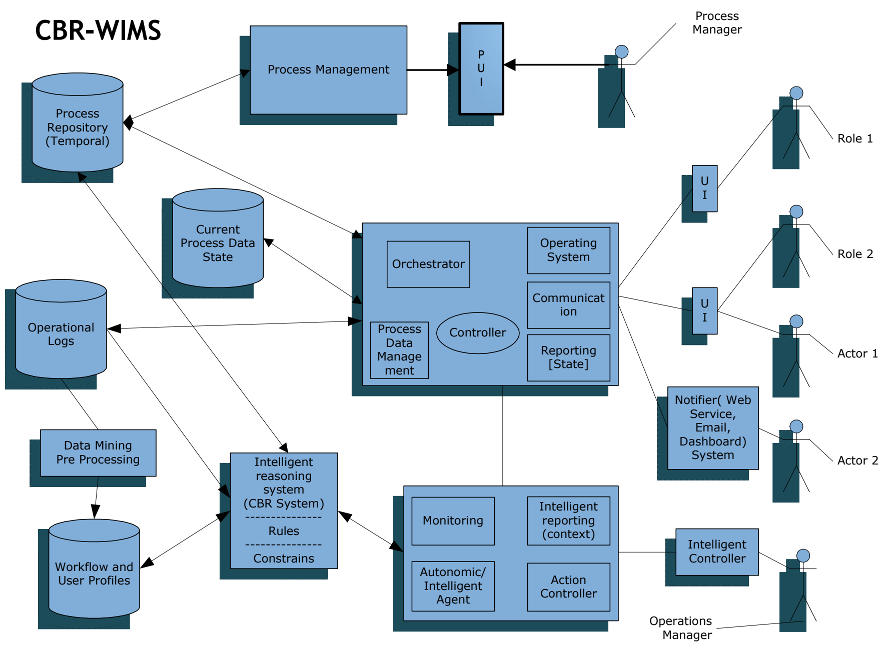

Fig. 3. The Intelligent Workflow Management System Architecture

The CBR monitoring system uses similarity measures based on a linear graph representation of temporal events in a workflow normalized by experience from past behaviour on individual user workflow participation patterns (Kapetanakis 2009)

The Architecture of the Workflow Intelligent Monitoring System

CBR-WIMS is an Intelligent Workflow Monitoring System incorporating a CBR component. The role of the system is to assist the transparent management of workflows in a business process and to orchestrate, choreograph, operate, monitor and adapt the workflows to meet changing business processes and unanticipated operational problems and inconsistencies. Fig. 11 shows the overall architecture and components of CBR-WIMS. The system allows process managers to create, modify and adapt workflows to suit the changing business needs, and/or to allow for variations related to special business requirements. Workflow descriptions are stored in a temporal repository and can be used for looking up past business processes and to provide historical context for past event logs of operations.

The main part of the system controls the operation of the workflows. It responds to actions of various actors to the system and communicates messages about the operation of the system to them. The control system has a workflow orchestrator component that looks up the current workflow definition and orchestrates responses by invoking specific Web Services. The control component also manages and updates the data stored and current state of the workflow operation and provides an event audit log of the key events and actions that occur within the operation of the workflow.

The workflow monitoring and intervention controller monitors, reports, and proposes possible remedial actions to the workflow operation manager. The monitoring system uses a CBR system to retrieve past useful experience about workflow problems occurred in the past by retrieving similar sequences of events/actions in the events log for a given workflow (or workflow part) compared to the current state and recent sequence of events/actions in the operation of the workflow. If a fault or possible problem pattern is detected, this is reported to the workflow operations manager together with the retrieved similar cases and associated recorded experience of any known remedy/course of action.

In the CBR system, workflow execution traces are represented as an event log. So, a workflow event log audit trace is represented as:

(Action1, Actor1, Interval1, Action2, Actor2, Interval2, Action3, Actor3,Interval3)

An example of this would be (intervals are in days):

(CoordUpload,John,3, ModUpload, Phil, 0,CoordUpload, John, 5)

Similarity metrics between events are defined as:

$$\sigma(e_1, e_2) = \begin{cases} 1, & \text{if} \quad e_1 = e_2 \\ 0 < \sigma < 1 & \text{if } e_1 \text{ is similar to } e_2 \\ 0, & \text{if} \quad e_1 \neq e_2 \end{cases}$$

The overall similarity between two workflow traces (cases) is calculated cumulatively over the minimum common subgraph between the two traces. For each new (unknown) target case, the n nearest neighbours are found using the KNN algorithm. The classification of the nearest neighbours is used to classify the new (unknown) target case (Kapetanakis 2009).

In order to deal with the uncertain and contextual dimension of workflow similarity, the CBR system relies on knowledge discovered from past cases about workflow norms and user profiles created by statistical and data mining pre-processing. The pre-processing component analyses operational logs and attempts to discover knowledge about norms and patterns of operation that can be used in the calculation of the similarity measures for the CBR process. This is particularly important for the monitoring process as any "interesting" or "abnormal" states need to be seen in the context of what has been normal or abnormal behaviour in past event sequence cases.

The Intelligent monitoring part of the CBR-WIMS system has been implemented into the system. Preliminary evaluation has shown that an intelligent workflow monitoring system using and past experience can help workflow managers to monitor complex business processes in an agile way (Kapetanakis 2009).

3.11 Summary

In summary the mainstream BPM solutions have provisions for business process modelling, design, enactment, execution and monitoring but do not address directly the problem described in Section 2.2. It is also clear that the existing approaches are mostly based on the web services technology and allow some level of application integration but fall short in providing satisfactory solutions to the problem. The work in progress in not directly on BPM integration but provides an interesting angle of looking at BAM which could be included into future work. A new approach is required and has been developed. In the following sections we describe a framework for BPM integration.

4. A case study from the Networked Virtual University (NVU)

Before we present the framework for BPM integration, we describe in detail a case study which is used to illustrate why such a framework is needed and how it would help.

4.1 The NVU project

The mENU project was an EC funded project that started in 2002 involving 11 partner institutions from 7 European countries (Hjeltnes & Mikalsen 2003). Its aim was to create a model for a European Networked Virtual University. The model proposed a management structure and quality assurance system spanning the partner institutions. Examples of joint courses and study programmes across institutional and national borders were also developed.

The core concept of mENU is to link universities in a network. Each individual university is able to offer courses from partner universities as part of their programmes. The partner offering the course would carry out some adaptation to make the course useable within their context e.g. by translating material and adjusting the method of assessment.

4.2 A Process for setting exam papers

Workflows are implementations of business processes. Once a business process is modelled, it can be instantiated with whom, what and when: i.e. who are the participants of the process; what is to be carried out in it; and when does it start and finish. In this section we use an exam paper setting process to illustrate a workflow. In Fig. 4 the main objectives of an exam paper setting application are depicted using the UML use case diagram. It shows the main roles played by the different participants (called actors and depicted as stickmen in UML), namely:

- the unit (module) coordinator - responsible for delivering the unit and setting the exam paper in terms of the expected learning outcomes;
- the unit moderator – responsible for approving the paper in terms of the teaching and the learning outcomes;
- the drafter – responsible for approving that the paper meets quality assurance regulations of the programme set by the university;
- the external examiner – responsible for approving that the paper meets quality assurance regulations of the programme set across the universities;
- senior member of staff – responsible for reconciling any unresolved issues by the moderator/external examiner/drafter;
- admin staff – responsible for preparing the paper for final printing

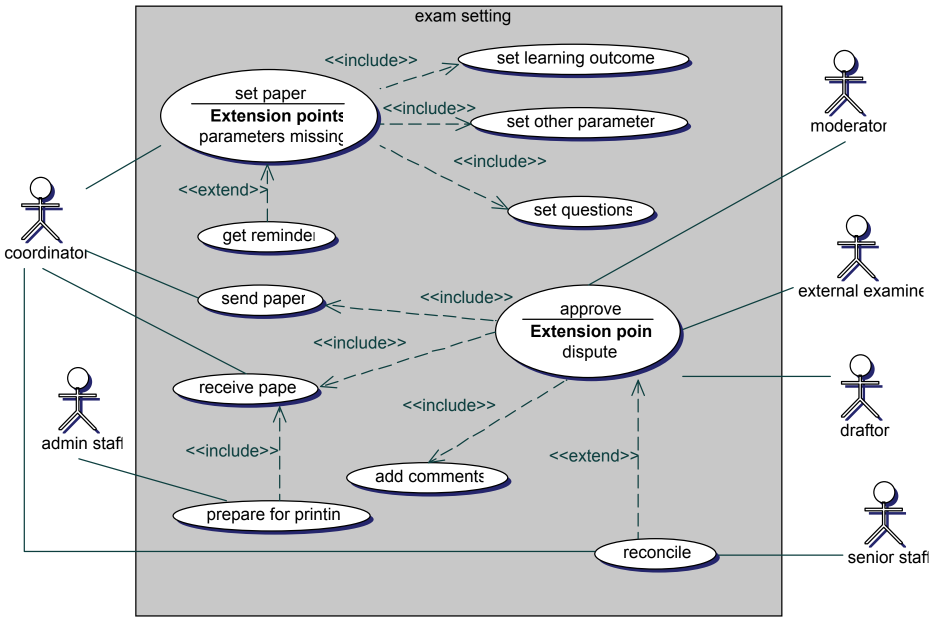

Fig. 4. A UML Use Case Diagram for exam paper setting from the NVU case study

It must be emphasised that some of the roles are played by externals, i.e. actors that reside in another organization. The main activities are:

- setting the papers: including setting the learning outcomes to be examined and other appropriate parameters such as date and time of the exam;
- approving/disapproving the papers;
- adding, sending and receiving comments;
- updating the papers;
- preparation for final printing

Fig. 5 depicts a UML activity diagram which shows the process of setting a paper and the timing when each actor is involved in certain activities. We assume that the templates for the exam papers have been well designed for re-use thus unresolved issues are rare. The workflow starts when a unit coordinator registers a draft exam paper with the system and enters the corresponding parameters. Note that there is no indication as to how the function may be implemented; for instance, send/receive may be implemented as upload/download in a web-based system. Next the unit moderator is notified and is granted access to the paper. If he/she approves it, the workflow moves to the drafter, otherwise comments are sent to the coordinator. The activities may be repeated several times until the paper is approved by the moderator. Some reconciliation procedure may be needed if the involved parties can't settle some of the issues but this aspect is not depicted in Fig. 5 or the diagram would look much cluttered. Similarly, the workflow moves to the activities to be carried out by the external examiner and the administrative staff until the paper is finalized for printing. The process of exam setting has been simplified as in the real world more than one actor may be assigned to an activity, and the administrative staff may get involved before the external examiner. The simplification should not affect in general the definition of the main problem. There are many other examples such as a coursework marking process which is more complex in the sense different activities have to be synchronised before the process can move a step further.

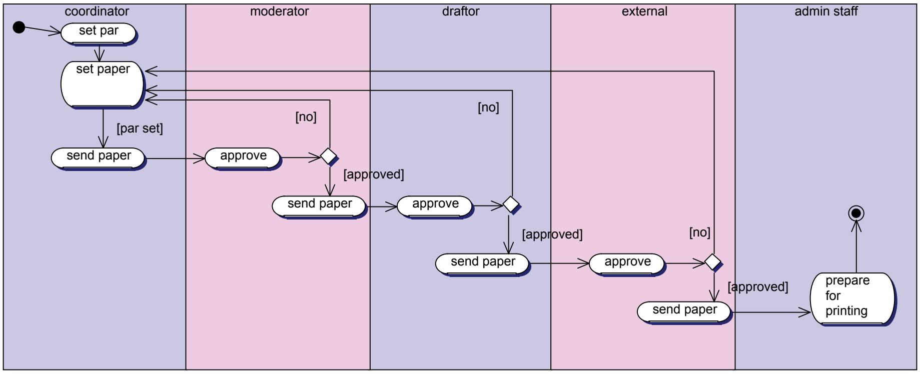

Fig. 5. A UML Activity Diagram for exam paper setting from the NVU case study

In the remaining sections, we present a framework for easy integration of BPM systems using this case study as an example.

5. A framework for BPM integration

As discussed earlier, BPM integration may take place at different stages. The major challenges for it vary by stage. A framework is clearly required and a few exist already (Ma et al., 2006, Meng et al., 2006 and Jung el al., 2006). In contrast to the others, Ma et al., (2006) proposed a portal-based framework that aims to make the integration easier and at the user level with minimum requirements for programming at a lower (i.e. API) level. The advantage of this approach is that it is very flexible no matter how the partnership would change. It supports BPM integration on the fly. One of the disadvantages of the approach is that it relies on an existing portal framework such as the uPortal framework (uPortal 2009). A portal framework that conforms to the WSRP standard (WSRP 2003) would allow a BPM system to be made available to different organisations through a portlet in a standard way.

However, differentiation in cultural, work practice and user preference supported through the interfaces to the systems are often the key to employee efficiency and productivity rather than standardisation. Standardisation is good at platform, components and service interconnection level, but not always so at the business procedure and user level, especially when collaboration across domain is considered. One important goal of this research is to develop a general framework that would allow organisations to achieve BPM integration in a fast changing environment but minimise the effect on differentiation. In this section, we present the requirements for such a framework, the design goals and an architectural design of the key aspects of the system.

5.1 The requirements and design goals

The main design goals for the framework are:

- to support cross-domain, human centric collaborative business process integration
- to support BPM integration at a higher level of abstraction
- to reduce IT investment through minimising the programming efforts for the integration
- to encourage the use of familiar BMP tools available to each participant of the shared business processes

The main requirements of a general framework for BPM integration are:

- provision for managing the full life cycle of business processes – support the business process life cycle from modelling to execution based on a broad array of industrial standards
- provision for process monitoring – provides notification if KPIs are in question
- provision for BPM integration - support for inter- and intra-domain collaboration and cooperation and task management
- provision for security - provides user identification management and role-based access control
- provision for personalisation - provides role-based access which helps users to focus on information, services and processes most relevant to their job
- provision for customisation - provides flexible web page layout and content organisation so that users have greater control over presentation aspects

Many of these come through leveraging the use of middleware such as an authentication service and an event engine for complex event processing as well as existing BPM engines and business process modelling tools. We developed Process Interceptor and Mapper (PIM) of which the main components and architecture are described in the next section.

5.2 The architecture and main components

Ma et al., (Ma et al., 2007) describe a design pattern for structuring a system that supports cross-domain, human-centric, collaborative business processes with minimum IT investment. A general framework for BPM integration has been developed to address the challenges identified in Section 2 using the design pattern. In the stage one of BPM integration, business users specify the high level business objectives typically in terms of use cases and user interactions by using UML or BPMN modelling tools. Fig. 4 and Fig. 5 show an example specification in UML which outlines the main objectives and workflow in UML. These specifications are typically created by business user together with the system analysts. They can do so with any business modelling tools they prefer as long as the definition can be passed to a BPM engine for execution in stage two. The interaction with the process will affect its statues which are captured in the process instance. The information is intercepted in stage three and will be fed into an IFM (InterFace Mapper). The main purpose of the IFM is to bridge the gaps between the users and the various "foreign" BPM systems the user encounters. This way the approach alleviates the need for heavy IT investment in order to glue the back-end services together to form an integrated system, which includes business and IT planning and programming at the much lower i.e. API level. Fig. 6 shows an architectural view of a system based on the design pattern. The ovals represent the components and the rectangles the views (aka interfaces to the user). The Interceptor component connects direct to the BPM engine and intercepts the running instances of the shared processes before they are passed to the IFM which presents the instance in a pre-defined view to the end users. In order to access the functions of the BPM engine and at the same time stick to the familiar views and steps supported by the preferred tools and user interfaces for monitoring and performing tasks, the user uses the PIM system which produces adapted views that match their preferences.

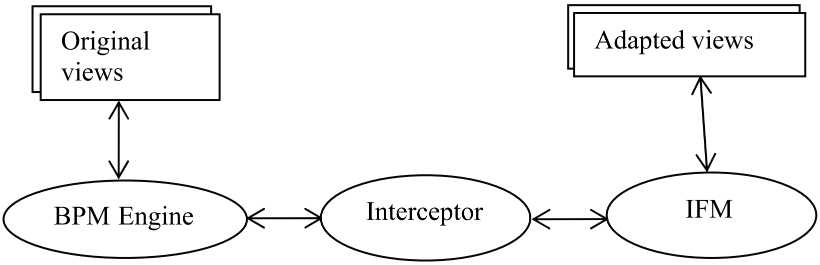

Fig. 6. The architectural design

The mapping of the instance to user adapted views is based on XML technology. In the next section, an implementation of the design is described.

6. An implementation

6.1 General description

A proof of concept implementation based on the design is described in detail in Caldera (2008). An open source Java BPM engine Enhydra Shark (2008) was used and extended for the purpose. Enhydra Shark (ES) supports XPDL as the native language and also allows easy incorporation of a number of database management systems including DB2, MySQL, Oracle and etc. ES comprises a suite of tools: SharkAdmin, SharkWebClient and Together Workflow Editor (TWE). TWE is a graphical editor used for process modelling. TWE can generate XPDL from the graphical process model. The generated XPDL design is then passed to the Enhydra Shark Workflow Engine through SharkAmdin. The same can also be done through the SharkWebClient which in addition supports a Web-based interface. An extension was made to the ShardAdmin to incorporate an Interceptor and an IFM component as described in Section 5.

6.2 Implementing the interceptor

One of the main challenges faced during the implementation was how to intercept the process instances for the IFM component to produce adapted views for the users. Fig. 7

shows a UML class diagram of the implementation which is for holding the detail of a process instance. First of all, a meta-language called procXML was defined to be an interchange format for process instance. procXML contains information about a process instances such as the process definition, activities, statuses of an instantiated processes, its activities and the participants. An XML schema was used to validate procXML files. Java Architecture for XML Binding (JAXB) framework (Ed Ort and Bhakti Mehta 2003) was used to map and bind process instance represented in XML into Java classes, interfaces and objects. Fig. 8 shows how it works. An XML schema is fed into the binding compiler which generates a set of Java classes and interfaces for representing a process instance. Through the JAXB APIs, XML files representing process instances can then be marshalled/unmarshalled to/from Java objects. This way process instances are captured from the Shark Workflow Engine into the XML files.

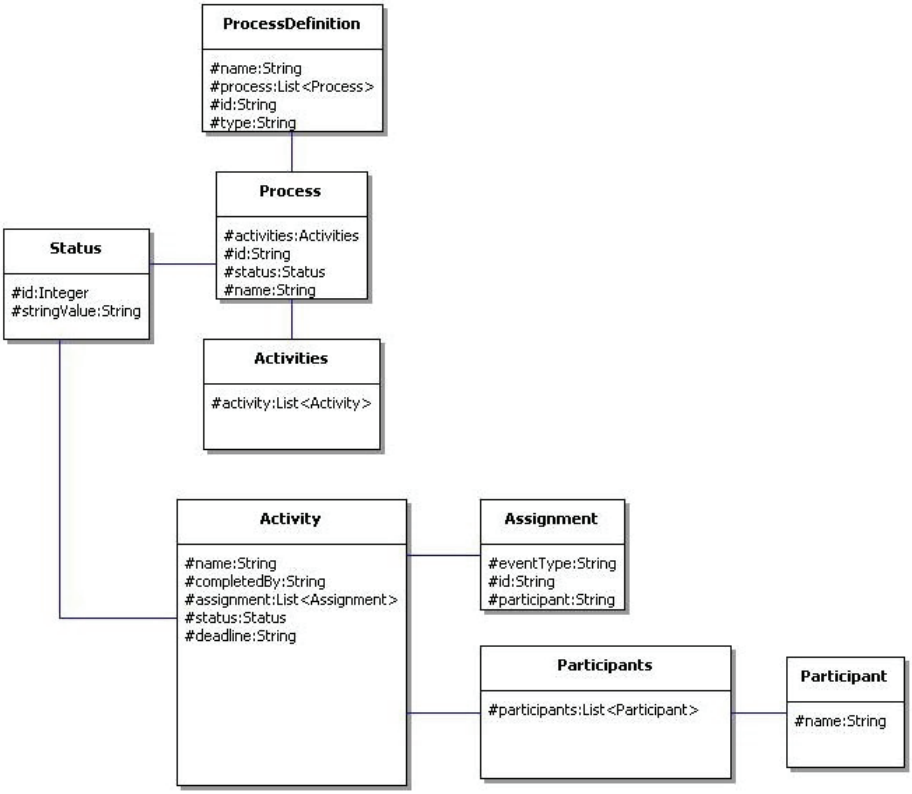

Fig. 7. Classes used by the interceptor to capture the process details

6.3 Implementing the IFM and testing results

The IFM is developed using the XML technology. Process instances captured into the XML files by the Interceptor are transformed according to user preferences using XSLT. Such transformation may occur on the server side or on the client side, and in this case on the

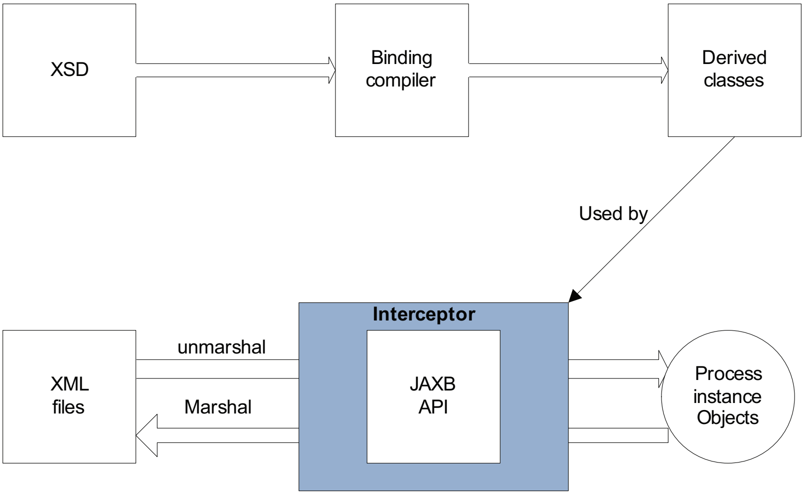

Fig. 8. Implementing the interceptor with JAXB

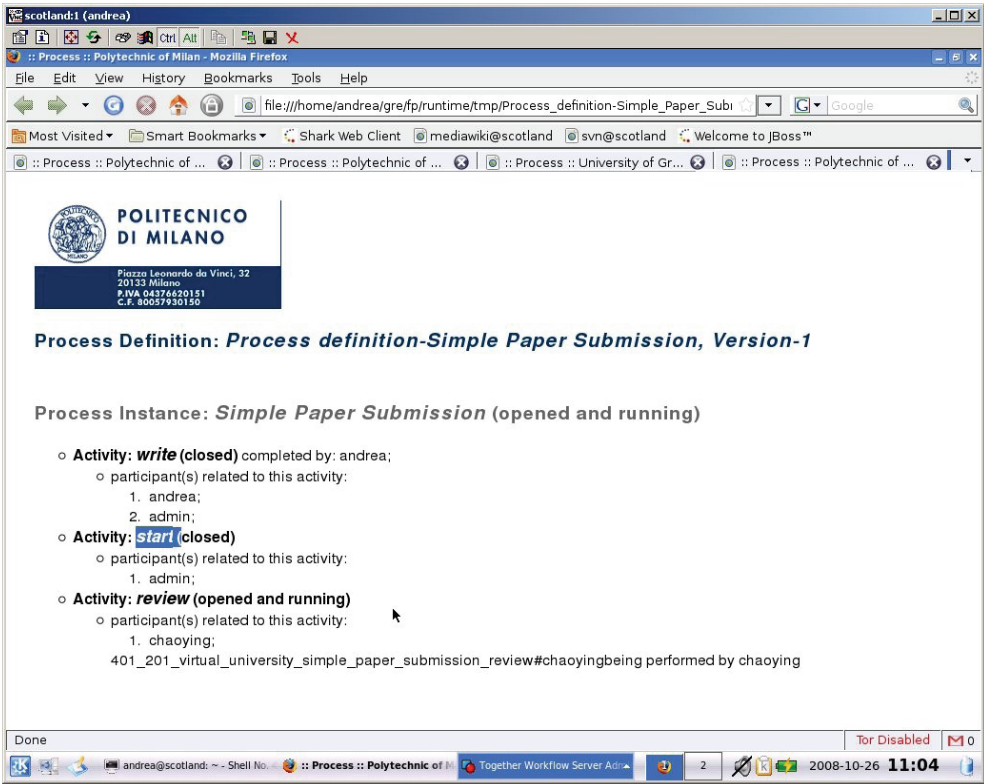

Fig. 9. The Politechnico Di Milano view of the process

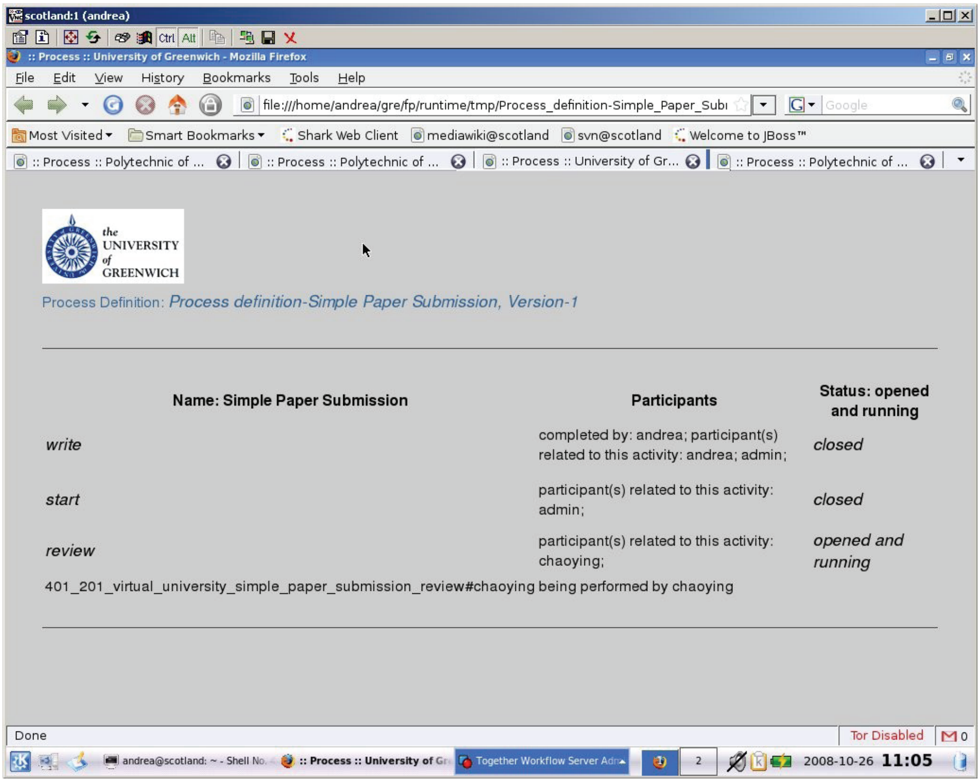

Fig. 10. The UoG view of the shared process

server side, through the Java API for XML processing (JAXP 2008). JAXP comes as a standard component of Java platform, and allows applications to parse, transform, validate and query XML documents using an API that is independent of a particular XML processor implementation. JAXP is used because it allows us to add the IFM as a pluggable layer without introducing dependencies in application code.

To illustrate how the framework may support BPM integration in a cross-domain environment, imagine a scenario in which two institutions work together in an exam paper setting process as described in the case study in Section 4. Note that the process was simplified in the prototype. Suppose the process was defined by the University of Greenwich (UoG) and followed by the Politechnico Di Milano. A member of staff called Andrea started writing and submitting a paper to the system. The paper is to be reviewed by a member of staff at UoG called Chaoying. Fig. 9 and Fig. 10 show two views: one original for the UoG and one adapted at Politechnico Di Milano. One can see that two activities in the process were completed and closed, and the third was still open and running.

As the implementation is only a proof of concept prototype. Several important issues should be addressed in future implementations as discussed in the next section. In addition the PIM component should be a separate entity from the SharkAdmin instead of an extension to it as it currently implemented. This was done to save time for develop GUI in order to interact with the PIM. Despite this, the current implementation does prove that the framework with PIM as a key system component meets the design goals. In the next section, we discuss some of the main issues encountered in the development of the framework.

7. Discussion and future directions

7.1 Culture and tool issues in workplace

BPM is changing the culture in the workplace. Whilst the scope of BPM can affect everything from role of the business analyst in defining business workflows, to the planning and management of BPM software through to the actual to services executed to implement a BPM workflow, there can be a hidden impact on the user changing the way human-centric business processes are implemented.

Before BPM, humans had a task to do and they were able to do it in their own individualised preferred way. With the advent of BPM, many users can be forced to follow the workflow and algorithm specified by a business analyst. This often doesn't work well as people work and think in different ways. In order to help employees embrace the workflow concepts, there is a view that technology needs to support humans in the way they want to work and not be prescriptive. This means being flexible and adaptable to different needs and ways of working. What the technology needs to do is allow the users to personalise their workflow and define how they want their tasks to be orchestrated. Note that is not always easy to prescribe all processes in advance, some might be ad-hoc and not sufficiently well defined to have a clear start and finish. In these situations it is important that the human remains in control.

There is also a move in the industry towards the integration of workflow with current working practices and tools, so instead of booting up a workflow tool to use, the idea is that the workflow would be integrated with tools the user is using to deliver their normal work e.g. email and mobile devices. The personalisation of workflow and integration with tools is a key direction for the development of this area however there is much work left to do (Schurter 2009). In developing the framework, we attempted to address personalisation and customisation issues through the PIM system and have successfully demonstrated that it is possible for each organisation in participating collaborative human centric processes to adapt the views according to their own definition.

7.2 Evaluation and future improvement

We have described a general framework and demonstrated how it could be used of for integration of cross-domain, human centric and collaborative BPM through use of a case study. With the framework, business users are empowered with the means to specify and create shared processes at a high level with tools such as UML use case, activity diagram, BPMN and/or other graphical modelling tools. They can run the defined processes with their local BPM suites. In order for the process to be shared by their partners from other organisations, we design and implemented a PIM system which can capture runnin process instances and produce user specified views for each of the partners. Although a Java BPM system based on XPDL was used in our implementation, the same design principle should work with any BPM suite no matter which language, e.g. XPDL or BPEL, is used by the engine. The challenge is however that it can be difficult if not impossible to obtain running process instances with many existing BPM packages. The representations of such instance are vendor specific. The newly released OMG standard BPDM (2008) could be used for standardisation of process instance representation. BPDM was not finalised when our system was developed but it is designed such that it is straightforward to replace ProcXML with a BPDM based solution for intercepting the process instances.

The provision for monitoring in this framework is limited to what are available through the BPM suite used. To incorporate intelligent BAM as discussed in Section 3.10, more work is required. The two approaches are now ready to be integratedmore closely in order to address the issues raise in Section 3.10.

As one of the design goals, the framework includes provisions such as an authentication service through leveraging the use of the existing systems or middleware rather than reinvent the wheel. Once the framework is in place, the organisations may define and have their specific views thtat the various BPM engines generated through the use of XML technology such as XSLT.

8. Conclusion

We have designed a general framework for integration of cross-domain, human centric and collaborative BPM system, and implemented the key aspects of it while reusing the existing BPM systems and other standard services as much as possible. We discussed the three different stages of BPM integration along side the issues and main challenges. The main advantage of the framework is that it addresses issues of integration at stage three while most existing work and BPM related standards address issues only at stage one and/or two. The work is still ongoing, and issues as discussed in Section 7 still need to be addressed. It is however a very positive way forward towards BPM integration. Looking to the future, in addition to the issues of working with personalised client devices, with the increasing trend towards more employees working remotely, this provides additional BPM challenges in working both within and across organisations involving issues such as security, firewalls, infrastructure issues, cloud computing and use of SaaS to support the delivery of BPM.

9. References

ASAP (2005). OASIS Asynchronous Service Access Protocol (ASAP). http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=asap.

Bennett, Keith; et al. (2000). "Service-based software: the future for flexible software" (PDF). Seventh Asia-Pacific Software Engineering Conference, 2000. APSEC 2000.. Proceedings: Seventh Asia-Pacific Software Engineering Conference, 2000. pp. 214-221. doi:10.1109/APSEC.2000.896702

BPEL. (2006). The Web Services Business Process Execution Language Version 2.0. May 2006. OASIS. http://www.oasis-open.org/apps/org/workgroup/wsbpel

BPEL4People (2005). OASIS WS-BPEL Extension for People (BPEL4People) http://www.oasis-open.org/committees/tc_home.php?wg_abbrev=bpel4people

BPRI. (2005). Business Process Runtime Interface. OMG RFP. Mar 2005. http://www.omg.org/attachments/pdf/PaulHarmonBParticle.pdf

BPDM 2008. Business Process Definition Metamodel. http://www.omg.org/

BPMN. (2006). Business Process Modeling Notation. OMG Specification, Feb, 2006. http://www.bpmn.org/

Bunke, H., Messmer, B.T.(1994): Similarity Measures for Structured Representations. In: Wess, S., Richter, M., Althoff, K.-D. (eds) *Topics is Case-Based Reasoning*. LNCS, vol. 837, pp 106-118, Springer, Heidelberg (1994)

eClarus (2009). eClarus Business Process Modeler http://www.eclarus.com/

Enhydra Shark (2008). An open source Java workflow engine URL: http://www.enhydra.org/, last accessed Nov. 2008

Hinchcliffe Dion (2006). What Is WOA? It's The Future of Service-Oriented Architecture (SOA) http://hinchcliffe.org/archive/2008/02/27/16617.aspx

Hjeltness T., Mikalsen A. B. (2003), Towards a Model of a European Networked University for e-learning, International Conference on Network Universities and e-Learning May 2003 Valencia, Spain, Available at http://ans.hsh.no/lu/inf/menu/final/publ/thorleif_hjeltnes.pdf accessed 7th November 2009

Hollar, R. (2004). Will Standards Turn Portal into Commodities? Tow approaches that work, *Web Services Journal*, Jan 2004.
URL: http://webservices.sys-con.com/author/2103Hollar.htm

Hollingsworth. D. (2004) The Workflow Reference Model: 10 Years On. Workflow Handbook 2004. Edited by Fischer, L. Future Strategies Inc. 2004. Also available for download at www.wfmc.org

Hopper, G. and Woolf, B. (2004). *Enterprise Integration Patterns*. Addison-Wesley, 2004. ISBN 0321200683.

Gartner (2009). Business Process Management Suites (BPMS) Will Be Among the Fastest Growing Software Markets through 2011. http://www.gartner.com/it/page.jsp?id=502645

Jung, J., Kim, H., Kang, S-H. (2006). Standards-based approaches to B2B workflow integration. *Computers & Industrial Engineering 51*, Elsevier

Kapetanakis, S., Petridis, M., Ma, J., Bacon, L.(2009) : Workflow Monitoring and Diagnosis Using Case Based Reasoning on Incomplete Temporal Log Data, *Proceedings of the Workshop on Uncertainty, Knowledge Discovery, and Similarity in Case Based Reasoning UKDS, in Workshop proceedings of the 8th International Conference on Case Based Reasoning*, Seattle, USA.

Kolodner, J. (1993) Case-Based Reasoning. Morgan Kaufmann Series in Representation & Reasoning.

Koulopoulos, T. M. (1995). The Workflow Imperative: In: *Building Real World Business Solutions*. ITP. 1995. ISBN 0442019750

Ma, C. and at el. (2006) Towards the Design of a Portal Framework for Web Services Integration, *Proc. of ICIW'06*, pp.163-168, ISBN: 0-7695-2522-9, Guadeloupe, French Caribbean Feb. 19-25, 2006, IEEE Computer Society, Guadeloupe.

Meng, J. et. al. (2006). DynaFlow: a dynamic inter-organisational workflow management system. *Int. Journal of Business Process Integration and Management*, Vol. 1, No. 2. 2006, pp 101-115, ISSN??

Mileman, T., Knight, B., Petridis, M., Cowell, D., Ewer, J. (2002): Case-Based Retrieval of 3-D shapes for the design of metal castings in *Journal of Intelligent Manufacturing*, Kluwer. 13(1): 39-45; Feb 2002.

Minor, M., Tartakovski, A. and Bergmann, R. (2007): Representation and Structure-Based Similarity Assessment for Agile Workflows, in Weber, R., O. and Richter, M., M.(Eds) Case-Based Reasoning Research and Development, *Proceedings of the 7th international conference on Case-Based Reasoning*, ICCBR 2007, Belfast, NI, UK, August 2007, LNAI 4626, pp 224-238, Springer-Verlag.

Oasis (1993). Organization for the Advancement of Structured Information Standards. http://www.oasis-open.org/specs/

Ed Ort and Bhakti Mehta. (2003) Java Architecture for XML Binding (JAXB), Technical Article, Sun Developer Network, March 2003.

OGSA. (2006). Open services grid architecture http://www.ggf.org/documents/GFD.80.pdf.

OMG. (1999). Object Management Group http://www.omg.org/.

Oracle. (2009). Oracle's Business Process Management solution, http://www.oracle.com/us/technologies/bpm/index.htm

Schurter T. (2009). BPM State of the Nation. http://www.bpm.com/bpm-state-of-the-nation-2009.html.

Singularity (2009). Business Process Management (BPM) Suite. http://www.singularity.co.uk/

Soap (2007) XML Protocol Working Group. http://www.w3.org/2000/xp/Group/

Sun. (2003). Introduction to JSR 168. July 2003. URL: http://developers.sun.com/prodtech/portalserver/reference/techart/jsr168/pb_whitepaper.pdf

Silver, B.(2006). The ABCs of BPM. *InfoWorld*. Feb. 2006. URL: http://ww6.infoworld.com/products/print_friendly.jsp?link=/article/06/02/20/75095_08FEbpmmap_1.html

UDDI (1993). Universal Description, Discovery and Integration. http://uddi.xml.org/

uPortal. (2009) A JA-SIG maintained web site. http://www.jasig.org/uportal, last accessed Nov. 2009.

Van der Aalst., W. (1999). Formalization and verification of event-driven process chains.
Information and Software Technology, 41(10):639 to 650, 1999

WS-CDL (2007). Web Services Choreography Working Group. http://www.w3.org/2002/ws/chor/

WS-Coordination (2009). Web Services Coordination http://docs.oasis-open.org/ws-tx/wscoor/2006/06

WF.(2009) Windows Workflow Foundation Overview. http://msdn2.microsoft.com/en-us/netframework/aa663340.aspx , last accessed Nov. 2009

Wf-XML (2006). WfMC Wf-XML http://www.wfmc.org/wfmc-wf-xml.html wf-html

WSRP. (2003). Web Services for Remote Portlets Specification 1.0, wsrp-specification-1.0, OASIS, Sept. 2003. http://www.oasis-open.org/

Wolf, M., Petridis, M.(2008): Measuring Similarity of Software Designs using Graph Matching for CBR, In *workshop proceedings of AISEW 2008 at ECAI 2008*, Patras, Greece (2008)

WSDL (2007). Web Services Description Working Group. http://www.w3.org/2002/ws/desc/.

W3C (2009) World Wide Web Consortium http://www.w3.org/ Last accessed Nov. 2009
XML (2003). Extensible Markup Language. http://www.w3.org/XML/
XML Schema (2006). http://www.w3.org/XML/Schema
XPDL. (2005). XML Process Definition Language. WFMC-TC-1025.WfMC. Oct. 2005. URL: http://www.wfmc.org/standards/xpdl.htm

12

The Reputation Crisis: Risk Management based Logical Framework to the Corporate Sustainability

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1. Introduction

The corporate reputation is an integral part of its overall performance. In this chapter, we argue that a stronger link should exist between risk management and corporate reputation in sustainable way. In view of the modern corporate risk management, reputation is the part of the risk intelligence based process management. This chapter is prepeared about managing corporate reputation with proactive process in the pre-crisis, crisis and pro-crisis situation. Managing reputation is not one time process. Our inspiration to this model comes from Weber's conceptual framework for modern sociology.

Managing reputational crisis is an integral part of ongoing risk management to corporate sustainability.

In today's globally warmed business environment the corporate reputation is closely tied to triple bottom line concept which includes economic, operational, environment and social performance. Corporate reputation is the most important value for business while it the part of good corporate governance. Reputation crisis affects the entire organization Management of the enterprise-wide (corporate) risks requires systematic approach via new business strategies to todays globally warmed business environment. Crisis that is process is the unexpected situations which affects on corporate reputation. The main research question is: "How is the best way to manage reputation crisis via ongoing process management approach?" Crisis arises from external and/or internals causes of the corporates. Crisis situations have a potential of the affect on both brand and reputation of corporates. Crisis situations offers opportunities that are why the modern risk management based approach should be implement in ongoing way to manage reputation effectively. In view of the modern corporate risk management, reputation crisis is the part of the risk intellience based process management. This is ongoing process which is not implay in the crisis situation. Reputation is strategic risk for companies and it should be manage all time. Corporate risks and their impact on reputation must be managed by managers to stay sustainable and competitive in globally warmed business environment.

We aimed to offer Risk intelligence based ongoing new logical framework to the reputation crisis which is the important risk to corporate sustainability. Reputation crisis requires logical framework to achive corporate sustainability via modern risk management based approach. The modern corporate risk management considers country or local risk. Country/local risk has direct impact on shaping (tailoring) framework to manage corporate reputation crisis. Our framework aimed to provide also, a clear social map which need to effective management of the reputation crisis. For this aim, our conceptual framework starts with the anaysis of the company's socio-cultural environment. In this point, Max Weber's ideas guided us to draw logical framework. Max Weber has been provided major contributions to sociology. By other words, Max Weber, is the founder of modern sociology as a distinct social science. He offered a philosophical basis for the social sciences, a general conceptual framework for sociology, and a range of learned studies covering all of the great world religions, ancient societies, economic history, the sociology of law and of music, and many other areas (Gordon, 1998). In the same way, we tried to do this exactly. We have been developed both the risk intelligence and logical framework. Modern sociology framework that founded by Weber is requires continious development to adopt environmental changes. Similarly, reputation management efforts framework needs adapt to the changes within their environment. For this reason, we have developed new *"Risk intelligence based ongoing logical framework to the reputation crisis"*. This characteristic provides a modern management framework to reputation crisis via ongoing risk management process alike Weber's conceptual framework to modern sociology. Our chapter intends to set bridge between the modern risk management and reputation crisis field since reputation is one of the most important risk for organizations in competitive business environment.

The business strategies about reputation crisis should be applied in the modern corporate sustainability risk management concept. We assumed that, the modern risk management embraces all corporate risk in the triple bottom line concept: environmental, financial and social risks. All of these risk categories has impact on corporate reputation. These risks can be reason to reputation crisis. Corporate risk map is the critic point of this topic. Corporate risks must be managed via ongoing modern process framework. Otherwise, costs of the crisis inreases for corporates. The most threaten cost is the reputation damage for companies. Also, Crisis situations are the risk factor in view of corporate sustainability.

The implementations of the risk management have both critical and strategic importance to manage corporate reputation crisis situations. It is assumed that, crisis situations have a strategic role in view of seeing opportunites in the crisis and the seizing of these opportunites towards corporate sustainability. Its purpose is the development of rigorous frameworks to manage corporate risks 8includes crisis situations and business continuity) successfully.

The proactive crisis management activities include forecasting potential crises and planning how to deal with them. There is important thing is organizations have time and resources to complete a holistic crisis management plan before they experience a crisis. Crisis management in the face of a current and potential, crisis includes identifying the real nature of a current and potential crisis and crisis sources risks, intervening to minimize damage and recovering from the crisis with proactive and corporate sustainability based approach. This conceptual framework is based on enterprise risk management concept. This model is offered to support reputation management efforts via risk management based perspective. Gaining a strategic view point for corporate via proactive crisis management framework is aimed with this research. A further aim of this study is the promotion of risk Intelligence.

We aimed to design "*The Proactive and Risk intelligence based ongoing logical framework to the reputation management.* The modern and logical framework has been developed by using verbal model in this research. We preferred a verbal model since risk management process have both qualitative and quantitative elements. The mission of our work is determined as to help manage reputation crisis via logical modern framework, advocating on their behalf in order to turn adversity into opportunity.

Proactive risk management practices support the effective handling of reputation crisis at the corporate level. We conclude, reputation crisis have serious potential to create cost. For this reason, reputation crisis is the important threat to corporate sustinability. It must be manage in the risk management concept. Several crises are reviewed to design logical and modern and holistic risk management framework. Also, risk management and crisis management frameworks are reviewed.

We tried to tie risk management to reputation management in modern logical way. Finally, the primary goal of this chapter in the book is to offer a logical modern framework to reputation crisis via holistic approach. The framework has ongoing processs approach.

Our new approach offers new process which has 3 main steps. Our framework has a flexible and dynamic composition. For this reason, it can be a living guide to manage corporate risks for managers in the sustainable way. Leading organisations in the globally warmed business world have risk/crisis management framework and crisis plans in place. Today, the next critical move is to make hollistic and full integration of these plans into a reputation risk management process.

We assumed that reputation crisis should be embedded in corporate risk management process. Corporate risk management highly interelated with business continuity and crisis management. Success level of crisis management highly depends on corporate risk management implementations holistically. Maximizing corporate reputation is possible via holistic management of the corporate risks in sustainable way. Integration of fundamental management systems is the key to effective management.

2. Corporate reputation risk and risk management

Reputation has intrinsic current value and shapes stakeholder behaviour to influence future value. A collection of perceptions and opinions, past and present, about an organisation which resides in the consciousness of its stakeholders (Rayner, 2004). Risk is a fundamental element of a company's sustainability strategy. The identification of the risk sources and theie analysis is critical. The relationship between the different types of risk, combination of the different types of risks and integrated affect of these risks should be considered in managing reputation both strategically and sustainable way (Joosub, 2006).

Risk management is a vital part of the internal management processes of the organization. Companies should set a strategy for reputation risk management, define the objectives, and set the metrics by which reputation damage is measured. Risks to reputation are then identified, prioritized, and treated. Because insurance is not available to protect firms against the loss of reputation value after a reputation damaging event, communication with the media and key stakeholders is discussed as a risk mitigation strategy (Regan, 2008).Risk management is essential to create value in volatile business world. In 2004, the Committee of Sponsoring Organizations of the Treadway Commission (COSO) issued its Enterprise Risk Management—Integrated Framework with this definition of ERM (see www.coso.org):

"Enterprise risk management is a process, effected by the entity's board of directors, management, and other personnel, applied in strategy setting and across the enterprise, designed to identify potential events that may affect the entity, and manage risk to be within the risk appetite, to provide reasonable assurance regarding the achievement of entity objectives."

Fig. 1. Creating Value through Risk Management (Accenture, 2009)

Risk management contributes to improvement of corporate reputation, but much depends on setting the right strategy with corporate-specific framework for a particular company. Shareholders influences pozitively since their business have risk management system. Many survey respondents are keenly aware of the reputational effects of good risk management. Asked how effective risk management confers competitive advantage on their organisations, significant minorities say that important areas in which it achieves this include better reputations among customers, rating agencies, shareholders and employees. For example, as trustees of pension funds push an increasing amount of money towards the managers of alternative assets (such as hedge funds) in the hope of generating higher returns, those providers that can define clearly their risk appetite and achieve sustainable returns within a strong risk management framework can expect to gain a competitive advantage over their rivals in terms of their relationship with these customers (PWC, 2007). Risk management can improve triple bottom lines of sustainability as well as company reputations (See Fig.1) (Accenture, 2009).

3. The science of corporate reputation management: reputation assest

> *"In the long term, an honest and fair approach to doing business willalways be the most profitable. And the business world holds such anapproach in much higher esteem than is generally imagined"*
> *(Robert Bosch, 1921)*

Crisis Management defined as the preparation and application of strategies and tactics that can prevent or modify the impact of major events on the company or organization. It is the way of thinking and acting when everything "hits the fan." At worst, crisis management can be the life-or-death difference for a product, career, or company (Caywood, 1997:189). Crisis has potential to do direct impact on corporate reputation. For this reason, crisis periods are indeed time of the reputation risk management for the managers in the competitive business environment. Crisis situations are risky process and it should manage timely manner.

Reputation Assest

Corporate Reputation is one of the critical intangible assest for companies as seen following list (Rayner, 2004):

- Leadership & governance
- People, skills and culture
- Innovation
- Intellectual property
- Brands
- Knowledge management
- Communication
- Business relationships
- Corporate reputation

Managing corporate reputation is vital for companies. A ''good reputation'' enhances the firm's transactional capacity; a ''bad reputation'' has negative consequences and a downside impact on the value of the firm to stockholders. Therefore, the risks generated by reputation can prove to be opportunities as well as threats. In fact, subjective and multidimensional approaches (consumer, product and situation characteristics) evidence that (Gaultier-Gaillard & Louisot, 2006):

- The concept of reputation is very broad and considered an intangible asset. The management of risks linked to reputation offers therefore long-term protection for brands.
- Brands are everyone's business in the firm and the same applies to managing risk to reputation. The management of inherent risks is transversal in essence.
- Reputation building is a long-term effort, a trust base on which the firm's image isforged and organized.

The organization's most important asset is at stake, their reputation. It is useless to conceal the truth from the public because eventually someone will blow the whistle. Firestone continued to sell faulty tires to the public when they knew there was a problem with the product. After many deaths, Firestone recalled millions of tires, and the public wondered how long Firestone knew about the problem. Now Firestone is on the verge of declaring bankruptcy and going out of business because they made poor crisis management decisions. Johnson & Johnson did not share the same fate as Firestone when crisis struck the company in 1982. One of Johnson & Johnson's well-known products, Tylenol was tampered with. Someone had been placing cyanide pills inside of Tylenol bottles, and it was killing people. Johnson & Johnson reacted quickly and pulled their product off the selves. Instead of suffering long-term damage to their reputation, Tylenol regained consumer confidence quickly because their crisis management plan told them to act in the interest of the consumer. Sometimes crisis management is used to protect a company from its customers. In 1991, a Pepsi customer claimed to have found a syringe in a can. Once the story hit the press, there were numerous reports of people finding screws, syringes and bolts in Pepsi cans. The Pepsi Company immediately denied that this was possible and that these claims were fraudulent. Pepsi started running ad campaigns against these incidents saying that they were "copycats" and Pepsi cans are "99.9% safe". This gave Pepsi enough time to discover what was happening. A grocery store surveillance camera caught a customer placing a syringe in the Pepsi can. Pepsi now had the proof they needed to refute the claims that their soda was unsafe to drink (Hayes, 2001).

The company's reputation highly affects corporate business result since It's both most valuable and intangible asset for corporates. Managing company's most valuable asset is one of the main subjects of corporate risk and crisis management in sustainable way. A business's reputation can influence (Rayner, 2004):

- Stakeholders' willingness to give a business the benefit of the doubt when a crisis occurs
- Investors' willingness to hold its shares
- Consumers' willingness to buy from it
- Suppliers' willingness to partner with it
- Competitors' determination to enter its market
- Media coverage and pressure group activity
- Regulators' attitude towards it
- Its cost of capital
- Potential recruits' eagerness to join
- Existing employees' motivation to stay

Corporate reputation is strategic asset and a source of economic value for investors. Research demonstrates that the essence of with stakeholders to build approval and appeal. Doing so requires putting in place a continuous loop of measurement and valuation, providing the underpinnings of a scientific approach to reputation management (Fombrun & Riel, 2004). Reputation management is concerned with knowing what people believe about organisation and ensuring they take actions that improve these attitudes to corporate benefit. A company's success may be determined solely by financial success (or failure) or outputs, but these things are actually dependent on what is known as reputation. Corporate reputations are determined by a variety of factors: leadership, finances, quality of products and services, operations, human resources, ethics, customers, business peers, and stakeholder and community engagement. Essentially, a person's attitude toward an organisation is based on their direct experiences of that organisation, their indirect experiences (what they know. about similar organisations), and their perceptions formed from second-hand information. (i.e. what other people tell them). The art of reputation management is ensuring the stakeholders. Experiences are positive and their expectations are well managed all the time. A good reputation makes people more likely to want to transact with an organisation as a customer, client, investor or stakeholder. (Senate Communication Counsel and TNS Global, 2007:7).

Corporate reputation is a growing factor in creating and maintaining corporate competitive advantage due to four trends in the business environment: the global interpenetration of markets, media congestion and fragmentation, the appearance of ever more vocal constituencies, the commoditization of industries and their products (Fombrun, 2005:303). According to the report of the Senate Communication Counsel and TNS Global (2007), every organisation in the survey thinks risks to their reputation are increasing. Internationally, executives identified direct threats to their reputation as the greatest risk their organisations faced. However, the Senate/TNS survey found that in New Zealand, only half as many bosses agreed, citing human capital risk as their main concern. This was followed by reputation, IT network issues and government regulation.

Risk management to corporate reputation provides support to track and evaluate reputation across a wide array of metrics including:

- Holistic Management and organization
- Strategic planning
- Business continuity planning (e.g., irregular operations, emerging risks)
- Competitive Innovation and differentiation

- Corporate culture
- Corporate relationship management
- Sustainability in Triple bottom line concept: social (e.g. corporate social responsibility), financial and environmental (e.g. environmental management systems, policy and prosedures)
- Personnel empowerment
- Stakeholder Relationships Management: Stakeholders are the new consumers. Leaving them out of the development and marketing mix is a missed opportunity and a huge risk to success (*Riggins, 2009)*.

What is the Reputation?

According to the Nuttall (2006), reputation is:
- an intangible asset
- greater than brand
- offering premium value growth opportunities to shareholders
- sum total of all stakeholders' experience

Reputation is the reason why people and organizations do business with company (Davies, 2002). Reputation is one of the most vulnerable values the corporations have to stay sustainable in the globally warmed business environment. Today, corporates focuses on stakeholder relationship management to sustain their process about sustainability. Corporate sustainability can be described as meeting society's expectation that organisations ought to add social, environmental and economic value to their conduct, products and services. It is therefore the continuing commitment by business to behave ethically and contribute to economic development while improving the quality of life of all involved stakeholders (Rensburg et al., 2008). Reputation is as much about *perception* and the perception of behaviors as it is about fact. It is about ethics, trust, relationships, confidence and integrity. It is built on the fundamental belief that management knows how to run its business and will win in the long term (Resnick, 2006). Reputation" is the perception of the corporation by the public (including the corporation's various stakeholders such as suppliers, customers, employees, local communities, etc.), and is a function of certain events exposing a corporate identity feature (a business practice, a behavioral incident, or a characteristic of the products sold) that was previously unknown to the public (The Conference Board, 2007).

True understanding of corporate reputation is critical to managing reputation crisis in the context of the risk management since identification is first vital step to holistic management process. From Fombrun and van Riel perspective, image and identity are the basic components of reputation. Their integrative perspective presents identity as the perception employees and managers – those inside the firm – hold of the nature of their firm. In contrast, image is the perception that external observers have of the firm. *Corporate Reputation is defined* as Observers' collective judgments of a corporation based on assessments of the fi nancial, social, and environmental impacts attributed to the corporation over time (Barnett et al., 2006:26-28). Corporate reputation is clearly different identity, image and capital (see Fig. 2.).

A corporate reputation is a stakeholder's overall evaluation of a company over time. This evaluation is based on the stakeholder's direct experiences with the company, any other form of communication and symbolism that provides information about the firm's actions and/or a comparison with the actions of other leading rivals. The relationships between the

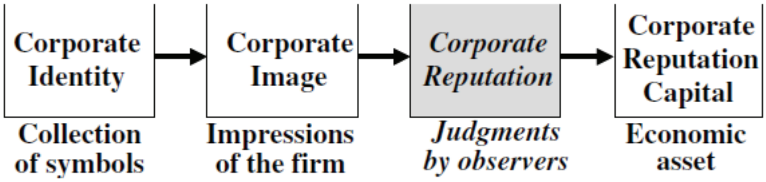

Fig. 2. Corporate Reputation: The Definitional Landscape (Barnett, M.L.; Jermier, J. M.; Lafferty, B.A. (2006). Corporate Reputation Review, Vol. 9, No. 1, pp. 26–38., Palgrave Macmillan Ltd, 2006).

corporate reputation that a company has with each of its stakeholders and the everyday corporate images that it projects, is schematically presented in Fig. 3 (Gotsi & Wilson, 2001). Once key stakeholder relations have been identified and categorized, management should analyze them from a situational and contextual point of view, so as to prioritize groups of stakeholders based on criteria including: their actual influence; the criticality, rationality, and urgency of their claims; their access to and control of key business resources; and the likelihood of their taking supporting action. (The Conference Board, 2007:13).

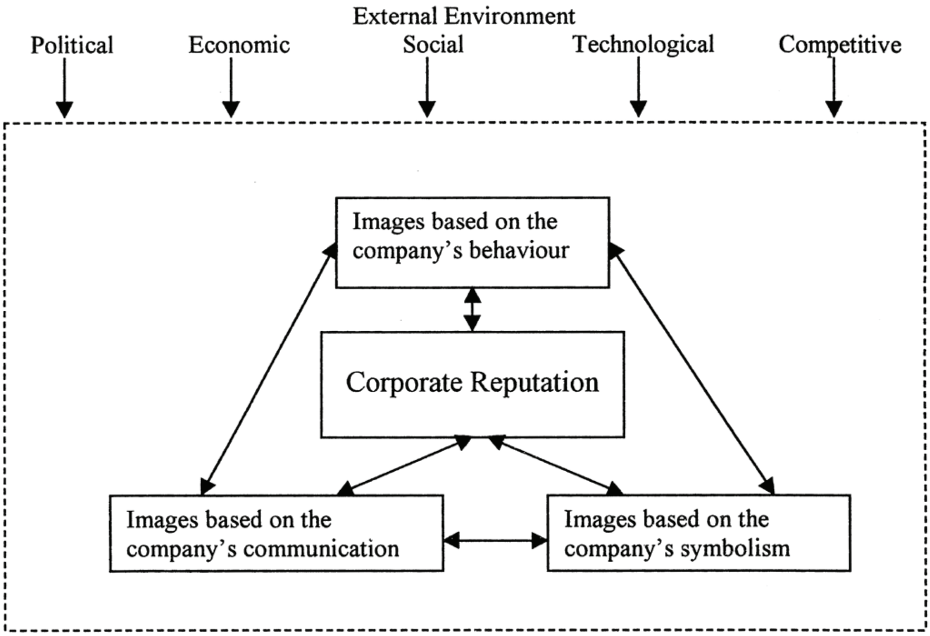

Fig. 3. Defining corporate reputation (Gotsi et al., (2001), Corporate reputation: seeking a definition, Corporate Communications: an International Journal, Volume:6, Number:1, 2001, pp. 24-30, MCB UP Ltd.

According to the Fombrun and Van Riel (2004), the value of a corporate reputation is magnified in a crisis because of the loss of physical assets and business momentum, the impact on people assets and the expected clear-up and associated legal costs associated.

(Fombrun & Van Riel, 2004, pp. 34-5). In order to protect and enhance their reputation capital, organizations must be able to rely on an enterprise-wide process that (The Conference Board, 2007):

- Maintains an asset inventory where the relationships constituting reputation capital are classified according to: their nature (i.e., enabling, customer, normative, peer, and special interest relations); the criticality, rationality, and urgency of stakeholders' claims; their influence on and control of key business resources; and their proneness to support corporate deliberations.
- Quantifies their intrinsic value, determines their propensity to be strategically deployed, assesses their impact on risk appetite (i.e., how much risk the business is capable of undertaking in the pursuit of its strategic vision), and evaluates their actual contribution to long-term business growth.
- Develops a set of extra-financial measures of performance appropriate to assess whether reputation-capital stakeholder relations are being adequately developed and deployed in the pursuit of the business strategy.
- Clearly communicates such information to the market.

Reputation Risk Management to Corporate sustainability provides sustainability in the economic, environmental, and social aspects of business in order to achieve a "sustainable company" target (See Fig. 4.).

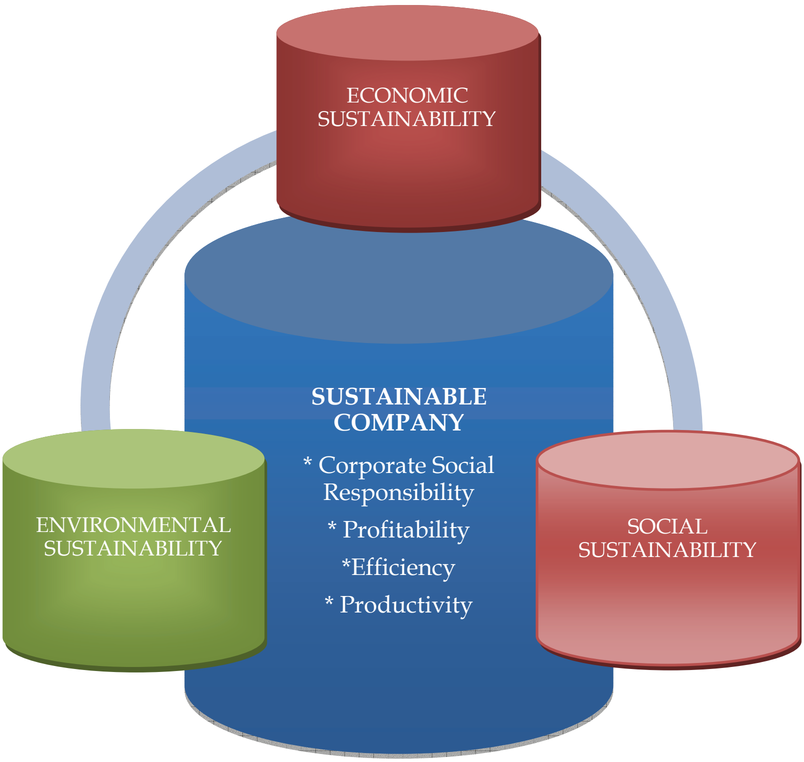

Fig. 4. Corporate Sustainability Components (Adapted from Nemli, E. (2004). Sürdürülebilir Kalkınma: Şirketlerin Sosyal ve Çevresel Yaklaşımları, Filiz Kitabevi, İstanbul, Türkiye).

Companies are beginning to understand the importance of building and protecting their reputation. Companies invest significant resources to understand how stakeholders feel, but very few measures the impact reputation has in shaping tangible business outcomes. By measuring return on reputation (ROR), companies can convert reputation from being an *intangible* asset to an asset with *tangible value* to the company. Reputation, and the efforts undertaken to protect and enhance it, have a measurable impact on several key factors that allow companies to succeed in the marketplace (Dumont, 2009):

- Creating a more favorable regulatory environment
- Managing risk, particularly in litigation and other crises
- Enhancing employee recruitment and retention
- Strengthening and differentiating the brand
- Improving company valuation

Reputation risk management should be integrated with Enterprise Risk Management (ERM) or other risk management programs in the organization. The value of reputation should be quantified to enable management to improve decision making regarding resource allocation to reputation risk management and to calculate a return on investment for those efforts. Employees should be used as corporate ambassadors to understand potential gaps in reputation. Organizations should develop an understanding of and build relationships with key stakeholders. Social networking and new media sites should be taken seriously and potentially monitored and engaged in to assess and influence stakeholder perceptions. Additionally, crisis management should be enhanced to take into account stakeholder emotions (Bayer & Hexter, 2009). The Corporate Reputation Quotient of Harris Fombrun is comprehensive measuring method of corporate reputation that was created specially to capture the perceptions of any corporate stakeholder group such as consumers, investors, employees or key influentals. The instrument enables research on the drivers of a company's reputation as well as comparisions of reputation both within and across industries. This business reputation model has the following 6 drivers of corporate reputation with subsequent 20 attributes: Emotional Appeal (Good feeling about the company, admire and respect the company, trust the company), Products and Services (Stands behind products/ services, offer high quality products/services, offers products/services that good value), Vision and Leadership (has excellent leadership, has a clear vision for future, recognizes/ takes advantage of market opportunities), Workplace Environment (is well managed, looks like a good company to work for, looks like it has good employees), Financial performance (record of profitability, looks like a low risk investment, strong prospect for future growth, tends to outperform its competitors) and finally, Social Responsibility (support good causes, environmentally responsible, treats people well).
(http://www.valuebasedmanagement.net/methods_corporate_reputation_quotient.html).

Stakeholder Relationship Management and Reputation Crisis

Reputation is patiently built on the history and the culture of the firm; therefore, deontology, corporate social responsibility, ability to internalize the concept of sustainable development, financial health, global strategy, and integrated risk management are among the key elements. However, even in the list given here, the importance of each of them in building stakeholders' trust varies substantially (Gaultier-Gaillard & Louisot, 2006). Stakeholders are the new consumers. Leaving them out of the development and marketing mix is a missed opportunity and a huge risk to success (Riggins, 2009). The Stakeholder Reputation Matrix illustrates some of the various groups that influence reputation. The potential for reputational distress from any one of these sources is inevitable during the life of a corporation.

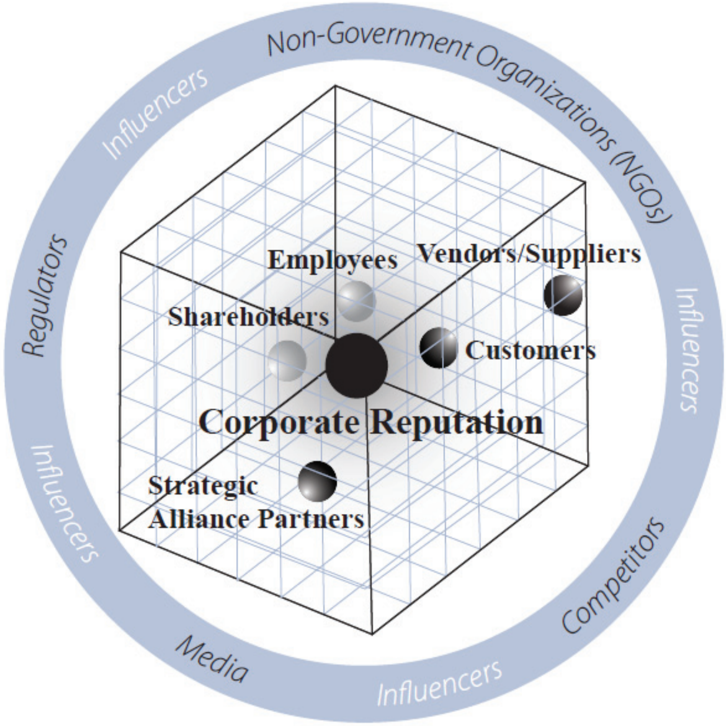

Fig. 5. Stakeholder Reputation Matrix. Resnick, Jeffrey T., (2006) Reputational Risk Management: A Framework for Safeguarding Your Organization's Primary Intangible Asset, Opinion Research Corporation, p.3.

4. Methodology: proactive and logical framework

" I would rather lose money rather than lose people's trust. The promises I make and reliability of my products are always more important to me than the short-term gains."
Robert Bosch

The link between corporate governance, risk management and reputation has been elusive for some time but it seems that the wake up calls have been numerous with financial scandals, terrorist attacks, natural event-induced disasters and technological catastrophes creating an unending chain of reminders of the complexity of the modern economy. Nobody now can ignore that long term development rests on a rational balance of risks, threats and opportunities, for their own merits and as a whole, to enhance the use of resources not only for this but also for future generations Gaultier-Gaillard & Louisot, 2006). Reputation management requires logical framework to achive corporate sustainability via enterprise risk management based approach. Enterprise risk management considers country or local risk. Country / local risk has direct impact on shaping (tailoring) framework to manage reputation risk. Our framework about Enterprise risk management provides a clear social map which need to effective management of the reputation crisis. For this aim, our conceptual framework starts with the anaysis of the company's socio-cultural environment. In this point, Max Weber's ideas guided us to draw logical framework.

Weber's perspective to developing new logical framework

According to Weber (1905), social action depends on the human subject who can select proper tools to achieve objectives. The individual (human) is able to create history since he is capable of creating his own realities. Social action is directly intended for the human subject who is the individual in the cultural process. We can adapt this idea to corporate sustainability. The organizational transformation is one of the key elements of corporate sustainability. Weber emphasized the "approche compréhensive". In Weber's opinion (1905), the ability to be comprehensive is important. The manager who has a comprehensive ability has power to have an impact on the economic dynamics of the business world. This shows the necessity to incorporate Weber's ideas into those of risk management. Max Weber provided major contributions to sociology. He has been described as the founder of the general conceptual framework of sociology as a science. He developed a consistent social science philosophy. In the same manner, we have developed a consistent risk management philosophy based on a new logical framework to corporate sustainability. The modern sociology framework that was founded by Weber, requires continuous development in order to adapt to environmental changes. Similarly, the risk management framework needs to adapt to the changes within the globally warmed business environment. For this reason, we have developed a new conceptual framework that has a flexible and systematic composition. This characteristic provides a modern framework to the risk management process. Our inspiration comes from Weber's conceptual framework for modern sociology.

Fig. 6. Main Steps of Reputation Risk Management Model

The effective management of corporate reputation across various stakeholders such as employees, suppliers, shareholders, regulatory bodies and general public requires specific and targeted strategies. A strong corporate reputation generates confidence which leads to long term competitive advantage. A strong corporate reputation can power a company's success by (Huber, 2009):

- providing easier a ccess to capital markets and attracting financial resources
- attracting, motivating and retaining talented employees
- facilitating price premiums, up- or cross-selling opportunities and new product launches

- gaining new customers
- leading to public goodwill and positive references.

The purpose of the Risk Management based Logical Framework to the Corporate Sustainability is to support the management of corporate financial, environmental and social responsibilities and the achievement of the corporate outputs and deliverables about corporate reputation via new systematic and hollistic process. The aim of this model (see fig. 6) is offer a framework for integrating reputation risk into corporate risk management in sustainable way.

Applying principles from the risk management to the management of reputational crisis provides both holistic and executive management with a framework. This framework is the valuable process to maintain and enhance corporate reputaion via best handling risks about corporate sustainability. This framework (see figure 8) aimed to support business continuity in time of crisis. Stakeholders can rely on the continuation of services from the company even in times of crisis.

Corporate reputation becomes increasingly dependent on an organisation's ability to executive an organizational model. Execution results in a good reputation and correlates highly with strong financial performance and overall success. Therefore a favourable organization reputation delivers financial payoffs (Le Roux, J R J, 2003). Potential benefits of corporate reputation risk management clearly shows necessity of its implemantation for us. Benefits of reputation. The benefits of holistic, proactive and systematic reputation risk management are identified by Rayner as following (Rayner, 2004):

- Builds stakeholder trust and confidence
- Maintains 'licence to operate'
- Attracts investment
- Boosts customer and supplier loyalty
- Reduces regulatory intervention
- Creates barriers to entry
- Facilitates premium pricing
- Enables recruitment/retention of the best
- Provides a store of reputational capital that protects against future crises

According to the Gaultier-Gaillard and Louisot (2006) all the recommendations and expectations listed above can be summarized in one simple commandment that stresses the link between trust and reputation: promote a virtuous circle of reputation building (Fig. 7).

Corporate Reputation risk Management Framework Model

There is, main steps of the framework are described in fundamental context.

In our model, Initial step includes to determination of the Corporate Objectives & Stakeholder Expectations in the following context:

- Corporate objectives
- Stakeholders' expectations: Identification and Dialogue
- Core Processes
- Key dependencies
- Risk as uncertainty
- Priority relationships
- Organizational competence
- Corporate Risk appetite
- Corporate Risk tolerance, threshold

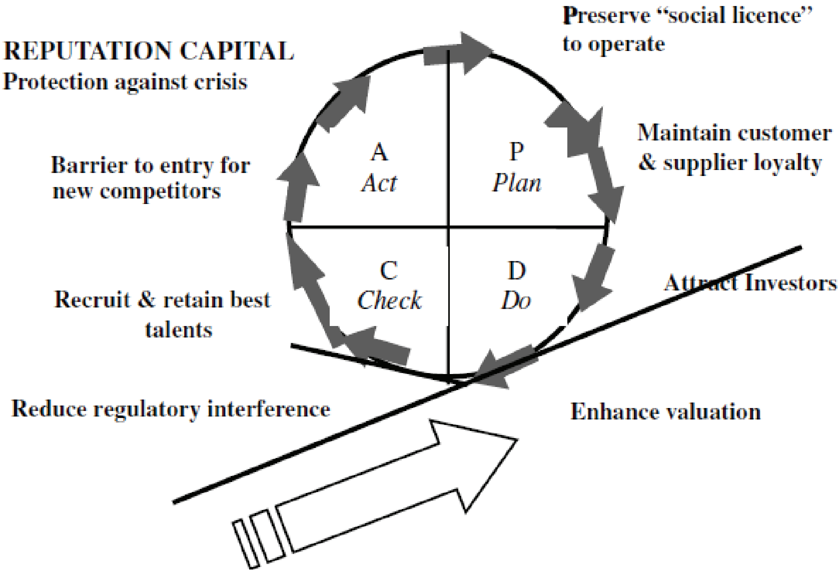

Fig. 7. Building stakeholders' trust. (Gaultier-Gaillard & Louisot, 2006). The figure developed by the authors and the students of the DESS Gestion Globale des Risques Universite' Paris 1 Panthe'on/Sorbonne – the Deming wheel of continuous improvement with the reputation capital to block roll backs.

In the first step, General attitudes and perceptions to reputation and risk management is determine by managers. Reputation should be well understood by throught of the organization.

- **Setting of Socia-cultural-financial Corporate map: analysis to corporate culture**
  - A kind of swot analysis to corporate structure about awarenes of risks to reputation and crisis situations
  - Corporate culture is a fundamental for long-term strategies according to our framework. Initial step involves mapping corporate culture, building communication strategy building information management system within the company for identifying reputational issues among the both external and internal stakeholders of company.
- **Setting relationship between risk and interested parties:**
  a. Reputational risk and customers
  b. Reputational risk and employees
  c. Reputational risk and shareholders
- **Establisment of The Reputation in a strategic context**
  - Internal Assests
  - External Assests
  - Market Assests
  - Performance analysis
- **Building crisis communication strategy**
- **Establisment of the Crisis information management system**
- **Public relations based organization: crisis committe and function**

Fig. 8. New Corporate Reputation Risk Management Process

In the second main step, Analysis and Implementation step includes;

- **Identify and prioritize the risk of reputation crisis factor and their resources**

If managing risks to reputation is to be efficient, the first step is to identify those risks. One can manage only what one knows. Therefore, a formal brainstorming exercise should be conducted to identify what makes the ''uniqueness'' of the entity. it is vital to mitigate the risks inherent to the company's core competencies if one is to manage effectively the risks to reputation (Gaultier-Gaillard & Louisot, 2006). Risks to reputation can arise from many sources the major drivers. Key sources of risk to reputation are listed as following (adopted from Rayner, 2004 and Joosub, 2006):

- Financial performance, long term investment value and profitability
- Corporate governance and ethical behaviour
- Communication and public relations
- Crisis management
- Corporate Social Responsibility
- Workplace talent and corporate risk culture
- Regulatory compliance
- Delivering stakeholder promise (e.g. customer)
- Employees and key manager's decisions
- Product/Professional liability
- Product recall and litigation
- Marketing innovation and customer relations
- Stakeholder relationships

Key risks organisations believe they face identify in this step as following (Senate Communication Counsel and TNS Global, 2007)**:**

® Financing risk
® Reputational risk
® Credit risk
® Terrorism
® Market risk
® Foreign exchange risk
® Natural hazard risk
® Crime and physical security
® Political risk
® Regulatory risk
® IT network risk

According to the Rayner (2004), Identifying reputational risk is "Any event or circumstance that could adversely or beneficially impact an organisation's reputation". For this reason identifying of impact severity of risk is important as well as identifying risk and its source. Potential reputational events should be examined at three levels: those that impact the industry, the enterprise, and the business unit. The most critical reputational events to track are those having the potential to impact all three (Resnick, 2006). (See Fig. 9)

- **Prioritize reputational risk elements: factors influencing quality of corporate reputation**

Factors influencing quality of corporate reputation is determined by Senate Communication Counsel and TNS Global, (2007). These should consider as sources of reputation risks. They are:

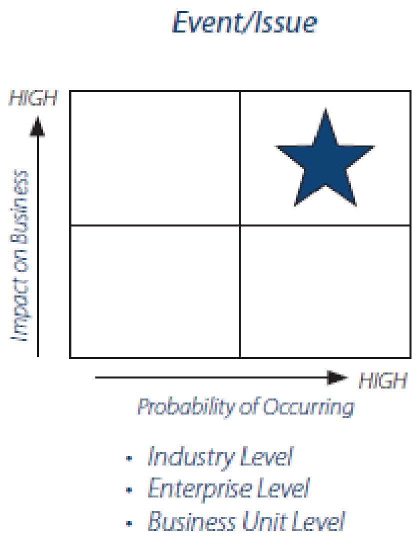

Fig. 9. Risk Matrix (Resnick, J T., (2006). Reputational Risk Management: A Framework for Safeguarding Your Organization's Primary Intangible Asset, Opinion Research Corporation, p.13. Retrieved 10/08/2009 from http://www.carma.com/Reputational_Risk_White_Paper.pdf.

- Theorganisation's sponsorship programme
- Exposure of unethical practices
- Poor crisis management
- Non-compliance with regulation/legal obligations
- The category of business/industry in which you operate
- Security breaches
- Failure to address issues of public concern pro-actively
- Environmental breaches
- The organisation's level of innoation
- Failure to hit financial performance targets
- Known level of the learders by public both nationally and internationally
- General public perception about corporate employment treatment

Risk Analysis

One useful qualitative tool is a risk map for reputation risks. This requires the firm to assign a score to the expected frequency of a reputation event and the expected severity of the reputation damage that might occur. Figure 10 illustrates a simple risk map with frequency on the x-axis and severity on the y-axis. When mapping frequency, the firm needs an estimate of the likelihood of the underlying event occurring, and the likelihood of reputation damage conditional on the event happening. (Regan, 2008)

To assessment of the corporate reputation related risks as:

- **Decide what strategy to take**
  - Terminate?

- Transfer?
- Treat?
- Tolerate?
- Transform?

- **Decide how to manage the risk to rebuilding stakeholder confidence and restructuring credibility,**
  - Control effectiveness?
  - Current risk score?
  - Residual risk - target score?
  - Action Plans?

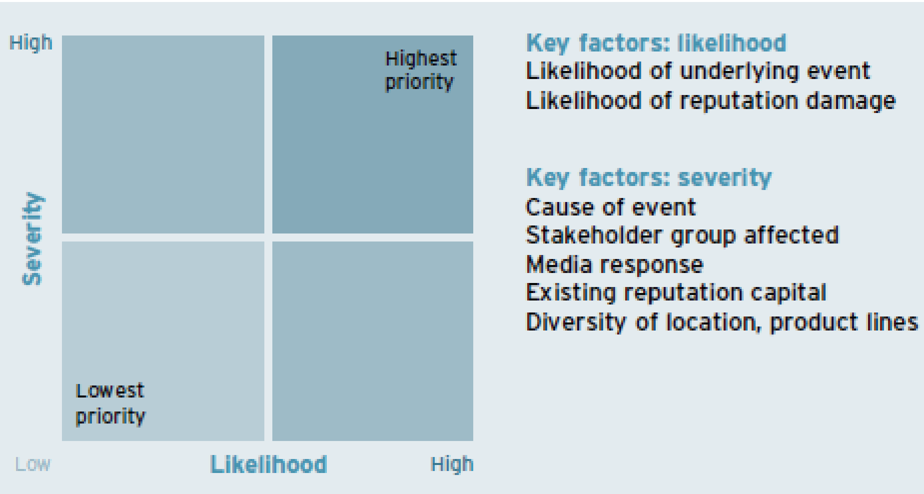

Fig. 10. Risk Map (Regan, 2008)

- **Analysis risk the impact to reputation**
  - If there is reputation damage, management put into practice their risk management strategies to revise of damage on corporate reputation
  - If risks don't impact on reputation, management provide risk management strategies continually improved and updated with emerging and transformed events.

Prioritization of stakeholders is an equally important exercise, especially because an enterprise is unlikely to have sufficient resources to audit all possible groups (which is not a recommended course of action). Available resources must be focused among stakeholders having the greatest impact on a business. Negative word-of-mouth communication from any of these groups on a frequent basis can result in significant reputational damage. Each enterprise is unique, however, and different stakeholders may emerge as more or less important to an entity. The situation becomes even more complex when considering the role of tangential stakeholders such as regulatory authorities and NGOs (nongovernmental organizations). These stakeholders wield the ability to carry enormous influence under certain circumstances. For this reason, a company should conduct its own stakeholder prioritization process (Resnick, 2006). Business managers should be highly aware of the stakeholder's concern and demand when setting a reputation strategy since corporate reputation includes the analysis of the different stakeholders. Hollistic perception is one of the critical challenges for managers. Stakeholders play a role and have an impact on corporate reputation.

In the final step of the model, Auditing & Monitoring & Reporting step includes;

- Review and make improvements from lessons learnt

Also, the new model includes assignment and collaborative efforts as following:

- Assignment of the Roles and Responsibilities
- Do collaboration with between all management departments to provide holistic reputation management: crisis management department, public relations and risk management department, financial management, human resource, etc. High level managers alike risk managers are responsible to set and implement the model.

Business environment is constantly changing; also strategy-setting is a dynamic process that never ends. The same applies to risk management to reputation crisis. These activities foster the delicate alignment of strategy, communication and leadership that drives positive reputation in both good and bad times. Communication that makes an organization transparend enables stakeholders to appreciate the organization's operations better and so facilitate ascribing it a better reputation. To build and sustain a good reputation, corporates must commit to following principles (Le Roux, 2003):

To make a corporate reputation strategy part of the overal business plan, so that everyone within the organization can understand what elements of the general business process have an impact on corporate reputation. This will have a positive impact on the organization's reputation.

i. To identify the financial management issues that to an organization's corporate reputation, and where possible to manage elements that undermine corporate reputation actively.

ii. To understand what the corporate marketing elements are that influence corporate reputation, in terms of the image that needs to be portrayed to the vaious stakeholders of the organization and the most effective incorporation and use of the marketing mix in terms of building the corporate reputation.

iii. To have a clear understanding of the corporate communication elements that influences the corporate reputation. To build a corporate culture that attracts top talent. Organizations with positive reputations are able to attract employees of high calibre, who in turn have a positive impact on the organization's reputation. It is necessary to have an understanding of corporate social responsibility; to devise a crisis management strategy to defend corporate reputation. These will enable the organization to be proactive in protecting its reputation in crisis times as well as to disseminate the organizational "story" to internal and external stakeholders. This will enable stakeholders to have a clear understanding of what exactly the organization is and what they can expect from it.

Corporate reputation management is conducted using an array of sophisticated tools and techniques including competitive benchmarking, reputation scorecards, key performance indicators, journalist surveys, media content analysis, new media measurement, PR research, stakeholder evaluation, internal communications measurement, opinion polls, omnibus surveys, and crisis research. Tools and techniques, such as thought leadership studies, reputation survey and analysis, PR and communications measurement and rating methodologies, stakeholder research and corporate image surveys can all be designed to support corporate reputation management (Echo Research, 2009).

5. Conclusion

Risk is a constituent part of both the business and the society in which we survive. Reputation is valuable assest for corporates in sustainable way. Integrating risk management with strategy-setting, such as an enterprise risk management (ERM) approach, helps an organization manage its risks to protect and enhance enterprise value in three ways. First, it helps to establish sustainable competitive advantage. Second, it optimizes the cost of managing risk. Third, it helps management improve business performance. These contributions redefine the value proposition of risk management to a business (Gibbs, 2006).
Maintain and enhancing of the corporate reputation is the most important and difficult process facing corporate risk managers. The leading companys ensures that the risk management to corporate sustainability and reputation crisis is embedded throughout the whole organization. The risk management process follows logical sequence just as any business process will. Corporates can create advantage to competition via reputation risk management. Reputation provides improvement of the competitive positions in their business environment both internally and externally. Our proposed process model can contribute in both risk management and reputation management field. This model can improve according to the company specific needs. For this reason, this fresh framework can give inspire to business managers to set their corporate reputation and risk management systems in a sustainable way. Trust and interactively understanding is core of the corporate reputation. For this reason, corporate reputation is topic of the strategic risk management. Reputation is strategical issue.
Reputation impact on throught of the organization should measure and score with risk analysis. To effective managing of corporate reputation,

- Risk management approach should be consider by managers,
- Reputation should be considered as an organisational asset.
- Reputation crisis should be considering one of the important strategic risk to any organization.
- key reputation drivers should identify in the concept of risk management process
- Risks about reputation crisis should be prioritize by managers such as failure to deliver product or service to the expected standard and timely manner
- Risks about reputation crisis should be analysis in view of corporate governance principles and ethical practices.
- Crisis must be analysis in view of impact of corporate value and reputation
- Holistic framework as systematic and dynamic process should develop to managing risks about reputation crisis.
- Proactive and risk management based approach should active in enhancing and protecting corporate reputation
- Risks involving a corporate reputation should monitor and identify in timely manner
- Resource allocation is important to risk management which includes reputation crisis

This chapter aimed to offer both a logical and proactive process for managing corporate reputation via risk management based perspective. The model has 3 main steps as initial, implemantation &analysis, monitoring, reporting & reporting. Each main step of the process has several sub-steps. These are listed in article. The model based on framework of existing ERM guides and standards. We suggest that reputation assest should be managed with risk management based proactive approach since corporate reputation is issue of the risk management to enhance and maintain corporate value.

6. References

[1] Accenture, 2009. Managing Risk in Extraordinary Times: Strategy for High Performance. Retrieved 10/21/09 from http://www.accenture.com/Global/Consulting/Finance_and_Performance_Mgmt/Risk_Management/Research_and_Insights/ManagingPerformance.htm.

[2] Bayer, Daniel Sandy and Hexter, Ellen S. (2009). "Managing Reputation Risk and Reward," The Conference Board, 2009. Retrieved 10/08/2009 from http://www.mgt.ncsu.edu/erm/index.php/articles/entry/reputation-manage-risk/

[3] Caywood, Clark L. The Handbook of Strategic Public Relations & Integrated Communications.McGraw-Hill Companies, NY, 1997.

[4] Corporate Reputation Quotient, Mart 25, 2004, http://www.valuebasedmanagement.net/methods_corporate_reputation_quotient.html

[5] COSO, (2004), Enterprise Risk Management- Integrated Framework. Retrieved 10/21/2009 from http://www.coso.org/documents/COSO_ERM_ExecutiveSummary.pdf.

[6] Cottrell, G., & Rankin, L. (2000, 17-18 April 2000). Creating Business Value Through Corporate Sustainability. Paper presented at the US Gold Institute Annual Meeting, Palm Springs, USA.

[7] Davies, David. (2002), risk Management – Protecting Reputation: Reputation Risk Management- The Holistic Approach, Computer Law & Security Report Volume 18, Issue 6, November 2002, Pages 414-420.

[8] Dumont, Bryan (2009), Measuring Your Return on Reputation, As appears in PR News' Guide to Best Practices in PR Measurement (2009), APCO Worldwide, Retrieved 10/08/ 2009 from http://www.apcoassoc.com/content/viewpoints/commentary.aspx

[9] Echo Research, (2009). Corporate Reputation Management, Retrieved 10/26/2009 from http://www.echoresearch.com/en/services/corporate-reputation-management/.

[10] Fombrun, Charles; Ries, Ces van (2004). Managing Your Company's Most Valuable Assest: Its Reputation, CriticalEYE Publications Ltd. 2004, September - October 2004. Retrieved 10/12/2009 from http://www.rsm.nl/portal/page/portal/RSM2/attachments/pdf1/Crital%20eyes-Managing%20Your%20Company's%20Most%20Valuable%20Asset.pdf.

[11] Gaultier-Gaillard, S.; Louisot, J P. (2006). Risks to Reputation: A Global Approach. The Geneva Papers, 2006, 31, (425–445). The International Association for the Study of Insurance Economics.

[12] Gibbs, Everet (2006). Which comes first ... managing risk or strategy-setting? Both! Effectively integrating risk. Financial Executive, January 01, 2006. Retrieved 10/14/09 from http://www.allbusiness.com/accounting-reporting/reports-statements/855633-1.html

[13] Hayes, John (2001), Crisis Management in Public Relations, Student Project, Interactive Media Lab, College of Journalism and Communications, University of Florida, spring 2001, http://iml.jou.ufl.edu/projects/Spring01/Hayes/ Retrieved at June 19, 2009.

[14] Huber, M. 2009. Corporate Reputation Management. TNS Global, Retrieved 10/20/2009 from

http://www.tnsglobal.com/_assets/files/Stakeholder_Management_Sales_Sheets_Corporate_Reputation_Management.pdf

[15] Joosub, T.S. (2006). Risk Management Strategies to Maintain Corporate Reputation, Master Thesis, Master of Commerce, Business Management, University of South Africa, 2006.

[16] Le Roux, J R J, (2003). Corporate Reputation in the Information Technology Industry: A south African Case Study, Thesis, Faculty of Economic and Management Sciences, University of Pretoria, 2003.

[17] Nuttall, Vicki. (2006) Managing Reputational Risk, Australasian Universities Risk and Insurance Management Society, Publications, 2006.

[18] PwC, 2007, "Creating value: effective risk management in financial services," PricewaterhouseCoopers

[19] Rayner, (2004).Managing Reputational Risk, APM/IRM, Manchester, 5th February 2004, Abbey Consulting. Retrieved 10/30/2009 from http://www.theirm.org/events/documents/managing_reputational_risk_jrayner.pdf.

[20] Regan, L. (2008). A Framework for Integrating Reputation Risk into the Enterprise Risk Management Process, Journal of Financial Transformation, 2008, vol. 22, pages 187-194.

[21] Rensburg, R.; Beer, E. De; Coetzee, E. (2008), Linking Stakeholder Relationships and Corporate Reputation: A Public Relations Framework for Corporate Sustainability, Public Relations Research, Part IV, VS Verlag für Sozialwissenschaften, pp. 385-396, 2008.

[22] Resnick, Jeffrey T., (2006) Reputational Risk Management: A Framework for Safeguarding Your Organization's Primary Intangible Asset, Opinion Research Corporation, Retrieved 10/08/2009 from http://www.carma.com/Reputational_Risk_White_Paper.pdf.

[23] Riggins, Phil (2009). How stakeholders Have Become the "New Consumers", As appears in PR News' Guide to Best Practices in PR Measurement (2009), APCO Worldwide, Retrieved 10/08/ 2009 from http://www.apcoassoc.com/content/viewpoints/commentary.aspx

[24] Senate Communication Counsel and TNS Global, (2007), Managing Reputation in New Zealand, Retrieved 10/08/ 2009 from www.senatecommunications.co.nz/.../Reputation_Management_Report-FINAL.pdf.

[25] Weber, M. (1968). Economy and Society. Translated and edited by Guenther Roth and Claus Wittich. New York: Bedminster Press.

[26] Yıldırım, Ö. (2009). Sosyolog Max Weber ve Sosyoloji, (Sosyoloji, Anthony Giddens) Retrieved 08/26/2009 from www.felsefe.gen.tr/sosyolog_max_weber_ve_sosyoloji.asp.

13

Planning Approaches to the Management of Water Problems in Mexico

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1. Introduction

Water scarcity is a worldwide issue. March 22nd has been declared by UN-Water& FAO, as the world water day. The 2007 world water day theme was "Coping with water scarcity". Water scarcity is defined as the point at which the aggregate impact of all users impinges on the supply or quality of water under prevailing institutional arrangements to the extent that the demand by all sectors, including the environment, cannot be satisfied fully" (UN-Water & FAO, 2007, p.). Although scarcity could be a social construct or the consequence of changing patterns in water supply, there are many options of being remedied or alleviated. Traditionally, it has been addressed through supply or engineering oriented solutions more than enforcing conservation options. Supply oriented approach assumes that water scarcity problems only exist when there was not enough water to meet social and productive demands. Increasing water supply infrastructure solves the water shortage problems. Under this approach, the main problem is how to identify a need and then how to make water available. As a consequence, dams, reservoirs and facilities for meeting these increasing human needs have been built, and rivers and streams diverted. Currently, 45 000 big dams, plus another 800 000 smaller ones have been built (MEA, 2005). Although this infrastructure building has brought about positive effects, negative effects have also been perceived. For humans, positive effects have been in terms of stabilizing flows for use in irrigated agriculture, flood control, drinking water supply and hydroelectricity production. Negatives effects are given in relation to capital costs per cubic meter of new supply are doubling every decade, environmental effects are more severe, and adverse effects on indigenous peoples are no longer acceptable (MEA, 2005). As a consequence of these effects, the water supply model was restructured in the Johannesburg World Summit on Sustainable Development in 2002. In fact, the failure of this model was recognized by the World Bank long time ago, during the Ninth Irrigation and Drainage Conference in 1992. Since this conference, it was recommended the need to change this approach. Two key constraints of this approach were pointed out, namely the increasing scarcity of water and the higher costs of projects both in technical and environmental terms. Furthermore, it was also recognized that a focus on the technical supply issues and less on how water was used and disposed of, left open the expectations that additional quantities of water supply could always relieve scarcity (Easter, et al. 1992). Although in Mexico, this approach has been reviewed as a consequence of the increasing costs necessary to exploit new water sources, in practice it still continues to be the favorite. The National Hydrologic Plan 2007-2012 (CONAGUA, 2007) promotes the demand and integrated approaches, provided that water quantity and quality issues are critically emerging. However, the results so far achieved indicate that the supply oriented approach is still supported, despite problems like scarcity, competence and mismanagement are becoming sources of conflicts. This chapter's aim is to provide an overview of how the planning approaches to water management have been implemented in Mexico and to what extent they have resolved critical issues like scarcity. This overview is basically supported on document review that has been published about water management approaches, as well as in official reports that the Mexican government has released. Although this chapter addresses the issue of scarcity in terms of planning, it would be worth exploring it since the social scarcity capacities. Because this perspective sustains that most than the physical problem, it is the intellectual base which constraint the development water based. The development of this social scarcity capacity will also help to face critical problems related to the ecosystem demands in terms of environmental flow and not least important, the variability climate change will pose on water availability.

2. Planning approaches for water management

In Mexico and worldwide, three main planning approaches have been implemented to manage water problems. Such planning approaches are: Supply oriented approach, demand oriented approach and integrated/holistic approach.

2.1 Supply oriented approach

For more than three centuries, and until the 1950s and 1960s, water management was designed to satisfy the basic functions of health and food production (Grigg, 1996; White, 1998). Policymakers were traditionally driven to manage water to make it available to people for these purposes (Al Radif, 1999). Under this approach, the main problem was how to identify a need and then how to make water available. These needs were purely conceived as a result of population growth and agricultural and economic development, and not as policy issues (Hoekstra, 2000). A common assumption of this approach was that water shortage problems only exist when there was not enough water to meet social and productive demands. Furthermore, water availability only should be assessed in qualitative and quantitative terms. Increasing water supply infrastructure solves the water shortage problem. At the international scale, the supply approach was behind the massive expenditure of the Water Supply and Sanitation Decade project. This project was designed to provide safe water and sanitation services worldwide to 1 300 million people without access to these services. However, the worldwide problem of water shortage was not solved. Despite the activities initiated during this decade, by the end of the 20th century, approximately 1.2 billion people still remained without access to safe drinking water, and 2.4 billion lacked adequate sanitation services (Dieterich, 2003). Also, it has led to over-use of the resources, overcapitalization, pollution and other problems of varying severity (Sharma & Vairavamoorthy, 2009).

For these reasons, the water supply model has been severely criticized. Certainly, the first Water Supply and Sanitation Decade was a landmark for the supply-oriented approach. However, the evaluation on how the inadequacy of institutional arrangements for water management proved the basis for new arrangements more similar with a demand oriented approach. These changes can be appreciated in table 1.

Institutional arrangements in the supply oriented approach	Institutional arrangements in the demand oriented approach
Water development	Water allocation
Emphasis on water quantity	Emphasis on water quantity or quality-quantity
Water and sanitation as basic human needs	Water and sanitation as basic human rights
Water as a social good	Water as an economic good
Centralized management and administration	Decentralized management and administration
Government provision	Government facilitation
Administrative domain	Service provision
Water supply	Water services
Production orientation	Customer orientation

Table 1. From supply oriented arrangements toward demand-oriented arrangements for the UN Water Decade 1980s, 2000 (adapted from Sepala, 2002)

2.2 Demand oriented approach

Water demand management has been defined as an approach that encourages the efficient use of existing water supplies, rather than developing new ones. It proposes that this can be achieved through policy, which involves ethical, economic, educational and technological consideration (Van der Merwe, 1999, cited in Schchtschneider, 2000). The logic of this approach is that as water availability is limited, demand cannot continue to increase, and water needs should be satisfied with the available resources (Hoekstra, 2000). Under this approach 'needs' and 'wants' means different things. Water use is a 'need' if it is related to the fulfillment of basic needs, and in principle, these needs cannot be manipulated because they exist independently of economic or political status. But the 'wants' for water imply additional water based goods and services, and then they are considered a luxury and largely subject to social and political desires. At the community level, water 'wants' are though to be largely a function of customs and human behavior, which may change through an improvement of environmental awareness or through the imposition of water taxes (Serageldin, 1995). The demand-oriented approach was the slogan that characterized the international water policy and strategies of the 1990s, which were discussed in the most important international forums. In the Third World Water Forum held in Kyoto in 2003, it was recognized the potentials of this approach and promoted it, in order to improve the economic performance of the water industry. In this forum, water was valued as an economic good and as consequence there was a need to move towards pricing it in order to recover the cost of service delivered (The United Nations, 2003). In summary, the demand-oriented approach seeks to achieve the satisfaction of the water needs by improving the efficiency of water use rather than by increasing its supply. This approach places water demands themselves, not structural or engineering solutions, at the centre of concern. It recommends the development of large, capital-intensive structures only after other possible options for lowering or mitigating the proposed water demands have been fully analyzed. It represents the cheapest form of easily available water, particularly in areas where additional demands are being placed on water resources that are already stretched to their limit (Baumann et al., 1998; Butler & Memon 2006, cited in Sharma & Vairavamoorthy, 2009). In the pursuit of efficient water use, market mechanisms and private sector participation would be allowed. Many countries, to different degrees have allowed and actually encouraged the participation of the private sector. For example, “full” privatization is to be found in England, Wales and the Czech Republic; investor-owner privatization in the US, and private concessions in France, Spain, Portugal, Poland and Mexico (Rogers et al. 2002). Despite its international acceptance, this approach faces big challenges. These areas related to the change in the perception of society about the true value of water and the need to instill an attitude of responsibility towards the resource as a whole. On the other hand, water management as a commodity has been identified as a complex issue. Water should fulfill at least, six prerequisites in order to be treated as another commercial commodity:

- It must be capable of being controlled, measured and treated as a commercial commodity
- The demand must exceed the supply
- The product must be provided when needed
- It must have sufficient mobility to be transferred to where it is most needed
- There must be acceptance of the market by society
- There must exist some mechanism of administration and regulation to assure fairness and equity (Campos & Studart, 2000).

Adherence to these prerequisites has been a difficult task, because as well as tacking the hydrology issues, there also needs to be an understanding of the rights for its use both in terms of law and popular habits.

Drawing on the previous arguments, it is evident that supply and demand planning approaches for managing water problems still face enormous challenges. There is an increasing consensus on the need to carry out an integrated and holistic management of water resources in order to prevent conflicts as well as to meet social and natural demands (Martinez-Austria, 2001; Jaspers, 2003).

2.3 The integrated/holistic approach

Integrated water resources management is an internationally recognized approach to develop sustainability in water resources**.** It has been regarded as necessary to combat increasing water scarcity and pollution. Integrated approaches have taken many forms, including integrated river basin management, integrated land and water management, ecosystem approach, integrated coastal zone management and integrated natural resource management. They seek integration of all the beneficial uses and costs associated with land use and water decisions, including effects on ecosystem services, food production and social equity, in a transparent manner; to involve key stakeholders and cross-institutional level, and to cross relevant bio-physical scales, addressing interconnectedness across subasins, river basin, and landscape scales (Falkenmark, et al., 2007). Consequently, a high level of coordinated interaction between all these key stakeholders is needed in order to they can collectively analyze the consequences of their actions. Despite everybody is clear about the need of coordination it is often incredibly difficult to achieve it. One of the key barriers for coordination is how to deal with uncertainty. According to Kreitner & Kinicki (1992), some of the factors that contribute to uncertainty are:

- unclear objectives;
- vague performance measures;
- ill defined decision processes;

- strong individual or group competition or
- any type of change.

All these are strongly present in most integrated water resources management situations.

On the other hand, Vissher et al., (1999) based on DANIDA (1991), (NEDA, 1998) and (UNDP, 1991) pose that integrated means development and management of water resources as regards both their use and protection, and considering all sectors and institutions which use and affect water resources. As well as the need to include a consideration of the whole water cycle, including rainfall, and both "blue" – ground or surface water – and "green" - soil moisture – components of the resource in order to gain a truly holistic overview. Methods for achieving this integration include water conservation and reuse, water harvesting, and waste management. Although an appropriate mix of legislation, pricing policies and enforcement measures is essential to optimize water conservation and protection. For guiding the implementation of the integrated approach, eight principles have been recommended, such as:

1. Water source and catchment conservation and protection are essential
2. Water allocation should be agreed between stakeholders within a national framework
3. Management needs to be taken care of at the lowest appropriate level
4. Capacity building is the key to sustainability
5. Involvement of all stakeholders is required
6. Efficient water use is essential and often an important "source" in itself
7. Water should be treated as having an economic and social value
8. Striking a gender balance is essential.

Despite the international consensus on these principles, the challenge remains in translating them into action. In this sense, the Mexican country will be employed as a testing ground to analyze the extent to which the supply, demand or integrated approach had been adopted in the decisions on water resources management.

3. The Mexican experience on water resources planning and management

3.1 Supply oriented approach

México is proud of its long standing tradition in hydraulic infrastructure development. This tradition dates from the creation of the so-called "commissions" oriented to river basin development. These commissions were inspired in the Tennessee Valley Authority developed in the United States to promote regional development. In Mexico, they were conceived as a way of planning and coordinating public expenditure in regions where it was difficult to do because of already established ministries and state governments (Barkin & King, 1970). Politically, they provided an opportunity for the central government to intervene in deprived regions. It was a way of gaining votes for the next government, through the construction of big facilities (Dourejeanni, 1998). In the thirteen year period that lasted these commissions, 8 of the 52 most biggest dams were built. As displayed in table 2, during 1947-1960, 7 Basin Hydrological Commissions were created.

Although, one of the attractive characteristics of these Commissions was their ability to work simultaneously in several states in projects that involved different ministries, the success of these projects was constrained by political and managerial factors. Although after the 1960 decade, these commissions disappeared and the building of big dams descended, after the 1980 decade 16 more dams were built. Perhaps, this emergence is joined with the international compromises Mexico engaged for the 1980 decade of Water and Sanitation.

River basin	The basin scope
Papaloapan River Commission	It was created in 1947. It covered an area of 18 000 square miles. It included parts of the states of Veracruz, Puebla and Oaxaca. Sugar cane was the most important crop. One of the largest dams in Latin America was built here, called "Miguel Aleman"
Grijalva-Usumacinta Rivers Commission	It was created in 1951. It covered an area of 48 000 square miles. It comprises states of Tabasco and Chiapas. Their combined run-off averages nearly thirty percent of the Mexican total. The largest dam in Latin America at the time it was built (1965) here, called "Malpaso".
Tepalcatepec River Commission	It was created in 1947. It covered an area of 7 000 square miles. It included the state of Michoacan and Jalisco. It was the first of the river basin projects for developing the hot dry area of the Pacific Coast.
Balsas River Commission	It was created in 1960. It covered an area of 43 000 square miles. In this year, this Commission also absorbed the Tepalcatepec Commission. The Balsas is the larges Mexican river. Also, two large dams were built here, called "El Infiernillo" and "La Villita".
Fuerte River Commission	It was created in 1951. It covered an area of 12 000 square miles. The El Fuerte river is the largest river in the northwestern region of Mexico, in terms of flow. It drains in areas of the state of Sinaloa, Sonora, Durango and Chihuahua. This Commission contributed to the north western agricultural development of Mexico. A dam, called Miguel Hidalgo was built for this purpose, as well as controlling floods.
Lerma Santiago and Chapala Projects	It was created in 1950. It covered an area of 50 000 square miles. This project included the largest river basin wholly included within the Mexican borders. This Project was different from the previous Commissions, because its function was to study the problems of the basin and the making of recommendations to other agencies of the Mexican government.

Table 2. The Basin Commissions created in Mexico during 1947-1960 (Barkin & King, 1970)

However, the delivery of tap water and sanitation as a result of constructing these big reservoirs did not reach local population. For example, the biggest reservoir is located in one of the three most deprived Mexican states. At least two reservoirs located in the State of Chiapas represent 10% of the total storage capacity in dams. In this state, just 73.5% of population has access to tap water. This figure is below the national mean, which is 89.2%.

Due to the strong social resistance to dams, in the 2000s decade, only one dam was built. Avila et al. (2005) pose that water scarcity has been accentuated by the perverse subsidies to electricity for water pumping, with almost US$700 million per year, and the failure to price water according to its scarcity.
However, most part of the National Water Commission budget continues to be allocated for infrastructure development. In 2008, 65% of the total expenditure was employed for delivering drinking water, sewerage and sanitation; 20% for promoting water efficiency in agriculture and; 15% for administration and water preservation (CONAGUA, 2008).
Therefore, it could be said that supply approach continues dominating Mexican water policy. Even more, if it is considered the increase in climatic variability, the concern about the decline of petroleum resources and the accelerated search for alternative renewable energy. Electricity demands are forecasted to increase dramatically with the need for more industrialization.

3.2 Demand oriented approach

Since the 1981 National Hydraulic Plan established that the public management of water in Mexico faced challenges akin to this approach. It recommended that water management agencies should generate enough income to pay for the cost associated with the operation, conservation and maintenance of the systems, as well as generating necessary surpluses to meet future investment requirements. In order to face these challenges, the Mexican government designed strategies oriented to decentralize and modernize the water management sector. These strategies entailed a structural break with the previous model of stat-led-development, which has been operating since the 1940s (Castro, 1995). This process broke with traditional policies in the sector, whose main feature was the role of state as supplier, donor and benefactor. In water services, the modernization and decentralization processes has meant a transfer of responsibilities of water management, from the state towards the participation of the private sector through diverse and complex mechanisms. These measures provided the formal basis for the creation of water markets by conferring water the status of a private property resource. According to the Global Privatization Fund formed in 1994 specifically aimed at attracting investors desiring to take advantage of investment opportunities, historically inaccessible to U.S. investors, Mexico was one of the top ten countries involved in privatization since 1985. Although Mexico undertook a privatization model based on concessions, these schemes have succeeded in the northern part of the country, in water users organizations linked to the United States market. By contrast, southern water user' organizations have not prospered. This contrast support the idea that most than physical scarcity, the problem lies in the social scarcity capacities to manage the water problem. According to the map displayed in figure 1, it can be seen that despite water resources are abundant in the south, and scarce in the north, economic develop does not follow this trajectory.
This figure reveals that while the north-centre-northwest regions hold more than two thirds of population and receive one third of precipitations, they generate 87% of the gross domestic product. Contrary to this, the southeast region sheds 23% of population, 69% of precipitation occurs there, but it only contributes to 13% of the gross domestic product. According to CONAGUA (2008) forecasts, this disparity will get worse by 2030. As 70% of population increment will occur in these water scarce regions, per capita water availability will be less than 1 000 m^3/person/year. A mayor effort will be needed to address these

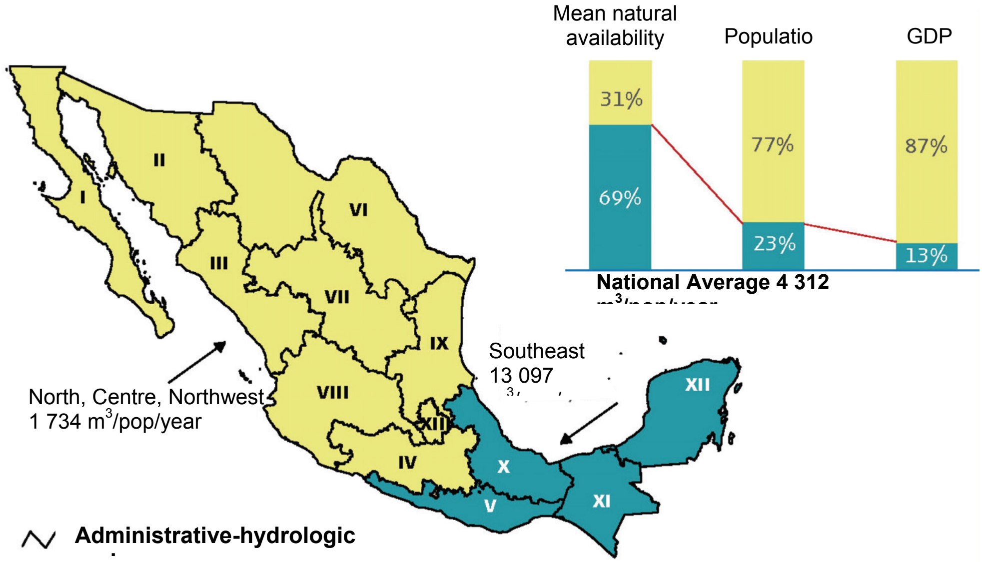

Fig. 1. Regional contrasts between development and water availability (CONAGUA, 2008)

water issues and this can only be accomplished by an integrated approach that considers the whole system, which includes de relationships and dynamic interactions between human and natural systems, land and water systems, and key stakeholders agencies and local groups.

3.3 Integrated/holistic approach

In normative terms, the mexican water law enjoys international recognition for including reforms that consider the ecosystems needs. The law vests federal government to declare as disaster zone those basins or hydrological regions that represent or potentially represent irreversible risks to a ecosystem (Falkenmark et al. 2007). The most recent version of the national water law, establishes that water should be managed in an integrated way, which fully recognizes the relationship between water resources, air, soil, flora and fauna, another natural resources, biodiversity and the ecosystems that are essential for keeping water integrity. Also, the National Hydrologic Plan 2007-2012 (CONAGUA, 2008), establishes objectives oriented to promote the efficient use, water users and organized groups participation, and the sustainable and integrated management on watershed based.

Considering the eight principles that should guide integrated water management, it can be said that Mexico has some progress on water source protection and stakeholders´ involvement.

In terms of stakeholders´ involvement progresses have been made through the basin council organization.

Basin councils were designed with the important purpose of acting as mediators between the National Water Commission (CONAGUA), different governmental offices and the representatives of water users within a water basin. The potential of basin councils for solving inter-state water conflicts were recognized after the successful experience of the

Lerma Basin Council. Here serious problems related to scarcity, water allocation, pollution, water use inefficiency, environmental deterioration, surface and groundwater water rights had been detected by 1989 (Mestre, 1997; Saleh & Dinar, 2000). It became clear that the federal government action would be insufficient to solve or mitigate this chaos. Therefore, many water users, including individuals and the private sector, became involved. Following a participatory process on 13 April 1989, the federal government and various river-basin state governments signed an agreement that is designed to offer solutions to the main problems of scarcity, water allocation, pollution, water use inefficiency, environmental degradation and water rights (Mestre, 1997). Following this experience, by December 2006, some 25 basin councils, 17 basin commissions (at the sub-watershed level), 22 basin committees (at the microwatershed level) and 76 underground technical committees (aquifer level) had been created (CONAGUA, 2007). This mechanism for stakeholders' involvement has received wide political support, in Mexico and in the world. It has been effective for managing water at an integrated way and to involve groups and organization scarcely been considered under other arrangements.

In relation to source water protection, Mexico has taken steps through the environmental service payments. In 2003, the mexican government, through the National Forest Commission initiated actions for paying for hydrological environmental services PSAH) in water scarce areas. The rationale behind this idea was that scarcity and deforestation were closely related. Accordingly, the targets for PSAH have been overexploited aquifers. Between 10% and 25% of PSAH resources have gone to these areas, and less tan 7% to the most overexploited aquifers (Munoz-Piña et al. (2008). At present, hydrological service payment programs have been recognized for compensating landowners who engage in preserving the services forest provided in watershed protecting and aquifer recharge. Compensation funds are collected on annual basis between water users. According to Muñoz-Piña et al. (2008), between 2003 and 2006, 110 million of us dollars were distributed among landowners belonging to local communities and private groups – which in total amount 500 000 ha in these protection schemes. Forest and hydrologic services deserve a great potential in Mexico. Mostly due to the high rated value and because services like wood has lost competitiveness in the domestic and international market. In fact, FAO (2009) forecast that in the event of the low economic feasibility of the forest industry, environmental services will continue gaining importance, in great part because of the public support.

4. Conclusion

In this chapter it has been established that Mexico figures among the nations facing severe scarcity. Scarcity was defined as a situation where population has less than 1000 cubic meter per capita per year to satisfy their basic needs. In order to face problems like scarcity, the Mexican government has employed three different approaches. The supply oriented approach was just conceived to solve particular problems and specific or sectoral water demands, eg. To enable and improve irrigation, to supply domestic and irrigation needs, to control flooding, to mitigate drought and to building power stations. It also involved the operation and maintenance of build facilities, like dams, but without taking heed of neither multiple water users nor carrying out any sort of management. This supply approach best moment occurred with the creation of institutions called "commissions" oriented to river basin development. The development of this model in Mexico occurred during the period of

1947-1960. In this period, 7 Basin Hydrological Commissions were created. According to David and Barkin (1970), these Commissions were conceived as a way of planning and coordinating public expenditure in regions where it was difficult to do because of already establish ministries and state governments. Politically, they provided an opportunity for the central government to intervene in deprived regions. It was a way of gaining votes for the next government, through the construction of big facilities. Later, in the Mexican government programs, there was a tendency to implement demand management approaches. Internationally, it was recognised that water was a finite resource that supply could not increase because of the cost for developing new sources were high. Efficient measures were need. So, private sector participation could take place in water provision. Private participation was allowed through concession, which means a partial participation, because government continue regaining control over the infrastructure. Integrated approaches are best exemplified in normative terms, through the national water law and the recent water hydrological programs. Specific examples of these programs are basin council organizations and environmental service payments. By December 2006, some 25 basin councils, 17 basin commissions (at the sub-watershed level), 22 basin committees (at the microwatershed level) and 76 underground technical committees (aquifer level) had been created (CONAGUA 2007). While this number appears high, it is still not enough, given that the number of basins and aquifers registered are much higher. CONAGUA (2007)
has reported that there are 94 basins and 653 aquifers in Mexico. Although there is no information many more small scales needed for the effective management of water. Environmental service payment are becoming a strong initiative for protecting water sources through compensating landowners for keeping forests in headwater regions. More than 500 000 ha has been included in this scheme. However, the mexican government faces two critical challenges. By one hand, it is the unique purchaser of the environmental services. On the other hand, it is in charge of forest management, which leads to the centralization of these services. Other alternatives are being needed to fix this dual role. Actions have been taken by local governments to introduce these programs among their water users.

5. References

Al Radif, A. (1999). Integrated water resource management (IWRM): An approach to face the challenges of the next century
and to avert future crises. *Desalination* No.124, (1999)145-153, ISSN 011-9164

Ávila, S.; Muñoz-Piña, C.; Jaramillo, L. & Martínez, A. (2005). *Decoupling the subsidy for water pumping*. INE Working Paper Series, vol. 0502. Instituto Nacional de Ecología, Mexico City, Mexico. http://www.ine.gob.mx/dgipea/agua/articulos.html.

Barkin, D. & King, T. (1970). *Regional economic development: The river basin approach in Mexico*, Cambridge University Press, ISBN 9780521078375, England

Campos, J.N.B. & Studart, T.M.C. (2000) A historical perspective on the administration of water in Brazil, *Water International*, Vol. 25, No.1(1999)148-156, ISSN 1941-1707

Castro, J.E. (1995). Decentralization and modernization in Mexico: the management of water services, *Natural Resources Journal*, Vol. 35(1995)461-487, ISSN 0028-0739

Comisión Nacional del Agua. (2008). *Estadísticas del Agua en México*, CNA, ISBN 978-968-817-895-9, México

Comisión Nacional del Agua. (2007). *Programa Nacional Hidráulico 2001-2006*, CNA, ISBN 030910582X, México

Dieterich, B.H. (2003). The unfinished agenda, *Water Policy,* Vol. 5(2003)91-99, ISSN 1366-7017

Dourojeanni, A., Andrei, J. & Chavez, G. (2002). Gestión del agua a nivel de cuencas: teoría y práctica, *Revista de la CEPAL*, No. 47(agosto 2002) 83, ISSN 0252-0257

Easter, K.W.; Feder, G.; Le Moigne, G. & Duda, A.M. (1992). Water policy and water markets, *World Bank's Ninth Annual Irrigation and Drainage Seminar* on water resources policy *Selected Papers and Proceedings*, pp. 11-16, ISBN 082133249X, Annapolis, Maryland, December 1992, The World Bank, Maryland

Falkenmark, M.; Finlayson, C.M. &. Gordon, L.J. (2007). Agriculture, water, and ecosystems: avoiding the costs of going too far. In: *Water for food water for life*, D. Molden (Ed.), 233-277, International Water Resources Institute, Earthscan, ISBN 978-1-84407-396-2, London

FAO. (2009). *State of the world's forests 2009*. Food and Agriculture Organization of the United Nations, ISBN 978-92-5-106057-5, Roma.

Grigg, N.S. (1996). *Water resources management: principles, regulations, and cases*, McGraw-Hill, ISBN 0-07-024782-X, New York

Hoekstra, A.Y. (2000). Appreciation of water: Four perspectives, *Water Policy*, Vol. 1, No.6(2000)605-622, ISSN 1366-7017

Jaspers, F.G.W. (2003). Institutional arrangements for integrated river basin management, *Water Policy*,No. 5 82003)77-90, ISSN 1366-7017

Kreitner, R. & Knicki, A. (1992). *Organizational behavior.* R.D. Irwin, ISBN 007338125X, USA

Martinez-Austria, P.F. (2001). Paradigmas emergentes para el manejo del agua en el siglo XXI, *Ingeniería Hidráulica en México,* Vol. 16, No. 4(2001)127-143, ISSN 0186-4076

Mestre R., J.E. (1997). Integrated approach to river basin management: Lerma-Chapala case study – Attributions and experiences in water management in Mexico, *Water International,* Vol. 22(1997)140-152, ISSN 1941-1707

MEA (Millenium Ecosystem Assessment). (2005). *Evaluación de los ecosistemas del milenio*, Island, Press, ISBN 1-559663-403-0, Washington, D.C.

Muñoz-Piña, C., Guevara, A., Torres, J. M. & Braña, J. (2008). Paying for the hydrological services of Mexico's forests: Analysis, negotiations and results. *Ecological Economics*, Vol. 65, No.4 (2008)725-736, ISSN 0973-1385

Muñoz Piña, C.; Guevara, A.; Torres, J.M. & Braña, J. (2006). *Paying for the hydrological services of Mexico's forests.* CIFOR, Bogor, Indonesia

Rogers, P.; Silva, R. de & Bhatia, R. (2002). Water is an economic good: How to use prices to promote equity, efficiency, and sustainability, *Water Policy*, Vol. 4, No. 1(1997)1-17, ISSN 1366-7017

Saleh, R.M. & Dinar, A. (2000). Institutional changes in global water sector: trends, patterns, and

Implications, *Water Policy*, Vol.2, No.3, (2000)175–199, ISSN 1366-7017

Schchtschneider, K. (2000). Water demand management and tourism in arid countries: Lessons learned from Namibia, In: *Hydropolitics in the developing world: A Southern African perspective,* A. Turton & R. Henwood (Eds.)(204-213) (htp://www.iahr.org/newsweb/newsflash/newsflash_dec.2002.htm), ISBN 0620295198

Seppala, O.T. (2002). Effective water and sanitation policy reform implementation: need for systemic approach and stakeholder participation, *Water Policy*, No. 4(2002)367-388, ISSN 1366-7017

Serageldin, I. (1995). Water resources management: a new policy for a sustainable future, *Water International*, Vol. 20(1995)15-21, ISSN 1941-1707

Sharma, S.J. & Vairavamoorthy, K. (2009). Urban water demand management: prospects and challenges for the developing countries. *Water and Environment Journal*, No. 23, (2009)210-218, ISSN 1747-6585

United Nations (2003). Water for people , water for life, Executive summary, *The United Nations World Water Development Report,* The United Nations, ISBN, 92-3-103881-8 New York

UN-Water & FAO. (2007). *Coping with water scarcity. Challenge of the twenty-first-century*. Http:www.worldwaterday07.org. Consulted September 2009

Vissher, J.T.; Bery, P.; Gould, T. & Monarty, P. (1999). *Integrated water resource management in water and sanitation projects. Lessons from projects in Africa, Asia and South America*, International Water and Sanitation Centre, ISBN, Delf, The Netherlands

White, G.F. (1998). Reflections on the 50-year international search for integrated water management, *Water Policy*, No. 1(1998)21-27, ISSN 1366-7017

14

Utilizing Wastewater Reuse and Desalination Processes to Reduce the Environmental Impacts of Agriculture

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1. Introduction

Designing production processes with reduced environmental impacts is becoming more important. In many industries, including but not limited to agricultural production, water use and wastewater generation have a major share in the total environmental impact of the production processes.

Integrating water and wastewater processes into industrial processes requires a multi-dimensional analysis that takes into account the various potential water sources, as well as the different options of wastewater treatment available. We developed a model for planning water supply from diverse sources, including groundwater, the water from national supply sources, wastewater reuse and seawater desalination. The model integrates hydrological, technological and economic considerations, and estimates the economic and environmental impacts of alternative water management policies.

The model was implemented on the case study of agricultural production processes, based on the unique geographical characteristics of Emek Heffer and northern Sharon regions in Israel. The hydrological model was developed on the basis of the specific hydrological database for these regions, and enabled to plan the local water resources use and forecast the chlorides concentration in the aquifer. Based on the results of the model and economic data, the costs of desalination processes and of the water supply to the region under various scenarios were estimated. The results include recommendations for the water treatment level and for desalination of different water sources, and forecasts of the implementation costs. We conclude that the economic cost of improving the quality of the supplied water and of the aquifer water should be considered in the planning of agricultural production to reduce its environmental impacts at minimal economic cost.

2. Background

Designing production processes with reduced environmental impacts is becoming more important. In many industries, including but not limited to agricultural production, water use and wastewater generation have a major share in the total environmental impact of the production processes. At the same time, increasing water shortage has caused an increase in issues related to water pollution as a result of wastewater use, as well as the option of wastewater reuse, mainly for agriculture.

Water use and wastewater production are part of nearly every type of production process, including urban, industrial, and, of course, agricultural. Choosing a different mix of water supply sources, or defining a different quality threshold for wastewater treatment, changes the groundwater quality levels over time; changes the financial costs to both the urban consumers and the farmers (also leading indirectly to changes in the consumer budget); changes the level of health risks faced by the consumers from drinking water and consuming food irrigated with wastewater; and changes the long-term ecological balance.

To address all of these concerns the choice of wastewater reuse and desalination processes should be done from a multidisciplinary view, taking into consideration not only the technological aspects of process design, but also the hydrological impacts, the economic implications for urban consumers and farmers, and the environmental – health and ecosystem – impacts of these processes.

We developed a model for planning water supply from diverse water supply sources, including groundwater, the water from national supply sources, wastewater reuse and seawater desalination, as well as the different options of wastewater treatment available. The model integrates hydrological, technological and economic considerations, and estimates the economic and environmental impacts of alternative water management policies. Through the model, we examine a case study of water supply to a chosen region that consists of both urban and agricultural areas. National and regional policy decisions regarding permits for well drilling, and thresholds for the level of water salinity allowed in drinking water and in water for irrigation can vary between regions, and in the same region over time. We considered the range of policy variations by using a range of potential policy scenarios in the model, and estimating the economic and environmental impacts across these policy scenarios.

3. Model structure

The model was constructed as a decision making tool that is meant to enable managers to plan the water supply process to their region, based on combining water from different potential sources, supplied to a combination of different end-users in urban and rural areas of that region. The assumed goals of the decision makers include minimal costs as well as minimal environmental impacts (specifically, minimal groundwater salinity levels). The potential water sources in the model include groundwater, national carrier water, treated wastewater for irrigation, and desalinated sea water.

The model is composed of four sub-components that describe the different types of processes that are part of the decision making complex: policy planning processes, physical hydrological water flow processes, technological water supply and treatment processes, and the economic implications of these processes. The planning sub-component describes the geographical area allocations between different water users. The hydrological sub-component describes the physical structure of the water source supply and is used to predict the aquifer water levels and the salinity concentration over time. The technological sub-component describes the available relevant water treatment and desalination processes and the ensuing costs. The economic sub-component is used to calculate the optimal treatment quantities and levels and the total cost of these decisions.

Description of the model's sub-components

A. *Policy planning component:* Includes a unique database for the hydrological cells in the case study region, structured in order to compute the demand for water by the various end users.

B. *Hydrological component:* Used to plan the water sources and to predict the groundwater levels and the chloride concentration in the aquifer. The model is based on the hydrological cells described by the national hydrological service in Israel. Each hydrological cell is constructed of an upper and a lower layer. The upper layer represents the unsaturated zone, stretching downward from the ground level to the top surface of the groundwater. The bottom layer represents the saturated zone, i.e., the groundwater, stretching from the top surface of the groundwater down to the bottom base of the aquifer.

The hydrological model is based on ten assumptions:

- The hydraulic characteristics of each layer are uniform and do not change over time, although they can vary from one cell to another.
- Surface water with varying chloride levels seep vertically downward through the unsaturated zone to the saturated zone.
- The surface water sources reaching the unsaturated zone may include water from the following sources: rain water, fresh water, wastewater used for irrigation, and water leakage from various sources.
- Only part of the water entering the unsaturated zone actually reaches the groundwater (for example, some water uptake by plants may occur in the process); but the chloride mass that is mixed with the water reaches the saturated zone in its entirety.
- The chloride moves downward with the water it is dissolved in, at the average rate of water movement, with no dispersion on the way.
- There are no additional sources of water or dissolved chlorides in the unsaturated zone.
- The flow of the chloride mass from the unsaturated zone to the the saturated zone of each cell is characterized by two consecutive time periods. The first period, Period A, begins with the entry of the water and dissolved chlorides into the unsaturated zone; the second period, Period B, begins when that water first reaches the saturated zone.
- In addition to the flow that enters from the unsaturated zone, water and dissolved chlorides may also enter a given hydrological cell from its neighboring cells and from drilling.
- The chloride mass in the cell's unsaturated zone is concentrated in an area termed “the mixing area”. Which lies from the groundwater surface to the depth of the drilling for pumping water out.
- The systems' land borders – the eastern, northern and southern borders – are impervious to entry of water and salt. The western border is an open border (reaching the sea).

The water supply is designated for two sectors: town and agriculture, which receive two types of water – fresh water and wastewater. The hydrological model is based on hydrological and planning input data, and enables to produce outputs for each one of the cells that include water balances and chloride masses as well as forecasts of water levels and chloride concentrations in the saturated zone, over a pre-defined period of time.

The hydrological model was used to quantify the potential water quantity available for pumping water in each hydrological cell, under the assumption that in each cell the water supply is equal to the water demand. The water sources for each hydrological cell were computed under the assumption of giving first priority to water supply from local sources, i.e., pumping from drillings in that cell's area, which is done within the limitation of the available water quantity, and under the limitations of the total annual pumping allowed from that aquifer. The volume of the additional water needed as supplement to fill the total water demand is supplied by National Carrier water, and the water consumers in the hydrological cells along the beach can only get their water from that national source. Agricultural use is given priority in water pumping, and irrigation with wastewater will continue at its present volume.

The predefined salinity threshold was based on policy considerations relating to the water supplied to the city, or to the city and agricultural uses, or for groundwater under a steady state condition. Our aim was to examine the implications of policy choices regarding different water quality thresholds on the level of groundwater salinity over time and on the costs of water supply to the region.

To do that, we examined a variety of scenarios that defined the threshold levels between the range of 50 to 250 mg Chlorides per liter (mg/Cl.). The forecasted level of groundwater salinity over one hundred years was computed for each scenario, based on the hydrological model's mathematical equations.

We compared the different scenarios for a steady-state solution, defined as a situation where the groundwater level and the chloride concentration in each cell do not change over time. The steady-state solution for the groundwater level is calculated by solving the set of equations for the annual water balance volume in the cells, when the total volume of water entering the cell from the unsaturated zone and from the neighboring cells is equal to the total volume of water that is pumped out of the cell. The steady-state of chloride concentration in the groundwater of each cell is calculated by solving the set of equations for the annual balance of chloride mass in the cells; that is, multiplying the components of the steady-state water balance with the target concentrations, when the total chloride mass entering the cell is equal to the total mass of chlorides that is pumped out of that cell.

C. *Technological component:* We calculated the costs of water desalination for each one of the potentially available water supply sources, based on engineering and technological data. We examined the alternative desalination processes available in order to evaluate the alternatives that were found as relevant, and calculate their average costs. The desalination alternative based on the Reverse Osmosis technology include desalination of brackish water, local well water, and wastewater, with the addition of pre-treatments that include tertiary treatment and pre-membrane treatments, while incorporating them with the water supplied from national sources, that were meant to serve as the main water supply source.

The desalination costs are influenced by different parameters such as the size of the plant, the quality of the feeding water and placement of the wastewater plant. The costs are also influenced by a number of planning variables, including rate of return on investment, various expenditure processes, the availability of plant operations, energy costs, membranes, chemicals, manpower, maintenance and overhead costs. The input data include: water quantity, the quality of the raw data that we fed into the system, the quality of the final product, rates of absorption, depth of drilling, pipe lengths, altitude of the desalination plant and volume of water storage.

D. *Economic component:* We computed the quantity of water that should be desalinated, and estimated the total costs of the water supply to the region for each of the alternative water sources. When the salinity of the supplied water exceeds the predefined threshold, water desalination processes are initiated. The desalinated water is then mixed with the additional sources of water supply in order to maintain the threshold, and the required quantity of desalinated water is computed accordingly. The multiplication by the cost of desalination gives the total cost of desalination, and accordingly, the total costs of water supply for the region for each alternative option of desalination.

4. The case study region

The model was implemented on a specific case study region, composed of eight hydrological cells located along the coast in the central/north-central part of Israel. The area includes the city of Netanya, whose urban wastewater flow is the main source of the total wastewater supply to the region. The case study region was further divided into two sub-regions - Emek Heffer and Northern Sharon - each composed of four hydrological cells. The Emek Heffer hydrological cells lie on the northern border of the Northern Sharon hydrological cells, and parallel to them.

The Israel National Hydrological Service divides the shore aquifer area into 16 areas, and each area includes four hydrological cells, lying from west to east. The Western Shore cells are the cells closest to the beach, followed by Western Aquifer cells and Eastern Aquifer cells, where most of the pumping in concentrated, and finally by the Eastern cells. The cells are divided by straight lines that divide the entire coastal area into square cells, with no consideration for the division of the areas according to geographical characteristics or urban administrative borders. Establishing a data base by hydrological cells was very complex, because the information needed for the allocation of the area among users and water uses does not exist for each individual hydrological cell.

We established the database by hydrological cells using a set of maps that included the administrative urban areas, horticultural areas by crop and built area. The combined maps resulted in the calculated area allocation presented in Table 1. The Emek Heffer area is mostly agricultural, while in the Northern Sharon area, which includes the city of Netanaya, close to half the area is defined as an urban area.

Area	Emek Heffer	Northern Sharon
Total agricultural	8.24	8.28
Build area	1.02	1.14
Citrus crops	1.21	2.89
Other horticultural crops	0.69	1.05
Field crops (estimation)	5.30	3.19
Total urban area	0.11	7.87
Total area	8.35	16.16

Table 1. Hydrological database results: Area use allocation (hectares)

For each hydrological cell we estimated the demand for water by type of users, based on established norms of water use by crop and water use by number of residents. The amount of wastewater used for irrigation was given. As Table 2 shows, the total water use in Emek Heffer was 24.6 million cubic meters (mcm) per year, of which 90% was used for irrigation, while in Northern Sharon the total use was 59.4 mcm/year, of which 58 percent was used for irrigation (in both areas the irrigation water use includes the wastewater data).

Type of water use	Emek Heffer	Northern Sharon	Total
Urban water use	2.6	24.7	27.3
Freshwater for agriculture	9.6	31.3	40.9
Total demand for freshwater	12.2	56.0	68.2
Wastewater	12.4	3.4	15.8
Total irrigation water	22.0	34.7	56.7
Total demand for water	24.6	59.4	84.0

Table 2. Hydrological database results: Water use allocation (mcm)

The results of the planning component, including area allocation and water use for each hydrological cell, as described above, was used as input data for the hydrological component, which was applied to predict the groundwater level and salinity over time, and for the technological component, which was applied to examine the relevant desalination technologies and the ensuing costs. The results of the hydrological and technological components were used in turn as inputs for the economic component, which was applied to evaluate and compare the the scope of desalination and the costs under different scenarios.

5. The results of the model

5.1 The hydrological component

The hydrological component was based on the results of the planning component, as described above. The levels of salinity are predicted over time for a variety of scenarios, who differ from each other in the predefined salinity thresholds permitted for urban and agricultural use. The baseline scenario – scenario 1 – describes a policy of defining a establishing a threshold of 250 mg/Cl., only for urban use. Scenarios 2, 3 and 4 include established thresholds for agricultural water use, at the levels of 250 (scenario 2), 150 (scenario 3), and 50 mg/Cl (scenario 4). The fifth scenario – scenario 5 – describes an agricultural area on the one extreme, which based on freshwater irrigation alone, and the final scenario – scenario 6 – is description of the opposite extreme scenario, which allows irrigation with highly saline wastewater. The scenarios are summarized in Table 3.

For each scenario, we predicted the groundwater salinity levels over time and after one hundred years. The salinity level was found to increase over time in every hydrological cell except for the two Western Shore cells, where pumping is not allowed. The results for each scenario are presented in Table 4. For the baseline scenario (scenario 1), the salinity in year 100 in the Emek Heffer region reaches 846, 497, and 1192 mg/Cl for the Western Aquifer cell, Eastern Aquifer cell and Eastern cells, respectively. The salinity levels in year 100 in the Northern Sharon area under this scenario reach 132, 100, and 739 mg/Cl for the Western Aquifer cell, Eastern Aquifer cell and Eastern cells, respectively.

Scenario	Salinity threshold for urban water use (mg/Cl.)	Salinity threshold for agricultural water use (mg/Cl.)	Irrigation with wastewater included?
1 (baseline)	250	-	Yes
2	250	250	Yes
3	150	150	Yes
4	50	50	Yes
5	250	-	No
6	250	-	Yes, with high salinity

Table 3. Scenarios for the model

Cell	Scenario 1 Urban threshold 250 mg/Cl.	Scenario 2 Add agricultural threshold 250 mg/Cl.	Scenario 3 Add agricultural threshold 150 mg/Cl.	Scenario 4 Add agricultural threshold 50 mg/Cl.	Scenario 5 No irrigation with wastewater	Scenario 6 Irrigation with highly saline wastewater
Emek Heffer						
Western Shore	310	189	210	137	232	370
Western Aquifer	846	459	364	182	741	1016
Eastern Aquifer	497	358	243	110	418	644
Eastern	1192	841	690	364	1639	1485
Entire Emek Heffer	*716*	*453*	*357*	*182*	*716*	*907*
Northern Sharon						
Western Shore	180	115	159	122	161	192
Western Aquifer	132	150	116	75	133	143
Eastern Aquifer	100	102	94	66	91	112
Eastern	739	654	438	222	693	760
Entire Northern Sharon	*158*	*159*	*130*	*84*	*157*	*174*

Table 4. Predicted chloride concentration in groundwater in year 100 by scenario (mg/Cl.)

Scenarios 1 – 4 describe a gradual increase in the strictness of the water quality regulations. Scenario one, as mentioned above, includes predefined salinity thresholds for urban use

alone, while scenarios 2 – 4 include salinity thresholds for agricultural water use as well, with the level of salinity permitted becoming gradually lower from scenario 2 to scenario 4. Comparing the different scenarios for a given cell, by examining each row individually across the first four columns of Table 4, shows that as the policy becomes more strict, the resulting salinity level over time is lower. For example, looking at the results for Emek Heffer's Eastern Aquifer cell, the chloride concentration in year 100 is 497 mg/Cl under the baseline scenario, which defines only urban water use thresholds, and becomes gradually lower through scenario 2 with an added restriction of 250 mg/Cl for agricultural water use as well, resulting in a salinity level of 358 in year 100; scenario 3, with an increased restriction of agricultural water use salinity level to 150 mg/Cl resulting in a groundwater chlorine concentration level of 243 mg/Cl in year 100; and finally scenario 4, which has the greatest salinity level restriction, permitting only 50 mg/Cl, and resulting in the lowest salinity level of 110 mg/Cl in year 100. Comparing scenario 5, which does not include any irrigation with wastewater, with scenario 6, which includes irrigation with highly saline wastewater, shows that irrigation with freshwater alone decreases the level of groundwater salinity in year 100 by 191 mg/Cl for the entire area of Emek Heffer.
We calculated the predicted chloride concentration under a steady-state situation, where the groundwater level and the chloride concentration in each cell do not change over time (Table 5). Under the baseline scenario, with a salinity threshold for urban water use alone of 250 mg/Cl, the resulting salinity level in the aquifer water under steady-state conditions is 1,358 mg/Cl in Emek Heffer and 318 mg/Cl in Northern Sharon. Under scenario 2, which includes a threshold of 250 mg/Cl for both urban and agricultural water use, the aquifer steady-state salinity level is 553 mg/Cl in Emek Heffer and 265 mg/Cl in Northern Sharon.

	Scenario 1: urban threshold of 250 mg/Cl		Scenario 2: both urban & agricultural thresholds of 250 mg/Cl	
Cell	Year 100	Steady-State	Year 100	Steady-State
Emek Heffer				
Western Shore	310	704	189	329
Western Aquifer	846	1358	459	514
Eastern Aquifer	497	548	358	380
Eastern	1192	2884	841	977
Entire Emek Heffer	*716*	*1358*	*453*	*553*
Northern Sharon				
Western Shore	180	176	115	174
Western Aquifer	132	200	150	197
Eastern Aquifer	100	244	102	204
Eastern	739	1184	654	670
Entire Northern Sharon	*158*	*318*	*159*	*265*

Table 5. Chloride concentration in year 100 and under steady-state conditions (mg/Cl)

The calculated chloride concentration in irrigation water needed to maintain an aquifer salinity threshold of 250 is shown in Table 6. For the entire Emek Heffer area, for example, the permitted chloride concentration in irrigation water would be 92 mg/Cl.

Scenario / Cell	Scenario 1 Urban threshold 250 mg/Cl.	Scenario 2 Add agricultural threshold 250 mg/Cl.	Scenario 3 Add agricultural threshold 150 mg/Cl.	Scenario 4 Add agricultural threshold 50 mg/Cl.
Emek Heffer				
Western Shore	379	381	273	52
Western Aquifer	75	76	84	50
Eastern Aquifer	139	145	151	50
Eastern	28	28	28	34
Entire Emek Heffer	*88*	*92*	*91*	*45*
Northern Sharon				
Western Shore	1492	1522	918	314
Western Aquifer	283	327	195	63
Eastern Aquifer	411	333	189	53
Eastern	72	72	72	54
Entire Northern Sharon	*243*	*233*	*142*	*57*

Table 6. Chloride concentration in irrigation water (mg/Cl) for a steady-state aquifer salinity threshold of 250 mg/Cl

So far, we have seen the implications of lowering or increasing the permitted threshold on the state of the aquifer. From these results we might conclude that a policy of strict thresholds level is preferable. However, this kind of policy comes at a cost; in the following sections we demonstrate the financial implications of the different salinity thresholds.

5.2 The technological component

The average cost of desalination under representative initial conditions is shown in Table 7. Based on the relevant alternatives for the Emek Heffer area, the cost of brackish water desalination is 36 cents per cubic meter (cm); the cost of national carrier water desalination is 29.4 cents/cm (depending, in practice, on the size of the plant); the cost of wastewater desalination is 41.6 cents/cm and the cost of seawater desalination is 54.2 cents/cm (again, the cost depends on the size of the plant; these calculations were done for a plant size of 50 mcm/year).

	Brackish	National carrier	Wastewater	Seawater
Infrastructure	13.0	14.6	3.3	32.5
Desalination	23.0	14.8	38.3	21.7
Total	36.0	29.4	41.6	54.2

Table 7. Average cost of desalination (cents per cm)

5.3 The economic component

The economic component of the model is used to estimate the total costs of water supply for each area for the different scenarios. The inputs for this component are the outputs of the previously described components: From the planning component results we took the water sources as inputs for the economic component; from the hydrological component we took the predictions of chloride concentration over time; and from the technological component we took the average costs of desalination for each potential source of water supply (groundwater, which is brackish water, national carrier water, wastewater and seawater).

The results of the economic component for the entire area of Emek Heffer are presented in the following tables. The total net present value (that is, the total economic value translated into today's economic value) is presented in Table 8, and the annual costs under steady-state conditions are shown in Table 9, for each one of the scenarios (except for the scenario of irrigation with highly saline water, which is not likely to be used as an actual policy option).

The results in Table 8 show that under scenario 1 (urban water salinity threshold of 250 mg/Cl), the net present cost of the water supply ranges from 95.19 million dollars for brackish water (groundwater) desalination to 96.44 million dollars for seawater desalination. In scenario 2 (urban and agricultural water salinity thresholds of 250 mg/Cl), the net present cost ranges from 101.08 million dollars for groundwater desalination, 177.69 million dollars for wastewater desalination and up to 207.09 million dollars for seawater desalination. In scenario 3 (salinity thresholds of 150 mg/Cl) the net present cost ranges from 120.58 million dollars for groundwater desalination, 216.71 million dollars for wastewater desalination and up to 353.49 million dollars for seawater desalination. In scenario 4 (salinity thresholds of 50 mg/Cl) the net present cost ranges from 219.19 million dollars for groundwater desalination, 246.70 million dollars for wastewater desalination and up to 392.47 million dollars for seawater desalination. In all of the scenarios, the lowest desalination costs were for National Carrier water, followed by groundwater, wastewater and seawater. We should note that seawater desalination is mostly meant to increase the total water supply available, so the cost of their desalination for improving the water quality includes only the additional costs.

Scenario	1	2	3	4	5
Desalinated water source	Urban threshold	Urban & agricultural thresholds	Medium-level salinity threshold	Low-level salinity threshold	No irrigation with wastewater
Brackish (groundwater)	95.19	101.06	120.58	219.19	129.57
Cost increase	-	5.87	19.52	95.61	-
Wastewater	-	177.69	216.71	246.70	-
Seawater	96.44	207.09	353.49	392.47	132.36

Table 8. Net present value of the cost for 100 years (million dollars)

In comparing between the scenarios, we can see that improving the salinity threshold from 250 mg/Cl for urban use alone to 250 mg/Cl for agricultural water use as well involves an increase in the total net present cost of water supply to the Emek Heffer area by 5.87 million dollars. Introducing the stricter condition of 150 mg/Cl involves an increase in cost of 19.52 million dollars, and the strictest threshold scenario of 50 mg/Cl involves the relatively high increase in cost of 98.61 million dollars.

The results in Table 9 show that under scenario 1 the annual cost ranges from 4.98 million dollars for groundwater desalination up to 5.26 million dollars a year for seawater desalination. Under the conditions of scenario 2, the annual cost ranges from 5.54 million dollars for groundwater desalination to 8.96 million dollars for wastewater desalination and up to 15.52 million dollars for seawater desalination. Under scenario 3, the annual cost ranges from 7.55 million dollars for groundwater desalination, 10.40 million dollars for wastewater desalination and up to 17.03 million dollars for seawater desalination. Under scenario 5, the annual cost ranges from 10.63 million dollars for groundwater desalination, 11.83 million dollars for wastewater desalination and up to 18.83 million dollars for seawater desalination. Again, in all of the scenarios examined, the lowest desalination costs were for National Carrier water, followed by groundwater, wastewater and seawater.

The comparison between the scenarios shows that improving the salinity threshold from 250 mg/Cl for urban use alone to 250 mg/Cl for agricultural water use as well involves an increase in the annual cost of the water supply to the Emek Heffer area by 0.56 million dollars. Introducing the stricter condition of 150 mg/Cl involves an increase in cost of 2.57 million dollars, and the strictest threshold scenario of 50 mg/Cl involves the relatively high cost increase of 5.65 million dollars. Maintaining a salinity threshold level of 250 mg/Cl for the aquifer water involves an annual cost ranging from 9.9 to 13.29 million dollars.

Scenario	1	2	3	4	5
Desalinated water source	Urban threshold	Urban & agricultural thresholds	Medium-level salinity threshold	Low-level salinity threshold	No irrigation with wastewater
Brackish (groundwater)	4.98	5.54	7.55	10.63	7.09
Cost increase	-	0.56	2.57	5.65	-
Wastewater	-	8.96	10.40	11.83	-
Seawater	5.26	15.52	17.03	18.83	11.62
Maintaining aquifer threshold level	9.90	9.82	11.06	13.29	10.65
Cost increase	4.92	4.28	3.51	2.66	3.56

Table 9. Annual cost under steady-state conditions (million dollars)

Compared with the threshold of 250 mg/Cl for urban water use alone, the net present value of the cost increase involved in a policy of a 150 mg/Cl threshold for urban and agricultural water use is 27.64 million dollars, and for a threshold of 50 mg/Cl the cost increase is 126.25 million dollars (Table 8). The increase in the annual cost under a steady-state condition for a threshold of 150 mg/Cl for urban and agricultural water is 3.13 million dollars, and for a threshold of 50 mg/Cl – 8.78 million dollars. The total water quantity in question is 24.6 mcm, meaning that the annual increase in cost per cm for improving the threshold for urban and agricultural water to 150 mg/Cl and 50 mg/Cl is 12.5 and 35.5 cents per cm, respectively. It should be noted that determining a threshold of 50 mg/Cl involves a relatively large increase in costs.

Maintaining a threshold of 250 mg/Cl for the aquifer water involves an annual cost increase of 2.66 to 4.92 million dollars, compared with the lowest cost for the same scenario without

the condition of maintaining the aquifer water salinity threshold. That means that the increase in annual cost per cm for maintaining a sustainable aquifer, with a salinity level of 250 mg/Cl under a steady-state conditions, ranges from 10.8 to 20 cents/cm.
The Israeli water sector is currently under conditions of water shortage, and at the stage of planning and establishing seawater desalination plants. At the same time, farmers have been moving to extensive use of wastewater for irrigation, which enables a significant reduction of the demand for freshwater for irrigation, as well as providing a practical solution for wastewater disposal. However, the problem of wastewater salinity should be addressed. The use of wastewater and desalinated seawater provide a partial solution for the problem of water shortage, but the impact on the deterioration of groundwater quality, as expressed in the increase in salinity levels, cannot be ignored. We have presented alternatives for water desalination in order to improve their quality and found that desalinating groundwater and wastewater can be done at a relatively low cost, although some technological and administrative issues remain to be addressed. Both issues of the quality of the water supply and the sustainability of the aquifer are important in the short term as well as in the long term. This research presents the additional costs of stricter salinity threshold levels that will help maintain a sustainable aquifer. Policy makers would need to weigh these additional costs against the added benefits.

6. Summary and conclusions

We developed an hydrological model for planning the water supply from different sources and predicting the chloride concentrations in the aquifer water, and implemented it on a unique database constructed for the case study of the hydrological cells of the Emek Heffer and Northern Sharon areas in Israel. We also estimated the costs of various desalination processes under these regional conditions, and calculated the total cost of the water supply for different policy-making scenarios.
Several findings arise from calculating the costs involved in improving the salinity threshold for water supply to the city and/or agriculture, or for maintaining a sustainable steady-state aquifer. The main conclusions are that the lowest-cost alternative is brackish water desalination; desalination of national carrier water is feasible under large-scale use conditions; wastewater desalination is important to maintain the agricultural water salinity threshold; and finally, seawater desalination is worthwhile when their contribution is essential for the national water balance. If we wish to maintain a salinity threshold of 250 mg/Cl in the aquifer water, we need to limit the salinity level of the irrigation water in Emek Heffer to approximately 90 mg/Cl. The additional annual expenditure needed to maintain the aquifer salinity level is between 2.5 to 5 million dollars, or between 10.75 to 20 cents per cm. It is important to keep in mind that improving the quality of the water supply and the quality of the groundwater comes at an economic price that has to be taken into consideration in the decision making process.
The model we developed and applied is used to examine the planning, hydrological, technological and economic aspects of the supply and desalination of different water sources, and to examine the implications on the economy, on groundwater quality and on the environment. The model's advantages lie in its multidisciplinary nature and in its practical applicability, as well as in its ability to evaluate and direct scenarios of supply and treatment of different water sources. At this stage, the model includes only the salinity level component of water quality, but the model can be expanded to examine the treatment of other components, such as nitrogen concentrations, and can be developed as a computerized model that will improve the policy-makers ability to make informed decisions.

15

Integration of Environmental Processes into Land-use Management Decisions

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1. Introduction

Land-use management decisions are confronted since ever with the challenge to consider complex interactions of different land-use types - natural ecosystems and man-made systems - and to balance at the same time various needs of different land-users (Dragosits et al., 2006; Kallioras et al., 2006; Letcher & Giupponi, 2005; Niemelä et al., 2005). Changing frame conditions such as Climate Change, changing intensity of land-use, changing impact by deposition, etc. impact eco- or man made systems, lead to a severe disturbance of system specific processes and lower in consequence the system stability and resilience (see e.g. Goetz et al., 2007; Metzger et al., 2006; Callaghan et al., 2004).

Taking the impact of Climate Change on European forest ecosystems as an example, biomass production and drinking water supply are severely affected by growing biotic and abiotic risks as a result of longer vegetation periods, higher annual mean temperature and lower annual mean precipitation with shift to the winter period (see e.g. Lindner & Kolström, 2009; Kellomäki et al., 2008; Bytnerowicz et al., 2007; Garcia-Goncalo et al., 2007). Respective observations were also made for agricultural land-use (see e.g. Miraglia et al., 2009; Olesen & Bindi 2002; Bonsall et al., 2002).

Back-coupled on landscape level, the effects of changing frame conditions on individual eco- or man-made systems impact neighbouring systems and might endanger the fulfilment of socially requested functions, goods and services (Fürst et al., 2007a) such aus Carbon sequestration (Schulp et al., 2008), water balance and provision of drinking water (Tehunen et al., 2008). These back-coupling effects must be considered in a holistic land-use management planning approach (Jessel & Jacobs, 2005; Bengtsson et al., 2000).

This becomes even more important with regard to changes in land-use philosophy and intensity such as the increased biofuel crop production and its multi-facetted environmental impact (Demirbas, 2009; Stoeglehner & Narodoslawsky, 2009).

To ensure a sustainable environmental development on the one hand and a sustainable provision of socially requested goods and services on the other, process knowledge must be an integral part of management planning decisions.

A process knowledge oriented land-use management demands:

a. for the identification of process-sensible indicators and for pathways how to make them accessible, understandable and usable for decision makers. (Castella & Verburg, 2007; Fürst et al., 2007a; Mendoza & Martins, 2006; Botequilha Leitao & Ahern, 2002).

b. Furthermore, instruments are demanded which are apt to deal with challenges such as the sectoral fragmentation of information on landscape level, missing data communication standards and which allow for complex knowledge and experience management (Mander et al., 2007; Van Delden et al., 2007; Wiggering et al., 2006).
c. Last but not least, such tools and instruments must fullfill the criterion of being designed in a user-friendly way to ensure their use in practice (Uran & Jansen, 2003).

The book chapter gives an introduction on process-integration into management decisions, starting with the choice of adequate process-indicators and a condensed overview on process-oriented management support approaches.

Focus is laid on the presentation of the software "Pimp your landscape" (P.Y.L.) and its application areas including some examples. The potential of P.Y.L. to support the integration of processes into land-use management decisions are discussed and remaining development tasks are identified.

2. Integration of environmental processes in land-use management decisions

The landscape is the integrative platform, where interactions and processes meet. Interactions are given between the land-users and decide upon land-use pattern changes. The land-use types interact between themselves and with their environment, with impact on environmental processes. These are pre-adjusted by the (regionally specific) environmental frame conditions, but the latter, such as regional climatic frame conditions or site potentials can be impacted again by land-use pattern changes. Figure 1 proposes a respective conceptual framework for process-oriented land-use management.

A process-oriented land-use management must consider this network of processes and interactions and is furthermore confronted with the challenge to bring together the three pillars of sustainability (i) the ecological view emphasizing environmental and ecosystem processes. On the other hand, also (ii) the economic view must be kept to optimize land-use management planning and decision making. And (iii) the (regionally specific) societal demands and frame conditions must be considered (Fürst et al., 2007a).

The DPSIR approach discussed e.g. by Mander et al. (2005) is a suitable and widely spread methodological framework for dealing with environmental management processes in a feedback loop, which controls the interactions within the cycle of **D**rivers–**P**ressures–**S**tate–**I**mpact–**R**esponses. The DPSIR-approach, demands (i) for a set of suitable indicators and (b) for process-models, which provide information on eco- and man-made system reactions under changing (environmental) frame conditions. Climate change as an example is one of the most important challenges for the future. Its complex impact on land-use management and the potential of single land-use types to contribute in the future to socially requested services and functions on landscape level are still under debate (Harrison et al., 2009; Prato, 2008, Metzger et al., 2006; Hitz & Smith, 2004). For supporting the integration of climate change induced processes into sustainable land-use management decisions, both - indicators and models - must be integrated into intelligent system solutions, which help to come to a common understanding and acceptance of process-based management decisions.

2.1 Process-indicators

Suitable process indicators must be apt to describe course, direction and progress of processes in single eco- or man-made systems. Furthermore, they should allow for an upscaling of such processes on landscape level (Fürst et al., 2009; Zirlewagen, 2009;

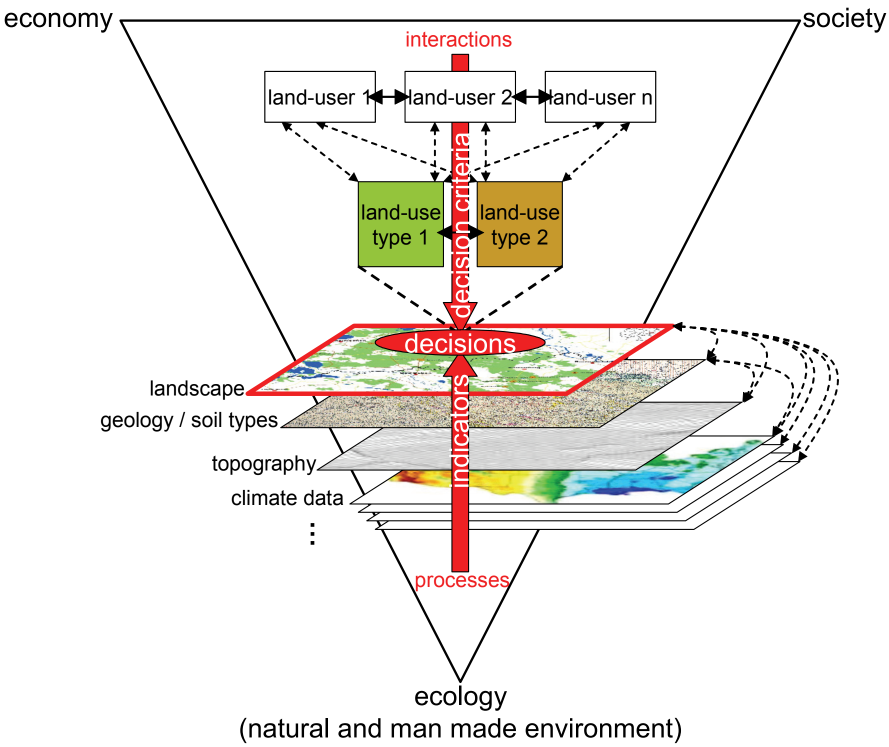

Fig. 1. Conceptual framework of process-oriented land-use management: land-use management decisions consider the close connection of interactions and processes on landscape level and are based on indicators, which reflect environmental processes and on decision criteria resulting from the interacting land-users.

Zirlewagen & von Wilpert, 2009; Fürst et al., 2007b, Zirlewagen et al., 2007; Mander et al., 2005). Finally, such indicators should also enable a comparative evaluation of processes in different eco- or man-made systems to come to a holistic view on landscape level. (Wrbka et al., 2004).

Herrick et al. (2006) highlightened the weakness of single indicators such as vegetation composition to conclude on ongoing ecosystem processes and proposed to combine the indicator vegetation composition with other process-indicators such as soil and site stability, hydrologic function and biotic integrity. Fürst et al. (2007b) propose a framework of change-ratio oriented indicators in forest ecosystems, which includes information on the natural frame conditions, man-made changes and temporal development. Nigel et al. (2005) analysed existing sets of criteria and indicators for biodiversity management impact in forests and agricultural land-use and propose a landscape oriented approach how to evaluate changes.

Concluding from research on appropriate process-indicators leads to the problem that process-indicator-based management planning is not yet realizable in practice, because the necessary holistic aggregation of single indicators or indicator sets from single ecosystems or land-use types with focus on single landscape services is still in progress (Therond et al., 2008).

2.2 Process-oriented management support tools and systems

To support the integration of environmental processes into management decisions, several scientific and technological approaches are used. The challenge to integrate manifold indicators and information as output of process-models into process-oriented decisions is picked up by computer-based management and decision support systems (MSS, DSS). They are drawing high attention as a means of improving the quality and transparency of decision making in natural resource management (Rauscher, 1999). Beyond, an increasing number of stakeholders, which are involved in natural resource management and the resulting necessity to consider multiple interests and preferences in the decision-making process led to the use of Multi-Criteria Decision Making (MCDM) techniques in DSS development. Collaborative technologies such as Group Decision Support Systems (GDSS) might help to avoid the consequences of knowledge fragmentation and will extend that support to decision-making processes involving several individuals. Mendoza & Martins (2006) remarked however that a paradigm shift is necessary in existing MCDM approaches to come from methods for problem solving to methods for problem structuring to ensure better support for the user.

Riolo et al. (2005) e.g. propose a combination of agent-based models and GIS to come to an integration of spatio-temporal processes into management decisions. Castella & Verburg (2007) tested a combination of process- and pattern-oriented models for decisions related to land-use changes. Le et al. (2008) used a multi-agent based model for simulating spatio-temporal processes in a coupled human–landscape system. From a review of existing multi-agent models (MAS), Bousquet & Le Page (2004) came to the conclusion that these mostly interdisciplinary approaches are helpful in complex decision situations.

However, Malczewski (2004) analysed appropriate systems for supporting the integration of processes and process-knowledge into management decision and compared different tools for GIS-based land-use suitability analysis. His analysis comprised methods such as GIS-based modelling and overlay mapping, multicriteria decision making and artificial intelligence methods (fuzzy logic, neural networks, cellular automatons, etc.). He highlightened, that the major limitation of GIS-based modelling and overlapping is the lack of well defined mechanisms for incorporating decision-makers preferences. Uran & Jansen (2003) found additionally that the lack of user friendliness is the reason, why most of these systems fail to be used in practice. According to Malczewski (2004), the main problem of multicriteria decision making consists in the high variability of methods, which are applied and the fact that the selection of different methods may produce different results. Considering artificial intelligence methods, Malczewski (2004) criticised in general their 'black box' style, which makes it difficult for the user to understand how spatial problems are analysed and how the results are produced.

Concluding from the research and comparison of existing tools and systems, (a) transparency how environmental processes and interactions are handled in the approach and how the results are produces, (b) user friendliness and (c) allowance for user dialog and user interactions seem to be the most important features (see also Diez & McIntosh, 2009).

3. Pimp your landscape - a process-oriented management support tool

3.1 Idea and conception

"Pimp your landscape" (P.Y.L.) was designed to support the understanding of complex interactions between various land-use types on landscape level and to provide a basis to evaluate the impact of user-made land-use pattern changes on most important land-use services. Therefore, the continuous spatial problem “landscape” must have been divided into spatially distinct units, which can interact and communicate with each other and to which different attributes can be assigned.

The mathematical approach, which has been chosen to reflect complex spatial interactions, was a cellular automaton with Moore-neighbourhood ship. Cellular automata were first introduced by Ulam (1952) and their potential to support the understanding of the origin and role of spatial complexity was highlightened by Tobler (1979). The approach was e.g. used to model urban structures and land-use dynamics (Barredo et al., 2003; White et al., 1996; White & Engelen, 1994, 1993), regional spatial dynamics (White & Engelen, 1997), or the development of strategies for landscape ecology in metropolitan planning (Silva et al., 2008). Nowadays, cellular automata are broadly used to simulate the impact of land-use (pattern) changes and landscape dynamics (e.g. Moreno, et al., 2009; Wickramasuriya et al., 2009; Yang et al., 2008; Holzkämper & Seppelt, 2007; Soares-Filho et al., 2002).

The starting point in P.Y.L. are land cover datasets, which are taken from Corine Landcover (CLC) 2000 or national level (biotope type / land-use type maps). The smallest unit in the P.Y.L. maps is the cell, which represents an area of 100x100 m² (CLC 2000) or 10x10 m² (only special test sites based on land register maps). A cell can only be attributed with one land-use type. Land-use types with a small share within a cell are assigned to the dominating land-use type. Furthermore, multiple other attributes can be imported as geo-referenced information layer (text or shape files) and can be assigned to the cells, such as geo-pedological information, topographical parameters and climate characteristics. Also, linear elements such as rivers, roads, railways or point-shaped elements of less than 100x100 m² such as power plants can be assigned to a cell. Regarding point-shaped elements, the extent of their spatial impact (e.g. deposition impact gradient) can be defined in the system.

Either it is possible to assign manually additional attributes to a cell, if digital information is not available. In opposite direction, information from P.Y.L. can be exported as geo-referenced text or shape file to a GIS.

The core of P.Y.L. is a hierarchical approach to evaluate the impact of land-use pattern changes, which are induced by the user, on land-use services and functions (Fig. 2).

The evaluation starts by selecting the land-use types (biotope types / ecosystem types), which are of regional relevance and by defining the land-use services and functions of regional interest. The land-use classification standards of CLC 2000 and the land-use services and functions (LUF) set described by Perez-Soba et al. (2008) are available as initial settings. The user can modify these initial settings or adopt completely different settings according to the regional application targets.

In a next step, indicator sets are identified, which provide information on the impact of the land-use types on land-use services and functions. This step requires several feed-back loops with regional experts: a major problem in the holistic evaluation on landscape level consists (a) in the different scales and dimensions of indicator sets at the different land-use types (Fürst et al., 2009) and (b) in the regional availability of respective knowledge sources. Therefore, a meaningful selection and weighting of the indicators is requested, which respects also regional expert knowledge and experiences to compensate existing knowledge gaps.

Based on the indicator sets, the impact of each land-use type on each land-use service or function is evaluated on a relative scale from 0 (worst case) to 100 (best case). The introduction of this relative scale enables (a) to compare the impact of different land-use

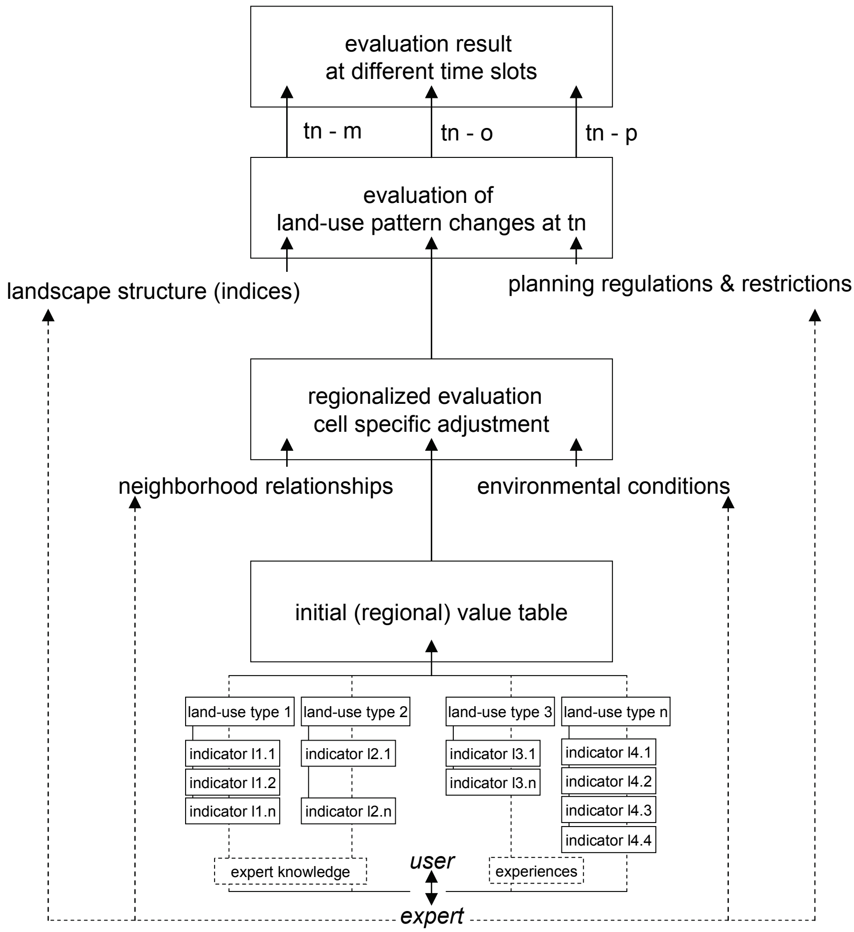

Fig. 2. Hierarchical evaluation of the impact of land-use pattern changes.

types on an individual land-use service or function. (b) The setting of a relative scale as reference supports also a multifunctional evaluation, which faces the challenge to make comparable reactions of different land-use services and functions on land-use pattern changes.

The resulting (regional) value table represents initial impact values of the land-use types on the services and functions. These must be regionalized to consider (a) the cell specific environmental frame conditions (e.g. height above sea level, mean annual precipitation and temperature, soil type and exposition) and (b) the neighbourhood of different land-use types. This step is supported by rule-sets, which offer the user the possibility to specify a possible increase or decrease of the initial value in dependence from neighbourhood type (homogeneous land-use types ⇔ different land-use types, edge to edge ⇔ corner to corner) and in dependence from the (available) environmental attributes.

Building upon the regionalized evaluation basis, landscape structure indices (landscape metrics) are introduced to adopt the evaluation of "soft" land-use services and functions referring to biodiversity or services related to the aesthetical value of a landscape. The indices help to integrate the heterogeneity of the land- use pattern, the size and connectivity of patches and the form of patches from the holistic landscape view (e.g Uuemaa et al., 2009).

In addition, the user is offered various options to insert regional planning rules and restrictions. These limit the degree of freedom to which the land-use pattern can be modified.

The user can specify (a) rules in dependence from the land-use pattern, such as if a land-use type can be converted into another, if a land-use type restricts the conversion of a neighbouring land-use type or if a linear element (street, water body) restricts the conversion of the land-use type at the cell to which this element is assigned.

Also rules for the spatial development of a land-use type can be defined, such as minimum or maximum thresholds and growth trends, i.e. if the share of a land-use type can increase, decrease or should remain equal.

(b) Rules depending from environmental frame conditions can be specified, such as if a land-use type is allowed to be converted into another in dependence from pedo-geological, topographical or climatic attributes. Here, the user can choose between the definition of value ranges of the attributes and the definition of upper or lower thresholds.

(c) Thresholds for the selected land-use services and functions can be defined. According to the evaluation logic, these must adopt a value between 0 and 100.

Taking the rules into account, the user can start the simulation and can start to modify the land-use pattern. He receives a feed-back on the impact of his changes on the land-use services and functions in real time: the system sums up the value of each cell for each land-use type and divides these sums by the total number of cells, which are displayed in the simulation. A mean value is calculated for each land-use service and the evaluation result is displayed as star diagram.

The evaluation result is based on the assumption that each land-use type as soon as it is established has its full impact on the land-use services and functions (time point tn). To come to a more realistic evaluation, the possibility to switch between the evaluation results at different time slots of 10, 30, 50 and 100 years is actually integrated into the system (time points tn-m, … tn-p).

3.2 Application areas and examples

P.Y.L. allows the user to test the complex and various effects of land-use pattern changes and the establishment of linear and point-shaped infrastructural elements on land-use services and functions by simple mouse click (Fig. 3).

The user can conduct local changes (cell by cell, freehand shape, establishment of a point-shaped element) or regional changes (changing all cells of a land-use type / changing all cells of a land-use type, which are spatially connected, establishment of linear elements).

In the philosophy of the system, natural transition processes between land-use types or ecosystems are not considered: the vision of the system is to teach the user the understanding of the effects of his actions on landscape level without additional impact factors, which he cannot influence.

In land-use management planning, P.Y.L. is adapted and tested for different application areas:

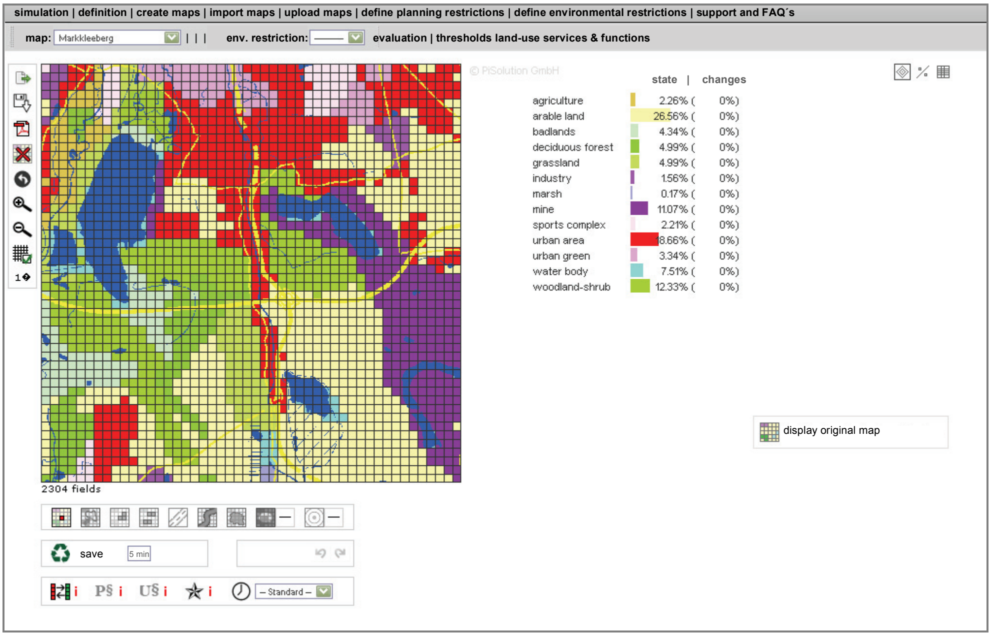

Fig. 3. Graphical user interface of P.Y.L. with variable options to modify the land-use pattern and to introduce linear / point-shaped elements (icons).

a. testing the effects of a regional application of rules and restrictions derived from EU regulations, such as EU Water Framework Directive (2000/60/EC) and Natura 2000 (79/409/EEC and 92/43/EEC) on regionally important land-use services and functions
b. testing different planning alternatives for the spatial development of urban areas and the establishment of infrastructural facilities, such as highways, railways and roads and deriving the extent of possible compensation measures to keep a politically / socially requested level of land-use services and functions such as live quality, biodiversity, etc.
c. testing the effects of flooding in the frame of open cast mining area restoration and of participatory elements in landscape planning (recreation areas and areas reserved for natural succession vs. establishment of touristic infrastructure)
d. testing the effects of climate change on regional risks and potentials and on possible mitigation strategies through changes in the land-use.

In case (a) - (c), additional effects of changing climatic frame conditions are considered, while responses to climate change are the focal point in case (d).

Considering (d), the impact of different climate change scenarios is currently tested at the model region "Dresden" (Saxony /Germany) in the project REGKLAM (Development and Testing of an Integrated Regional Climate Change Adaptation Programme for the Model Region of Dresden, www.regklam.de). Regionalized climate change scenarios are combined with soil and topographical data to derive scenario specific risk maps for erosion and drought. These are used as layers in P.Y.L. instead of primary climate, geological and

topographical parameters. In a first step and based on a region specific evaluation, it is tested, how the actual land-use pattern increases or decreases the drought and erosion risk. In a next step, planning scenarios for urban growth, spatial development of forestry and agriculture are combined with the risk maps to get (a) information on possible range of responses to regional climate change impact by land-use pattern changes and (b) on areas, where additionally land-use type specific changes in management are demanded.
Figs. 4a - 4b show a typical run at the model region Leipzig (Saxony / Germany), where the effects of building a highway are evaluated on regional level (4a) and with local focus (4b) and where a compensation measure (increase of regional forests from 12 to 30 %, 4c) and finally the possible impact of the construction of a lignite power plant with well described gradient (4d) are tested. The star diagram displays the effects of the planning measures for five regionally selected landscape services, the drinking water quality, the aesthetical value of the landscape, climate change sensitivity (based upon regionalized climate change scenarios), regional economy and human health.
The example reveals also a still existent problem in the evaluation: the impact of linear elements on a region (based on the model of a cellular automaton) is hardly appraisable. Here, the switch between two evaluation perspectives, the regional one (Fig. 4a) and the local one (Fig. 4b) helps to approximate to the impact of this planning measure. On the other hand, the increase of the forest area seems to overcompensate the highway construction and also the power plant construction. Here, the adjustment of the evaluation result by landscape metrics is still outstanding.

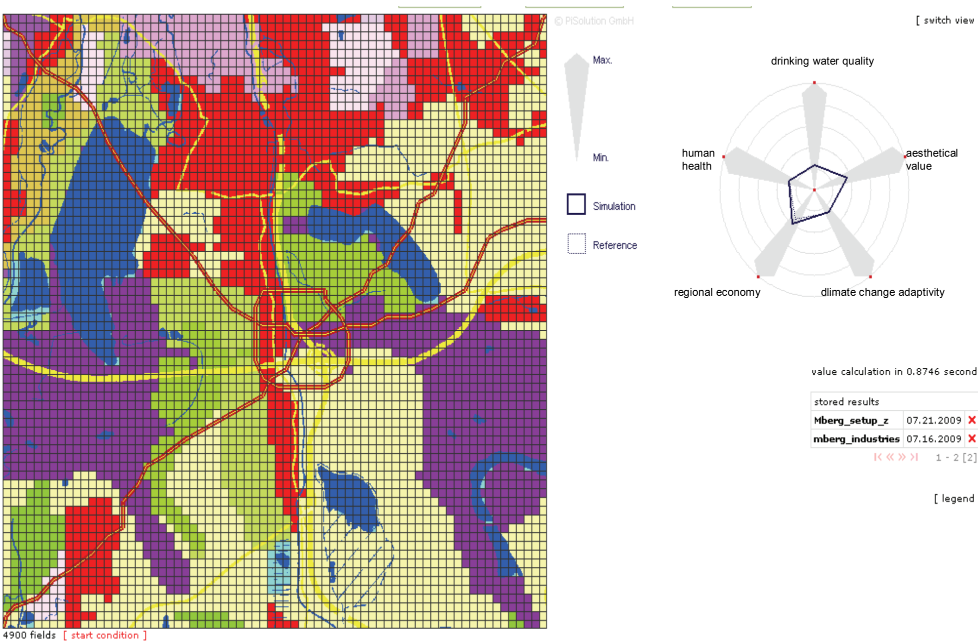

Fig. 4a. Test of the impact of a highway construction on regional level.

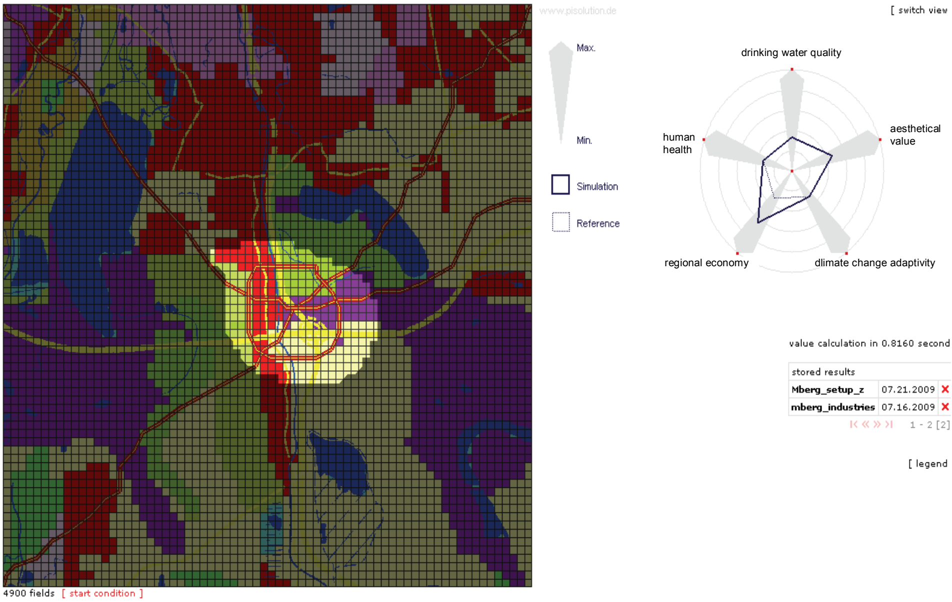

Fig. 4b. Switch to the local impact of the highway with focus on a planned motorway junction.

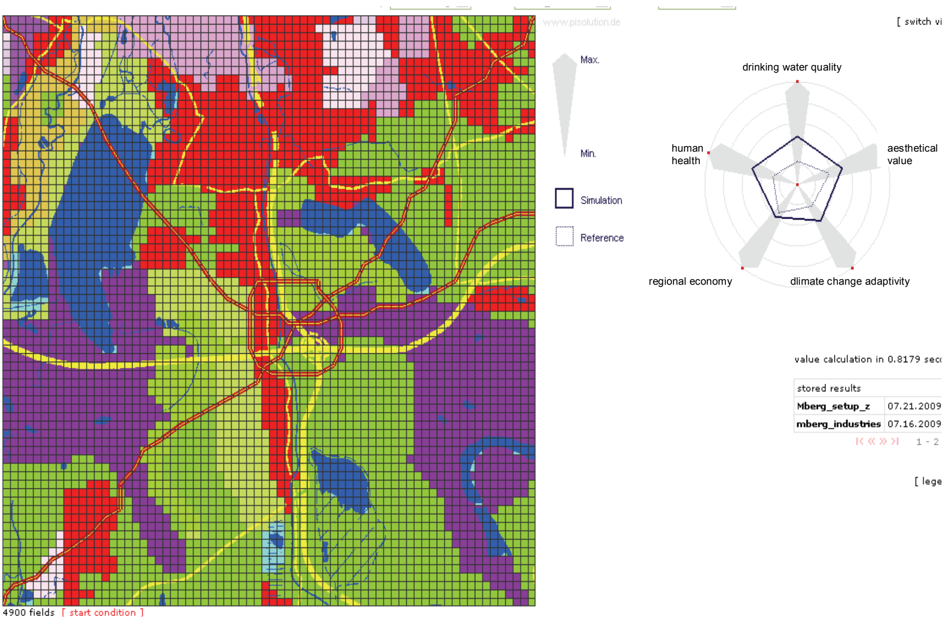

Fig. 4c. Test of a large scale compensation measure by increasing the share of forest land from 12 to ca. 30 %.

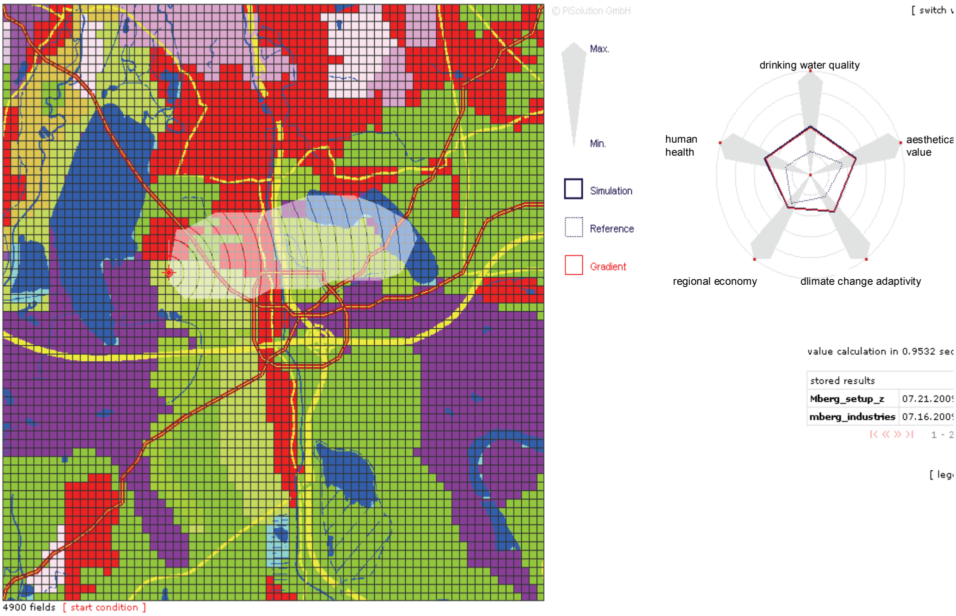

Fig. 4d. Testing of the sensitivity of the compensation measure "afforestation" against the additional establishment of a power plant with western deposition gradient.

4. Discussion and conclusions

"Pimp your landscape (P.Y.L.)" was developed since 2007 to support process-knowledge integration into land-use management planning decisions on landscape level (Fürst et al., 2008). The integration of process-knowledge is realized by several characteristics of the system:

a. the mathematical approach of a cellular automaton enables to simulate by a set of rules dynamic interactions between land-use types and to consider the spatial complexity at landscape level (White et al., 1997).
b. GIS features of P.Y.L. enable to overlay various land-use pattern scenarios with various environmental parameters, which can also be scenario-driven, such as e.g. climate data (as primary data set) or risk maps (as secondary data set) etc.
c. The evaluation approach comprises a complex bundling process of indicators and expert knowledge, which is highly sensible for specific regional demands, changing evaluation targets and variable societal demands.
d. The process of changing the land-use pattern and adding linear of point-shaped elements with their resulting impact on land-use services and functions is strictly driven and defined by the user on the basis of his planning questions and the planning alternatives, he wants to test. Therefore, the criterion transparency is given and as requested by Mendoza & Martins (2006), "decision making" is replaced by support in "problem structuring and testing".

Compared to complex spatial decision or management support approaches, P.Y.L. is based on knowledge, which might be derived from modelling, but takes its results not by coupling of models as e.g. done by Le et al. (2008) or Castella et al. (2007). Therefore, also no transition probabilities between different land-use types and historical land-use development can be simulated. This shortcoming in applicability to real world was tolerated with regard to the intention to make better understandable the effects of user-driven land-use pattern changes.

The requested complex process of knowledge bundling and the identification and selection of indicators and their combination with expert knowledge and experiences must be moderated by science individually for each region and can only build upon results from comparable regions. Furthermore, the use of a relative scale from 0 to 100 to evaluate the impact of land-use changes on land-use services and functions gives no quantitative, but only qualitative information. A resulting risk, which is not specific for P.Y.L. but applies for all knowledge management and decision support systems, is the improper parameterization and use and hereby derived inaccurate decisions (Richardson et al., 2006). However, if the evaluation process is managed well under close participation of regional experts and with detailed documentation of the knowledge sources, the evaluation results in P.Y.L. can experience a high regional acceptance. The easy adaptation of the evaluation base and the rule systems supports also testing how the "system landscape" reacts under variable assumptions on the future value of land-use types for land-use services and functions.

Finally, a possible problem can occur in the case that P.Y.L. is used at different scale levels in a region, as actually tested in the frame of the REGKLAM project. Moreno et al. (2009) e.g., highlighten the sensitivity of cellular automata to cell size and neighbourhood configuration. Furthermore, problems in the classification logic can appear, when assigning land-use types over different scale levels to the dominating land-use type in a cell. Last but not least, also landscape metrics react sensible on scale level changes (Pascual-Hortal & Saura, 2007; Uuema et al., 2005). Here, approaches how to bridge scale level problems and recommendations for the proper use of the system are actually under development.

5. References

Barredo, J.I.; Kasanko, M.; McCormick, N.; Lavalle, C. (2003). Modelling dynamic spatial processes: simulation of urban future scenarios through cellular automata. *Landscape and Urban Planning*, 64(3), pp.145-160

Bengtsson, J.; Nilsson, S.G.; Franc, A.; Menozzi. P. (2000). Biodiversity, disturbances, ecosystem function and management of European forests. *Forest Ecology and Management*, 132(1), pp. 39-50.

Bonsall, C.; Macklin, M. G.; Anderson, D. E.; Payton, R. W. (2002). Climate Change and the Adoption of Agriculture in North-West Europe. *European Journal of Archaeology*, 5(1), pp.9-23

Botequilha Leitao, A. & Ahern, J. (2002). Applying landscape ecological concepts and metrics in sustainable landscape planning. *Landscape and Urban Planning*, 59(2), pp.65-93

Bousquet, F. & Le Page, C. (2004). Multi-agent simulations and ecosystem management: a review. *Ecological Modelling*, 176(3), pp.313-332

Bytnerowicz, A.; Omasa, K.; Paoletti, E. (2007). Integrated effects of air pollution and climate change on forests: A northern hemisphere perspective. *Environmental Pollution*, 147(3), pp.438-445

Callaghan, T.V.; Björn,L.O.; Chernov, Y.; Chapin, T.; Christensen, T.R. ; Huntley, B.; Ims, R. A.; Sitch, S. (2004). Effects of changes in climate on landscape and regional processes, and feedbacks to the climate system. *Ambio*, 33(7), pp.459-468

Castella, J.C. & Verburg, P.H. (2007). Combination of process-oriented and pattern-oriented models of land-use change in a mountain area of Vietnam. *Ecological Modelling*, 202(3), pp.410-420

Castella, J.-C.; Pheng Kam, S.; Dinh Quang, D.; Verburg, P.H.; Thai Hoanh, C. (2007). Combining top-down and bottom-up modelling approaches of land use/cover change to support public policies: Application to sustainable management of natural resources in northern Vietnam. *Land Use Policy*, 24(3), pp.531-545

Demirbas, A. (2009). Political, economic and environmental impacts of biofuels: A review. *Applied Energy*, 86, pp.S108-S117

Diez, E. & McIntosh, B.S. (2009). A review of the factors which influence the use and usefulness of information systems. *Environmental Modelling and Software*, 24(5), pp.588-602

Dragosits, U.; Theobald, M.R.; Place, C.J.; ApSimon, H.M.; Sutton, M.A. (2006). The potential for spatial planning at the landscape level to mitigate the effects of atmospheric ammonia deposition. *Environmental Science and Policy,* 9(7-8), pp. 626-638

Garcia-Gonzalo, J.; Peltola, H.; Briceno-Elizondo, E.; Kellomaki, S. (2007). Effects of climate change and management on timber yield in boreal forests, with economic implications: A case study. *Ecological Modelling*, 209(2), pp.220-234

Fürst, C.; Zirlewagen, D.; Lorz, C. (2009). Regionalization of magnetic susceptibility measurements based on a multiple regression approach. *Water, Air, and Soil Pollution*, doi: 10.1007/s11270-009-0154-1

Fürst, C.; Davidsson, C.; Pietzsch, K.; Abiy, M.; Makeschin, M.; Lorz, C.; Volk, M. (2008). "Pimp your landscape" – interactive land-use planning support tool. Transactions on the Built Environment (ISSN 1743-3509). *Geoenvironment and Landscape Evolution,* III, pp. 219-232.

Fürst, C.; Vacik, H.; Lorz, C.; Makeschin, F.; Podraszky, V.; Janecek, V. (2007a): Meeting the challenges of process-oriented forest management. *Forest Ecology and Management*, 248(1-2), pp. 1-5

Fürst, C.; Lorz, C.; Makeschin, F. (2007b): Development of forest ecosystems after heavy deposition loads considering Dübener Heide as example - challenges for a process-oriented forest management planning. *Forest Ecology and Management*, 248(1-2), pp. 6-16

Goetz, S.J.; Mack, M.C.; Gurney, K.R.; Randerson, J.R.; Houghton, R.A. (2007). Ecosystem responses to recent climate change and fire disturbance at northern high latitudes: observations and model results contrasting northern Eurasia and North America. *Environmental Research Letters*, 2(4), p.045031

Harrison, P.; Rounsevell, M., Luck, G.; Harrington, R.; Sykes, M.; Vandewalle, M. (2009). A conceptual framework to analyse the effects of environmental change on ecosystem services. IOP Conference Series: *Earth and Environmental Science*, 6(30), p.302017, doi:10.1088/1755-1307/6/30/302017

Herrick, J.E.; Schuman, G.E.; Rango, A. (2006). Monitoring ecological processes for restoration projects. *Journal for Nature Conservation*, 14(3), pp.161-171

Hitz, S. & Smith, J. (2004). Estimating global impacts from climate change. *Global Environmental Change*, 14(3), pp.201-218

Holzkämper, A.; Seppelt, R. (2007). A generic tool for optimizing land-use patterns and landscape structures. *Environmental Modelling & Software*, 22, pp.1801-1804
Jessel, B. & Jacobs, J. (2005). Land use scenario development and stakeholder involvement as tools for watershed management within the Havel River Basin. *Limnologica - Ecology and Management of Inland Waters,* 35(3), pp. 220-233.
Kallioras, A.; Pliakas, F.; Diamantis, I. (2006.) The legislative framework and policy for the water resources management of trans-boundary rivers in Europe: the case of Nestos/Mesta River, between Greece and Bulgaria. *Environmental Science and Policy*, 9(3), pp. 291-301
Kellomäki, S.; Peltola, H.; Nuutinen, T.; Korhonen, K.T.; Strandman, H. (2008). Sensitivity of managed boreal forests in Finland to climate change, with implications for adaptive management. *Philosophical Transactions of the Royal Society* B: Biological Sciences, 363(1501), pp. 2341-2351
Le, Q.B.; Park, S.J.; Vlek, P.L.G.; Cremers, A.B. (2008). Land-Use Dynamic Simulator (LUDAS): A multi-agent system model for simulating spatio-temporal dynamics of coupled human–landscape system. I. Structure and theoretical specification. *Ecological Informatics*, 3(2), pp.135-153
Letcher, R.A. & Giupponi, C. (2005). Policies and tools for sustainable water management in the European Union. *Environmental Modeling and Software*, 20(2), pp. 93-98
Lindner, M. & Kolström M. (2009). A review of measures to adapt to climate change in forests of EU countries, *IOP Conference Series: Earth and Environmental Science*, 6 (38), p.382007, doi:10.1088/1755-1307/6/38/382007
Malczewski, J. (2004). GIS-based land-use suitability analysis: a critical overview. *Progress in Planning*, 62(1), pp.3-65
Mander, Ü.; Wiggering, H.; Helming, K. (2007). *Multifunctional land use - meeting future demands for landscape goods and services*. pp. 1-14. Springer. Berlin.
Mander, Ü.; Müller, F.; Wrbka, T. (2005). Functional and structural landscape indicators: upscaling and downscaling problems. *Ecological Indicators*, 5 (2005), pp. 267–272
Mendoza, G.A. & Martins, H. (2006). Multi-criteria decision analysis in natural resource management: A critical review of methods and new modelling paradigms. *Forest Ecology and Management*, 230(1), pp.1-22
Metzger, M.J.; Rounsevell, M.D.A.; Acosta-Michlik, L.; Leemans, R.; Schroter, D. (2006). The vulnerability of ecosystem services to land use change. *Agriculture, Ecosystems and Environment*, 114(1), pp.69-85
Miraglia, M.; Marvin, H.J.P.; Kleter, G.A.; Battilani, P.; Brera, C.; Coni, E.; Cubadda, F.; Dekkers, S. (2009). Climate change and food safety: An emerging issue with special focus on Europe , *Food and Chemical Toxicology*, 47(5), pp.1009-1021
Moreno, N.; Wang, F.; Marceau, D.J. (2009). Implementation of a dynamic neighborhood in a land-use vector-based cellular automata model. *Computers, Environment and Urban Systems*, 33(1), pp.44-54
Niemelä, J.; Young, J.; Alard, A.; Askasibar, M.; Henle, K.; Johnson, R.; Kurttila, M.; Larsson, T.B.; Matouchi, S.; Nowicki, P.; Paiva, R.; Portoghesil, L.; Smulders, R.; Stevenson, A.; Tartes, U.; Watt., Q. (2005). Identifying managing and monitoring conflicts between forest biodiversity conservation and other human interests in Europe. *Forest Policy and Economics*, 7(6), pp. 877-890.

Nigel, D.; Baldock, D.; Nasi, R.; Stolton, S. (2005). Measuring biodiversity and sustainable management in forests and agricultural landscapes. P*hilosophical Transactions of the Royal Society B: Biological Sciences*, 360 (1454), pp.457-470

Olesen, J.E. & Bindi, M. (2002). Consequences of climate change for European agricultural productivity, land-use and policy European. *Journal of Agronomy*, 16(4), pp.239-262

Pascual-Hortal, L. & Saura, S. (2007). Impact of spatial scale on the identification of critical habitat patches for the maintenance of landscape connectivity. *Landscape and Urban Planning*, 83(2), pp.176-186

Perez-Soba, M.; Petit, S.; Jones, L.; Bertrand, N.; Briquel, V.; Omodei-Zorini, L.; Contini, C.; Helming, K.; Farrington, J.; Tinacci-Mossello, M.; Wascher, D.; Kienast, F.; de Groot., R. (2008). Land use functions – a multifunctionality approach to assess the impacts of land use change on land use sustainability. In Helming, K.; Tabbush, P.; Perez-Soba, M. (Ed.) *Sustainability impact assessment of land use changes*. pp.375-404, Springer Berlin-Heidelberg

Prato, T. (2008). Conceptual framework for assessment and management of ecosystem impacts of climate change. *Ecological Complexity*, 5(4), p.329-338

Rauscher, H.M. (1999). Ecosystem management decision support for federal forests in the United States: A review. *Forest Ecology and Management,* 114(2), pp. 173-197

Richardson, S.M.;/ Courtney, J.F.; Haynes, J.D. (2006). Theoretical principles for knowledge management system design: Application to pediatric bipolar disorder. *Decision Support Systems*, 42 (3), pp.1321-1337

Riolo, R.; Brown, D,G.; Robinson, D.T.; North, M.; Rand, W. (2005). Spatial process and data models: Toward integration of agent-based models and GIS. J*ournal of Geographical Systems*, 7(1), pp. 25-47

Schulp, C.J.E.; Nabuurs, G.J.; Verburg, P.H. (2008). Future carbon sequestration in Europe-Effects of land-use change. *Agriculture, Ecosystems and Environmen*t, 127(3), pp.251-264

Silva, E.A.; Ahern, J.; Wileden, J. (2008). Strategies for landscape ecology: An application using cellular automata models. *Progress in Planning*, 70(4), pp.133-177

Soares-Filho, B.S.; Coutinho Cerqueira, G.; Lopes Pennachin, C. (2002). dynamica—a stochastic cellular automata model designed to simulate the landscape dynamics in an Amazonian colonization frontier. *Ecological Modelling*, 154(3), pp.217-235

Stoeglehner, G. & Narodoslawsky, M. (2009). How sustainable are biofuels? Answers and further questions arising from an ecological footprint perspective. *Bioresource Technology*, 100(16), pp.3825-3830

Tenhunen, J.; Geyer, R.; Adiku, S.; Reichstein, M.; Tappeiner, U.; Bahn, M.; Cernusca, A.; Dinh, N.Q.; Kolcun, O.; Lohila, A.; Otieno, D.; Schmidt, M.; Schmitt, M.; Wang, Q.; Wartinger, M.; Wohlfahrt, G. (2009). Influences of changing land-use and CO2 concentration on ecosystem and landscape level carbon and water balances in mountainous terrain of the Stubai Valley, Austria. *Global and Planetary Change*, 67(1), pp.29-43

Therond, O.; Turpin, N.; Belhouchette, H.; Bezlepkina, I.; Bockstaller, C.; Janssen, S.J.C.; Alkan-Olsson, J.; Bergez, J-E.; Wery, J.; Ewert, F. (2008). How to manage models outputs aggregation for indicator quantification within SEAMLESS integrated framework, In: *Proceedings of Impact Assessment of Land Use Changes*. April 6-9, 2008, Berlin, Germany. - Berlin : Humboldt University

Tobler, W. (1979). Cellular geography. In: Gale, S.; Olsson, G.: *Pilosophy in Geography*, pp. 379-386, Reidel Publisher, Dordrecht

Ulam, S. (1952). Random processes and transformations. *Proceedings of the International Congress on Mathematics* (2), pp. 264-275, American Mathematical Society, Providence RI

Uran, O. & Janssen, R. (2003). Why are spatial decision support systems not used? Some experiences from the Netherlands. *Computers, Environment and Urban Systems*, 27, pp. 511–526

Uuemaa M. A.; Roosaare J.; Marja R.; Mander U. (2009). Landscape Metrics and Indices: An Overview of Their Use in Landscape Research. *Living Reviews of Landscape Research*, 3(1). [Online Article]: cited 28.10.2009, http://www.livingreviews.org/lrlr-2009-1

Uuemaa, E.; Roosaare, J.; Mander, U. (2005). Scale dependence of landscape metrics and their indicatory value for nutrient and organic matter losses from catchments. *Ecological Indicators*, 5(4), pp.350-369

Van Delden, H.; Luja, P.; Engelen, G. (2007). Integration of multi-scale dynamic spatial models of socio-economic and physical processes for river basin management. *Environmental Modeling and Software*, 22(2), pp. 223-238

White, R. & Engelen, G. (1997). Cellular automata as the basis of integrated dynamic regional modelling. *Environment and Planning B: Planning and Design*, 24, pp. 235-246

White, R. & Engelen, G. (1994). Urban systems dynamics and cellular automata: Fractal structures between order and chaos. *Chaos, Solitons and Fractals*, 4 (4), pp.563-583

White, R. & Engelen, G. (1993). Cellular automata and fractal urban form: a cellular modelling approach to the evolution of urban land-use patterns. *Environment and Planning A*, 25, pp. 1175-1199

White, R.; Engelen, G.; Uljee, I. (1997): The use of constrained celluar automata for high-resolution modelling of urban land-use dynamics, *Environment and Planning B*: Planning and Design 24, pp 323-343

Wickramasuriya, R.C.; Bregt, A.K. van Delden, H.; Hagen-Zanker, A. (2009). The dynamics of shifting cultivation captured in an extended Constrained Cellular Automata land use model. *Ecological Modelling*, 220(18), p.2302-2309

Wiggering, H.; Dalchow, C.; Glemnitz, M.; Helming, K.; Müller, K.; Schulz, A.; Stachow, U.; Zander, P. (2006). Indicators for multifunctional land use - Linking socio-economic requirements with landscape potentials. *Ecological Indicators*, 6, pp. 238-249

Wrbka, T.; Erb, K.-H.;/ Schulz, N.B.; Peterseil, J.; Hahn, C.; Haberl, H. (2004). Linking pattern and process in cultural landscapes. An empirical study based on spatially explicit indicators. *Land Use Policy*, 21(3), pp.289-306

Yang, Q. & Li, X. / Shi, X. (2008). Cellular automata for simulating land use changes based on support vector machines. *Computers and Geosciences*, 34(6), pp.592-602

Zirlewagen, D. (2009). Regionalisierung der bodenchemischen Drift in der Dübener Heide im Zeitraum 1995–2006. *Waldökologie, Landschaftsforschung und Naturschutz*, 8, pp. 21-30

Zirlewagen, D. & Wilpert, K. von (2009). Raum-Zeitmuster von Stoffflüssen im Boden: Verbindung von Sickerwasserchemie und Bodenfestphase, *Waldökologie, Landschaftsforschung und Naturschutz*, 8, pp. 31-40.

Zirlewagen, D.; Raben, G.; Weise, M. (2007). Zoning of forest health conditions based on a set of soil, topographic and vegetation parameters. *Forest Ecology & Management*, 248(1–2), pp. 43-55.

Guidelines to Improve Construction and Demolition Waste Management in Portugal

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1. Introduction

The construction industry is a major contributor to excessive natural resource consumption, depletion and degradation; waste generation and accumulation; and environmental impact and degradation. The amount of waste generated by the construction and demolition activity is substantial. Surveys conducted in several countries found that it is as high as 20% to 30% of the total waste entering landfills throughout the world (Bossink & Brouwers, 1996). Moreover, the weight of the generated demolition waste is more than twice the weight of the generated construction waste. Other studies compared new construction to refurbishment, and concluded that the latter accounts with more than 80% of the total amount of waste produced by the construction activity as a whole. The building activity at historical city centres tends to be an important waste generator because both refurbishment projects and new projects often include demolition (Teixeira & Couto, 2000). Construction site activities in urban areas may cause damage to the environment, interfering with the daily life of local residents, who frequently complain about dust, mud, noise, traffic delay, space reduction, materials or waste deposition in the public space, etc. Regarding this theme, an attempt was made to order each impact by the importance given to each one in scientific publications, being the following the most frequently mentioned (Couto, 2002; Couto & Couto, 2006):

- Production of waste;
- Mud on streets;
- Production of dust;
- Soil and water contamination and damaging of the public drainage system;
- Damaging of trees;
- Visual impact;
- Noise;
- Increase in traffic volume and occupation of public roads; and
- Damaging of the public space.

A recent research study carried out by the Instituto Superior Técnico da Universidade Técnica de Lisboa (Technical University of Lisbon) reveals that most of the construction and demolition (C&D) waste is not recycled in Portugal in opposition to what is happening in most European Countries. This study advances that Portugal generates around 4.4 million tones (Mt) per year of core C&D. However, in most construction sites the waste is selected

but its destination is not controlled. Only a few local authorities require the promoters to make a plan for C&D waste (Couto & Couto, 2009).
This inappropriate management for long time has lead to the appearing of many disposals in green areas, adjoining roads and other sensible places.
On the other hand, there is not yet a market for recyclable materials. Most practitioners have been manifesting distrust and lack of information about this issue.
In the Historical City Centres (HCC) the negative effects of the construction projects have even a greater relevance, since they are urban areas with very particular characteristics. As they are touristic locations, it is necessary to maintain them as much as possible as pleasant places to live, work and enjoy. Furthermore, these areas frequently have significant restrictions regarding the available space, which brings about more difficulties for the construction projects. Therefore, the HCC, in view of their specificities, require a special attention from the intervenients of the construction sector in order to minimize the impacts of the construction projects.
The national inquiry carried out with the Portuguese Association of Cities with Historical Centers (Couto, 2002; Teixeira & Couto, 2002), of which 50% of members (56) answered, had the results showed in table 1 regarding the most common prevention attitudes towards the waste impact.

Common prevention attitude - waste	Answers (%)
Generally Compulsive Prevention – in the licensing of the construction project according to municipal norms/regulations	54
Sporadically Require Prevention – in the licensing of the construction project, in some circumstances	29
Eventually Require Prevention – during the work execution due to complaints from affected citizens	14
Without Prevention – considering the inconveniences caused by the normal execution of the construction project	3

Table 1. Common prevention attitudes towards waste production impact

The result shows that only about half of the respondents have expressed that preventive measures are generally required in the licensing stage, which is quite worrying due to the importance and sensibility of those places. The lack of a preventive attitude from both the authorities and the contractors, followed by an inefficient inspection and control by the authorities are the main causes for the majority of complains from neighbors and transients.
This work presents a strategic actions set necessary to improve and promote the waste construction management in Portugal. An effort should be made in order to reduce waste production on site and to increase its recycling value. The reuse, based on deconstruction process, should be considered a good solution and an opportunity market.

2. Reasons to a good practice on Waste Minimisation & Management (WMM)

2.1 The main benefits of a WMM

Waste management involves identifying potential waste streams, setting target recovery rates and managing the process to ensure that these targets are met.

Adopting the principals of good practice waste minimisation on a project can demonstrate a firm commitment to sustainable construction and environmental management. Good practice in waste management when are well implemented, bring a number of benefits. The main benefits include (WRAP (a), 2009):

- Reduced material and disposal costs – less waste generated means that a reduced quantity of materials will be purchased, and less waste taken to landfill will reduce gate fees for disposal. Cost savings will stimulate the adoption of improved recovery practices and motivate a sustained change in waste management practice;
- Increased competitive differentiation – benefits both developers and contractors, particularly where this will help to meet prospective client's sustainability objectives;
- Lower CO2 emissions;
- Complementing other aspects of sustainable design; and
- Responding to and pre-empting public policy – those organisations responding to the thrust in public policy making for the increased sustainability of construction and the built environment will be in an advantageous position in comparison with those that wait until they are compelled to act by legislation.

With the implementation of good practice waste minimisation and management it is possible to be significantly more efficient in the use of natural resources without compromising cost, quality or construction programmes (WRAP (a), 2009).

Fully benefiting from good practice waste minimisation and management on a project will mean adopting its principles at the earliest possible stage, preferably mandated by the client through procurement requirements. The principles of good practice should then be communicated and implemented by the design team, contractor, sub-contractors, and waste management contractors through all project phases – from outlines design to project completion. This can be illustrated on the figure 1 in following page.

2.2 The costs of waste

The costs of waste are not limited to the cost of landfilling, as illustrated in figure 2.

The costs mentioned in figure 2 should also be added the following costs:

- The time taken by on-site sorting, handling and managing waste;
- Poor packing or overfilling of skips leading to double leading to double handling (this cost is very difficult to quantify); and
- The cost of material that have been wasted.

3. Strategies to mitigate the waste production: potencial uses for waste

3.1 Implementing a waste minimisation hierarchy

The waste minimisation hierarchy is an important guide to managing waste. It encourages the adoption of options for managing waste in the following order of priority (Morgan & Stevenson, 2005):

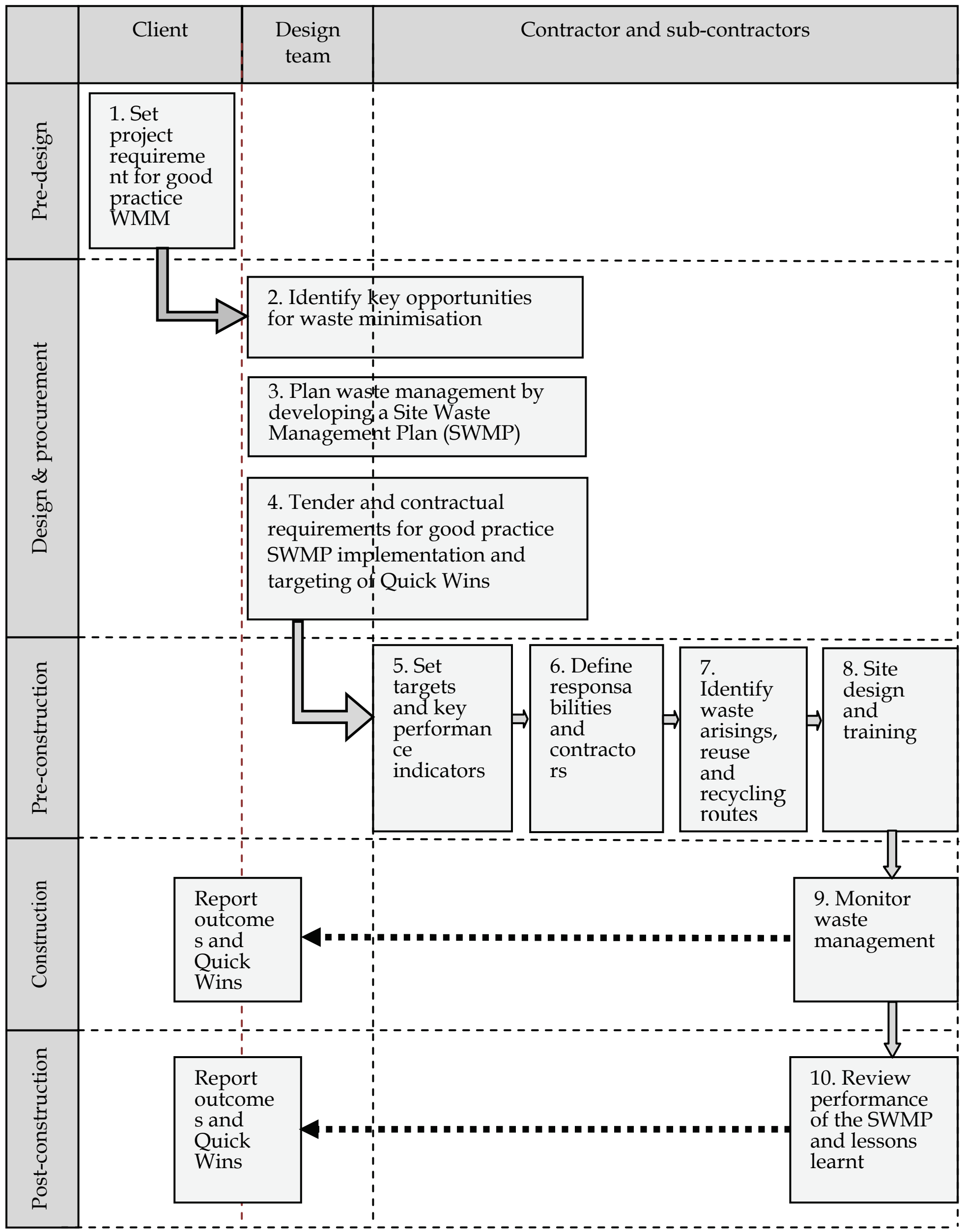

Fig. 1. Achieving good practice waste minimization and management. Source: Adopted from (WRAP (a), 2009)

Waste cost = Purchase cost of the delivered materials wasted + Cost of waste storage, transport, treatment and disposal + Loss of not selling waste for salvage or not recycling

Fig. 2. The costs of waste. Source: Based on (WRAP (a), 2009)

- Waste should be prevented or reduced at source as far as possible;
- Where waste cannot be prevented, waste materials or products should be reused directly, or refurbished before reuse;
- Waste materials should then be recycled or reprocessed into a form that allows them to be reclaimed as a secondary raw material;
- Where useful secondary materials cannot be reclaimed, the energy content of waste should be recovered and used as a substitute for non-renewable energy resources; and
- Only if waste cannot be prevented, reclaimed or recovered, it should be disposed of into the environment by landfilling, and this should only be undertaken in a controlled manner.

In figure 3 is illustrated the waste hierarchies for demolition and construction operations.

Construction waste management should move increasingly towards the first of these options, using a framework governed by five key principles promoted by the European Union (EU):

- The proximity principle;
- Regional self sufficiency;
- The precautionary principle;
- The polluter pays; and
- Best practicable environmental option.

Clearly, the reuse of building elements should take priority over their recycling, wherever practicable, to help satisfy the first priority of waste prevention at source.

The following section offers some advice on how to approach the project, so as to facilitate waste management of all stages of the project.

3.2 Avoiding waste

Avoiding generating waste in the first place is the best way to manage waste. Efficient, lightweight designs, which respond well to site characteristics, minimize not only waste, but also often result in cost savings in construction. Such buildings also often have significantly lower long-term operating costs. Identifying potential waste early in the design process decreases waste generated during construction.

3.2.1 Design stage

Recent research by WRAP (WRAP (b), 2009) has identified the important contribution that designers can make in reducing waste is through design. WRAP has developed a number of exemplar case studies on live projects, working with design teams to identify and build the business case for action around designing out waste. This work has improved current understanding of how to reduce construction waste and has led to the development of five key principles that design teams can use during the design process to reduce waste:

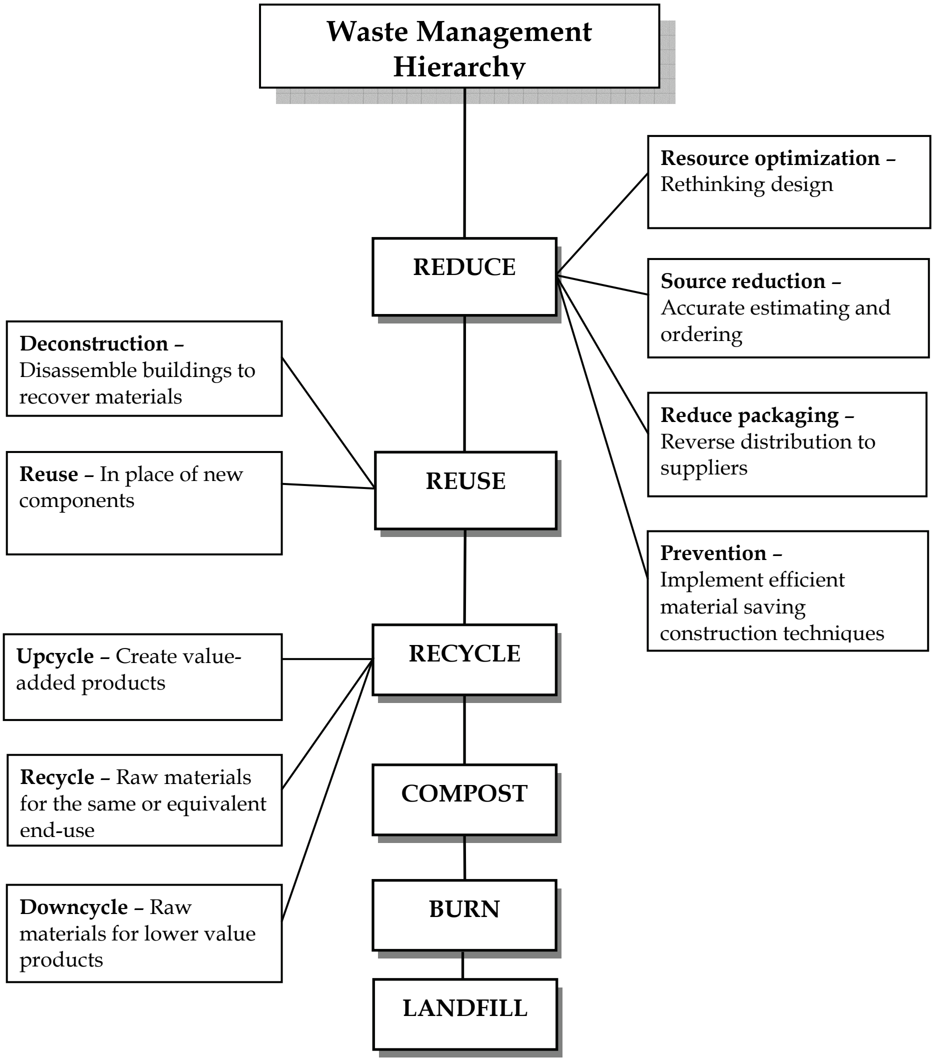

Fig. 3. Hierarchies for demolition and construction operations. Source: Adopted directly from (kibert & Chini, 2000)

- Design to reuse and recovery - reuse of materials components and/or entire building has considerable potential to reduce the key environmental burdens (e.g. embodied energy, CO2, waste, etc) resulting from construction;
- Design for off site construction - the benefits of off site factory production in the construction industry include the potential to considerably reduce waste especially when factory manufactured elements and components are used extensively;
- Design for materials optimization – this principle draws on a number of "good practice" initiatives that designers should consider as part of the design process. Good

practice in this context means adopting a design approach that focuses on materials resource efficiency (see figure 4) so that less material is used in the design (i.e. lean design), and/or less waste is produced in the construction process, without compromising the design concept. The figure 4 shows in the grey boxes the areas where designers can have a significant impact;

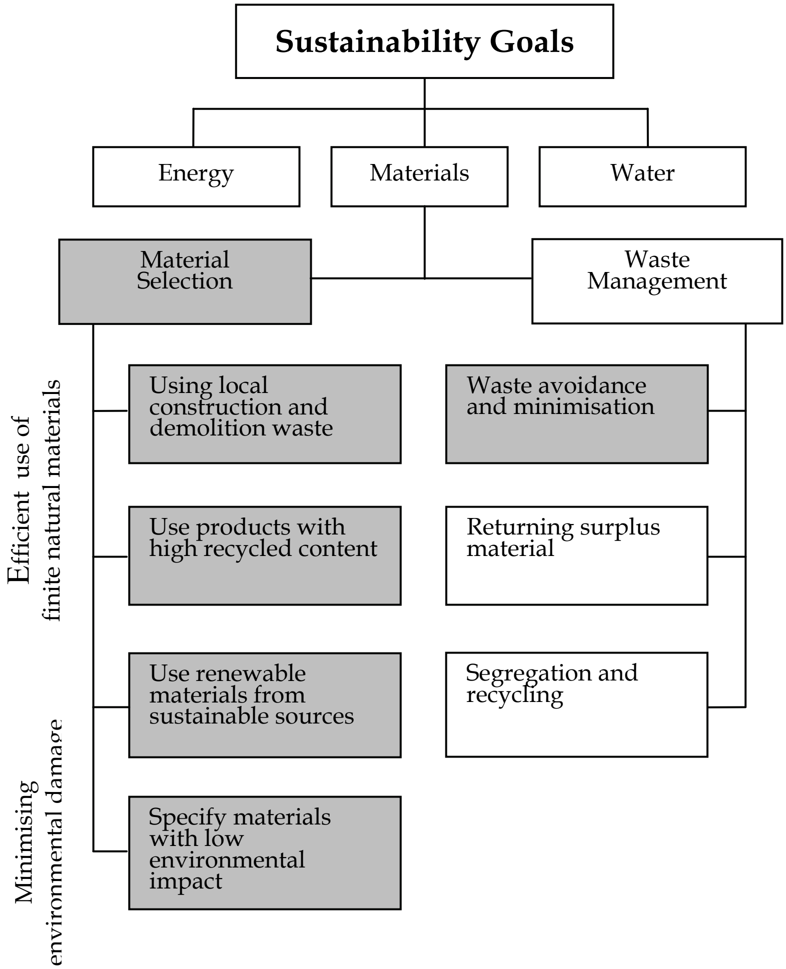

Fig. 4. Materials resource efficiency as part of sustainable construction. Source: (WRAP (b), 2009)

- Design for waste efficient procurement – designers have considerable influence on the construction process itself, both through specification as well as setting contractual targets, prior to the formal appointment of a contractor/constructor. Designers need to consider how work sequences affect the generation of construction waste and work with the contractor and other specialist subcontractors to understand and minimize

these, often by setting clear contractual targets. Once work sequences that causes site waste are identified and understood, they can often be "designed out"; and
- Design for deconstruction and flexibility – designers need to consider how materials can be recovered effectively during the life of building when maintenance and refurbishment is undertaken or when the building comes to the end of its life. Not to design with Design for Deconstruction and Flexibility in mind limits the future potential of Design for Reuse.

During the construction design stage there are several actions that could avoid waste generation, which may include:
- Designing to standard sizes, to modular and prefabricated construction, and requiring minimal earthwork;
- Incorporating recyclable, recycled and reusable products in construction;
- Designing for dismantling or deconstruction. Some of the principles include: the dis-entanglement of systems, materials bolted together instead of glued, a construction and deconstruction blueprint, buit-in tie-offs and connection points for workers and machinery, no hazardous materials and highly recyclable materials (Resource Venture, 2005);
- Considering renovating or refurbishing an existing building, rather than demolishing and rebuilding;
- Designing to reduce future energy use, by orienting the building to use passive solar heating and natural ventilation;
- Co-ordination between designers and construction companies should be attended in the definition of materials and construction products; and
- Packing conditions should be discussed with suppliers in order to reduce the number of packs and the amount of packaging materials, especially those not possible to reuse or difficult to recycle.

3.2.2 Construction planning stage

During the construction planning stage there are several actions that could avoid waste generation, which may include (CIRIA, 1997; EnviroSense, 1996; Couto, 2002; Couto & Couto (a), 2007; Teixeira & Couto, 2000):
- Co-ordination between designers and construction companies should be attend in the definition of materials and construction products;
- Promoting adequate communication among owners, project designers and contractors. Lack of communication is often the cause of partial demolition and removal of applied material, contributing towards needless output of debris;
- Keeping the workers and concerned parties up to date, whether on the steps taken to minimize debris or the importance of such steps, as it easier to take action when one knows the motives for it;
- Before commencement of construction works, asses needed materials and make an effort to locate and acquire used materials beforehand, whenever possible;
- Arrival of materials and products should be planned, according to available place on site and to production flow, to avoid excessive stocks and possible deterioration of goods and packs;
- Stockpiles of sand, gravel, soil and other similar material should be located so that they do not spill and cannot be washed onto the adjacent street;

- Accident spills of those materials should be removed prior to the completion of the day's work;
- Quality control should reject defective materials at the time of delivery thus avoiding later disposal;
- Materials should be delivered packed on site so that cracking can be reduced during transportation and handling operations on site;
- Packing conditions should be discussed with supplies in order to reduce the number of packs and the amount of packaging materials, especially those not possible to reuse or difficult to have recycling waste;
- Orders to supplies of materials should respect sizing needs so that adjustments can be avoided during construction;
- Select products that output the least possible amount of waste or, at least, less toxic waste. A good example would be oil-based paint, which contain organic solvents that may render paint waste more dangerous. Water-based paint (latex) is safer to users and easier to handle. One should also try to use paints without metallic pigments, as these may also make the waste dangerous;
- Store vegetable soil on piles no higher than 2 meters, and handle it as little as possible, as this may damage its structure;
- Cut down as few trees and bushes as possible when cleaning out terrain to implant a construction site. Trees, trunks, branches and other vegetable matter, are solid waste that must be conveniently handled, at considerable cost; and
- Label packages of materials as it comes in, and record the date for reception of materials that deteriorate easily, so that the first to come in are employed first.

3.2.3 Construction stage

Most waste generated during the construction stage can be avoided. Ways to avoid waste are (Couto & Couto (a), 2007; Couto & Couto, 2009):

- Ordering pre-cut, prefabricated materials that are the correct size for the job;
- Reduce packaging by returning to the supplier, or requesting reusable packaging such as cardboard or metal instead of plastic;
- Bulk-buy to avoid excess packaging (however, ensuring site requirements are not exceeded, avoiding the environmental impact of transportation and excess storage)
- Orders to suppliers of materials should respect sizing needs so that size adjustments can be avoided during construction;
- Make sure storage areas are secure and weatherproof (where required);
- Keep the site tidy to reduce material losses and waste;
- Promote good practice awareness as part of health and safety induction/training for workers onsite;
- Protect materials from deterioration. Store them in sheltered areas if they are subject to degradation by rain or sunshine. Materials that can be degraded by mud or dust must be stored away from heavy traffic areas;
- Waste selection. Waste must be stored in segregated containers, according to the material origin; wood, metal, packages, aggregates, etc. Storing waste inconveniently has costs – the storage of dangerous waste is much more expansive than that of harmless materials – and may make the construction site unsafe. Piles of waste scattered throughout the site make accidents more likely; storing waste correctly not

only bolsters reuse and recycling as it contributes towards health and hygiene at the site. Waste selection involves roam enough on site to dispose containers and allow for the operation of trucks and cranes and skill workers to the selection procedures, but these conditions are often difficult to achieve, especially in historical city centres. Some private companies already operate in the area of waste selection and possible reuse of materials in the construction industry;

- Cutting concrete due to lack of precision in design implementation shuttering and placement of holes should be avoided because it produces waste besides it is time consuming and involves noisy operations;
- Reusable shuttering materials with eventual wreck value should be preferred even if investment costs are higher; and
- Storing in safe areas using adequately labelled containers for chemicals and recycling.

3.3 Reusing waste

Reusing building materials prevents environmental impacts by reducing the need for virgin natural resources to be mined and harvested, while saving forests and natural areas from further degradation. Reusing waste is efficient, as it does not require further processing, thereby not requiring further energy use. Efficiency can be improved further by reusing materials on site, eliminating the need for transportation. There are several opportunities for waste reuse as following is described:

- Careful demolition can maximize the reuse value of materials, particularly fittings, floorings and timber linings;
- Sort demolition materials and identify the materials that can be reused, and grade accordingly to quality and re-usability;
- Reuse rock, soil and vegetation on site for landscaping;
- Stockpile the materials for removal and reuse off site, ensuring adequate provision for sediment and erosion control (ensuring minimal impact to the aesthetic quality of the surrounding environment);
- Reuse materials from the demolition stage;
- Buy used materials from reclamation yards where possible re-usable shuttering materials with eventual wreck value should be preferred even if investment costs are higher;
- Re-usable shuttering materials with eventual wreck value should be preferred even if investment costs are higher; and
- Waste selection (Couto, 2002). Residue must be stored in segregated containers, according to the material origin of the material; wood, metal, packages, aggregates, etc. Storing residue inconveniently has costs – the storage of dangerous residue is much more expensive than that of harmless materials – and may make the construction site unsafe. Piles of waste scattered throughout the site are more likely to cause accidents; storing residue correctly not only bolsters reuse and recycling as it contributes towards health and hygiene at the site. Waste selection involves room enough on site to dispose containers and allow for the operation of trucks and cranes and skilled workers for the selection procedure, but these conditions are often difficult to achieve, especially in historical City Centres. Some private companies already operate in the area of waste selection and possible re-use of materials in the construction industry.

3.4 Recycling waste
Many waste products unable to be reused directly, can be reprocessed into new products. Successful waste minimisation requires the appropriate handling of waste on site at all stages of development. In particular:

- Sort waste according to type, use and quality. Several bins or storage areas should be provided, and should be clearly signed. Waste for disposal should be kept separate from recyclables;
- Ensure waste is kept clean and free of contaminants. This can be done by providing dry storage areas, clearly marked bins, and waste management information to contractors and staff; and
- Provide for ongoing waste management.

3.5 Disposing of waste
Disposal of waste should be considered a last resort, for materials that cannot be reused or recycled in the region. Unsorted loads may incur in a disposal penalty at landfills. Hazardous materials need to be disposed of correctly.

4. Deconstruction technique as alternative to traditional demolition

4.1 Factors affecting the choice of demolition method
According to what has been previously mentioned, the demolition is one of the main construction activities in concerning the production of waste. The demolition industry has undergone major transformations within the last 20 years. Traditionally it has been an intensive labor activity with low technology, low skills, and poorly regulated dealing mainly with the disassembly and demolition of simply constructed buildings. With the arising of new challenges, namely the increasing complexity in building design, the financial pressures from clients, health and safety issues, regulatory and legal requirements, it has followed the trend of all major industries and mechanized the process by replacing labor with machines (Hurley & Hobbs, 2004).

The older buildings often have several components with an aesthetic or antique value which results in them being salvaged. As the complexity and size of buildings has risen so have the technical demands placed on contractors taking them down safely. Research from the University of Salford (Bowes & Golton, 2000) reveals that demolition techniques are now not only numerous but also varied in their technology, application, cost and speed. Traditional methods such as the steel ball are being rapidly replaced by more modern methods as the emphasis changes from masonry and brickwork to concrete and steel structures.

Traditionally, factors are concerned with the physical aspects of the building to be demolished, its technology and materials, size, location, site, use and the scope of the demolition required, the safety of operatives, the public and the environment and the time period (Kasai & Lindsell, 1988). The incorporation of the time factor shows that the contractual conditions can have an effect on choice, whilst the inclusion of safety aspects points to the influence of wider issues such as legislation, and the environment. However, nowadays a new factor should be added to the initial group of factors:

- *The proposed fate of the building materials and components* once the structure is demolished will probably affect the choice to some extent. Some of the methods available, for example, explosives, merely reduce a building into manageable size pieces taking little or no account of the separation of materials. Clearly such methods would be unsuitable for a project where a high degree of reuse of individual components was specified.

There are usually several methods of tackling a demolition, all of which have various advantages relating to the factors above. There are not 'right' or 'wrong' methods, just alternative options based on different assessment of the relevant factors in a case.

The choice for the best option for managing a project's waste, should take into consideration the value of the various materials. For instance, there may be materials on a project that have a greater value "as is" for salvage compared to their value as material for recycling. Some of these materials may be valuable to reuse on-site; others may be donated or sold to a used building material retailer or charitable organization. The initial costs for deconstruction services may be offset by returns from salvaged materials or reduced purchasing costs. Some deconstruction services may also give a tax deduction for materials that are donated (Resource Venture, 2005).

In some cases, reused materials may also provide functional or aesthetic features not available in new materials. For example, salvaged wood is often of a quality and a variety of species that is difficult to find in the market place.

There are two ways to recover materials for salvage and reuse: Deconstruct the building or conduct a selective salvage operation prior to demolition. Deconstruction involves the careful dismantling of a whole structure in reverse order of assembly, usually by hand, to re-harvest materials for reuse. Salvage is the removal of certain valuable reusable building materials before demolition.

4.2 Deconstruction technique

Deconstruction is a new term used to describe an old process. As its primary purpose, deconstruction encompasses a thorough and comprehensive methodology to whole building disassembly and seeks to maintain the highest possible value for materials in existing buildings by dismantling them in a manner that will allow the reuse or efficient recycling of the materials that comprise the structure (Moussiopoulos et al., 2007). For demolition projects that involve removing a large portion of a structure or an entire building, deconstruction may be the best option. Deconstruction is a specific type of demolition work that is growing in popularity in the United States and in other European countries and that poses the greatest potential for waste recovery on a wide range of construction projects. Deconstruction contractors take the entire structure apart, separating out resources that can be salvaged, recycled or reused.

The feasibility and cost-effectiveness of deconstruction is determined by how the building was constructed and what building materials were used. The building components, their condition and the manner in which they are secured to the structure can affect the cost-effectiveness of salvaged materials.

Another factor to consider is whether site conditions allow for mechanical versus manual demolition, which will add labor costs. To be cost-competitive with conventional demolition, the added costs of deconstruction (primarily, the extra labor of disassembly and removal) must be offset by the value of the salvaged building material and the avoided cost of disposal.

4.3 Salvage

Salvage is the removal of reusable building materials before demolition. In many cases, it may not be feasible or cost-effective to fully deconstruct a building, but there may be materials on a project that can be salvaged instead of recycled or discarded. This is also a very good cost-saving strategy for a remodeling or tenant improvement project. Most demolition contractors are practicing some level of salvage on selected buildings. In many cases, demolition contractors will sub-contract with deconstruction contractors or specialty sub-contractors to conduct salvage operations before demolishing specific components or materials.

4.4 Barriers and advantages of deconstruction

4.4.1 Barriers and opportunities for deconstruction

There are a number of areas where the authorities may influence design and planning strategies at an early stage. These include fiscal incentives such as the maintenance of a fixed price for recovered products or increased costs for waste disposal through the landfill tax. Incorporation of deconstruction techniques into material specifications and design codes on both a National and European level would focus the minds of designers and manufacturers. Education of the long-term benefits of deconstruction techniques for regulators and major clients would provide the necessary incentive for the initial feasibility stage. Design for deconstruction is not, however, solely an issue for the designers of buildings. The development of suitable tools for the safe and economic removal of structural elements is an essential pre-requisite of the more widespread adoption of deconstruction (Couto & Couto, 2007).

A study carried out by BRE (Building Research Establishment) (Hurley et al., 2001) has shown what the industry has known for decades; that there are keys factors that affect the choice of the demolition method and particular barriers to reuse and recycling of components and materials of the structures. The most factors are physical in terms of the nature and design of the building along with external factors such as time and safety. Future factors to consider should well include the fate of the components, the culture of the demolition contractor and the 'true cost' of the process. For the latter, barriers to uptake include the perception of planners and developers, time and money, availability of quality information about the structure, prohibitively expensive health and safety measures, infrastructure, markets quality of components, codes and standards, location, client perception and risk.

According Hurley and Hobbs (Hurley & Hobbs, 2004) the main barriers in the UK to the increased use of deconstruction methods within construction include:

- Lack of information, skills and tools on how to deconstruct;
- Lack of information, skills and tools on how to design for deconstruction;
- Lack of a large enough established market for deconstructed products;
- Lack of design. Products are not designed with deconstruction in mind;
- Reluctance of manufactures, which always prefer to purchase a new product rather than to reuse an existing one;
- Composite products. Many modern products are composites which can lead to contamination if not properly deconstructed or handled; and
- Joints between components are often designed to be hidden (and therefore inaccessible) and permanent.

Although the market for products from deconstruction to be poorly developed in Portugal can be noted that the interest in low volume, high value, rare, unique or antique architectural components it's much higher than the interest in materials that have high volume, low value, such as concrete.

Even though there are significant advantages to deconstruction as an option for building removal, there are still more challenges faced by this alternative:

- Deconstruction requires additional time. Time constraints and financial pressure to clear the site quickly, due to lost time resulting from delays in getting a demolition, or removal permit, may detract from the viability of deconstruction as a business alternative;
- Deconstruction is a labor-intensive effort, using standard hand tools in the majority of cases. Specialized tools designed for deconstructing buildings often do not exist;
- The proper removal of asbestos-containing materials and lead-based paints, often encountered in older buildings that are candidates for deconstruction, requires special training, handling, and equipment; and
- Re-certification of used materials is not always possible, and building codes often do not address the reuse of building components.

The main opportunities which require development include:

- The design of joints to facilitate deconstruction;
- The development of methodologies to assess, test and certify deconstructed elements for strength and durability, etc.;
- The development of techniques for reusing such elements; and
- The identification of demonstration projects to illustrate the potential of the different methods.

Modern materials such plywood and composite boards are difficult to remove from structures. Moreover, new building techniques such as gluing floorboards and usage of high-tech fasteners inhibit deconstruction. Thus, buildings constructed before 1950 should be ideally targeted for deconstruction (Moussiopoulos et al., 2007). In Portugal, it is expected a substantial increase in investment in rehabilitation of buildings. The deconstruction should have a relevant contribution in this process.

The greatest benefit will be achieved by incorporating deconstruction issues into the design and feasibility stage for all new construction. Each case can then be judged on its merits in terms of the potential cost of recovery and recycling or reclamation and reuse of construction materials.

The following in table 2 is an attempt to systematize the main barriers in the implementation of deconstruction in Potugal from the analysis of the barriers identified in the international literature (Storey & Pedersen, 2003):

Barrier	**How this relates to PT**	**Solutions**
Legislation		
Current standard specifications.	Standards give the impression that new materials must be specified.	- Development of standard specifications etc, which incorporate reused/recycled components. - Document and publish examples of the successful use of reused and recycled components. - Government and local council as examples in new development.

Markets		
The high cost of transport and storage of recycled components and materials.	______________________	- Market networking. - Direct sales from site.
Uses for some salvaged materials are undeveloped.	Finding uses for some recycled or salvaged materials is difficult.	- Increased research focusing on problem materials.
Designer/public/builder attitude: "new is better" and new buildings are permanent.	The majority of building materials specified and used in PT are new. Design for deconstruction is uncommon.	- Education for architects in life cycle considerations and holistic design principles. - General education of public, designers and builders. - Easy to use guides in the use of salvaged materials/design for deconstruction. - Publishing and compilation of research into quality aspects of reused goods.
The lack of a grading system for reused components.	______________________	- Development of a grading system. - Training in the grading of reused materials. - Liability issue addressed.
Guaranteed quality /quantities of reused materials are difficult.	______________________	- Increased networking of salvage. - Increased deconstruction.
Lack of information and tools to implement deconstruction.	There is a lack of PT specific documents or information kits for the implementation of deconstruction and specific feasibility studies or clear PT examples cases.	- Compilation of guides, development of implementation ideas. - Clear ways to implement PT Waste Strategy targets are needed. - Increased pilot studies and test cases. - Strategic planning to address barriers.
C+D Industry		
Lack of communication and networking in the C&D industry.	______________________	- Greater communication, networking and collaboration. - Increased conferences, email discussion groups, networking, professional articles publications, etc.
Lack of design for deconstruction.	International research is not always applicable to PT. There is a lack of example cases built in PT. Design for deconstruction is	- Education of architects and designers through conferences/exhibitions/case studies etc. - Education at architecture

	not taught at architecture schools.	schools. - Development and sharing of teaching resources and case study examples.
Difficulty in securing funding for research.	Science and Innovation Policy.	- Governments and funding agencies need to make waste minimisation a priority.
Economics Factors		
The benefits of deconstruction are long term and collective.	______________________	-Increased education on environmental building impacts for developers.
Lack of financial incentive for deconstruction.	______________________	- Implementation of economic incentives and deterrents to encourage deconstruction.
Market pressures – the current climate of “as fast as possible”.	Limited time to salvage maximum materials in the demolition stage. Deconstruction takes longer.	- Salvage operations to work along side but independently of demolition contractors. - Share of environmental responsibility to developers.
It is difficult to access or apply economic assessment tools for deconstruction or LCA in some cases.	There are no PT specific deconstruction evaluation tools or national feasibility studies.	- Collection of existing tools in one place. Possibly website. - Development of non region-specific tools or more flexible parameters.
Deconstruction needs a more skilled workforce than demolition.	Unregulated demolition industry. Lack of case jobs to train on.	- Increased opportunities for training and transition from traditional demolition to deconstruction. - Cooperative between the construction and demolition sectors.
Technical Issues		
Lack of documentation.	Records of materials used in construction are not kept.	- Better recording of materials used. - Storage of records in the actual building.
Increased use of in situ technology, chemical bonds and plastic sealants, etc.	Commonly used in new buildings in PT. Most concrete structures have in situ components.	- Research viable alternatives to these techniques. - Development of ways to separate these bonds
Most existing buildings are not designed to be deconstructed.	This is true in PT.	- Research and development to find ways to effectively deconstruct these buildings. - Implementation of design for deconstruction techniques into learning establishments a priority.

Table 2. Main barriers to deconstruction in Portugal. Adapted from (Storey & Pedersen, 2003)

4.4.2 Deconstruction benefits

Deconstruction seeks to close the resource loop, so that existing materials are kept in use for as long as possible and the deployment of new resources in construction projects is diminished. The benefits from deconstruction are considerable. Deconstruction offers historical, social, economic and environmental benefits. Older buildings often contain craftsmanship, which have significant historical value. Deconstruction can carefully salvage these important historical architectural features because materials are preserved during removal. Deconstruction is more time consuming and requires more skill than simply demolishing a structure. Although the extra time required could act as a detriment, deconstruction provides training for the construction industry and also has the potential to create more jobs in both the demolition and the associated recovered materials industry. Deconstruction provides a market for labour and sales of salvaged material. More important, deconstruction puts back into circulation items which may be directly used in other building applications. Environmental benefits of deconstruction are essentially two fold. Primary, resource use is reduced through a decreased demand on new materials for building. This means that climate change gas emissions, environmental impact, pollution (air, land and water) and energy use are all reduced. Deconstruction also means that less waste goes to landfill because materials are salvaged for reuse. This means fewer new landfills or incinerators need to be built which reduces the environmental and social impact of such facilities, and environmental impact of existing landfills is reduced. Currently there are few incentives to break the historical practice of landfilling debris. The occasionally higher cost of selected demolition can be offset by the increased income from salvaged materials, decreased disposal costs, and decreased costs from avoided time and expense needed to bring heavy equipment to a job site (Couto & Couto, 2007).

Based on the review of international literature it is possible to categorize the main benefits of deconstruction as follows:

- Reuse and recycle materials: materials salvaged in a deconstruction project can be reused, remanufactured or recycled (turning damaged wood into mulch or cement into aggregate for new foundations) (Hagen, 2008);
- Foster the growth of a new market — used materials: recovered materials can be sold to a salving company. The market value for salvaged materials from deconstruction is greater than from demolition due to the care that is taken in removing the materials in the deconstruction process;
- Environmental benefits: salvaging materials through deconstruction helps reducing the burden on landfills, which have already reached their capacity in many localities. By focusing on the reuse and recycling of existing materials, deconstruction preserves the invested energy embodied in materials, eliminating the need to expend additional energy to process new materials. By reducing the use of new materials, deconstruction also helps reducing the environmental effects, such as air, water and ground pollution resulting from the processes of extracting the raw materials used in those new construction materials. Deconstruction results in much less damage to the local site, including soil and vegetation, and generates less dust and noise than demolition; and
- Create jobs: deconstruction is a labour-intensive process, involving a significant amount of work, removing materials that can be salvaged, taking apart buildings, and preparing, sorting, and hauling the salvaged materials.

Others benefits less obvious may also come from the deconstruction, but that depend on the specific characteristics of countries and regions.
The following (table 3) is presented an attempt to systematize the benefits that can come from the implementation of deconstruction in Portugal.

Benefits of Deconstruction in Portugal	
Environmental	Reduce primary resource use
	Reduce waste to landfill
	Increase opportunities for recycling
	Site impacts caused by demolition such as noise, compaction, dust, etc. are mitigated
Economic	Profit increased taking into account the sale of salvaged goods and reduction landfill costs
	Promotion of PT´s green image
	Increase local market for the salvage and recycling industry
	Export opportunities for deconstruction related machinery and consulting
	Recycled goods may be of a higher quality and be of a more durable nature than new goods
Social	More jobs are created with deconstruction
	Deconstruction trains workers for the construction industry
	Deconstruction could provide low cost materials to low income communities
	Improve knowledge about the construction techniques applied
Health and Safety	Careful removal of hazardous materials
	Deconstruction means less new waste facilities
Legislative	Contributes to meeting local authority and central government obligations for waste targets, zero waste, kyoto targets and energy efficiency targets

Table 3. Benefits of deconstruction in Portugal

4.4.3 Cost of deconstruction

Deconstruction, as an environmentally-sound business practice, is not necessarily more costly than traditional demolition. Buildings can be often deconstructed more cost-efficiently than they can be demolished. There are many different factors involved, including the type of construction and the value of the materials that can be recovered. But overall, deconstruction can be more cost-effective than demolition. Not only can buildings be deconstructed more cheaply than they can be demolished, but deconstruction provides construction companies with low-cost materials for reuse in their own building projects. Deconstruction is also an ideal training ground for the construction trades. Preliminary results from pilot projects carried out in different parts of the USA by the US Environmental

Protection Agency (EPA) have indicated that deconstruction may cost 30 to 50% less than demolition (CEPA, 2001).

Deconstruction is labor-intensive, involving a higher level of manual work than there would be in a demolition project. But the higher labor cost can be offset by lower costs for equipment rent and energy usage, cost savings in the form of lower transportation and landfill tipping charges, and the revenues from sales of the salvaged material.

Research shows that the market value for salvaged material is greater when deconstruction occurs instead of demolition, because of the care taken in removing materials. Money made through salvaging can be used to offset other redevelopment costs. Lastly, disposal costs are lower with deconstruction because the process reduces the amount of waste produced by up to 75 percent.

Different studies carried out in Germany on deconstruction methods has showed that optimized deconstruction combining manual and machine dismantling can reduce the required time by a factor of 2 with a recovery rate of 97% (Kibert, 2000). In the Oslo region, Norway, it is estimated that between 25% and 50% of C&D waste stream is recycled or reused (Kibert, 2000).

In Portugal the construction waste management is now beginning its first steps, so that, its outcomes are not still known.

Previous research analysis to point out that from the clients' perspective the following are sound economic reasons for using deconstruction (Couto & Couto, 2009):

- To increase the flexible use and adaptation of property at minimal future cost;
- To reduce the whole-life environmental impact of a project;
- To maximise the value of a building, or its elements, when it is only required for a short time;
- To reduce the quantity of materials going to landfill;
- To reduce a future liability to pay higher landfill taxes;
- To reduce the risk of financial penalties in the future, due to changing legislation, through easily replaceable building elements; and
- To minimise maintenance and upgrading costs incurred by replacement requirements.

A key economic benefit of design for deconstruction is the ability for a client to "future proof" their building, both in terms of maintenance and any necessary upgrading, with minimum disruption and cost. The wider economic benefits to society include minimising waste costs at all levels.

Numerous projects have been costed, and while some have come in on budget, others have not. Much depends on the canniness of the design team and contractor, from the outset, with cost savings to be viewed as bonus rather than a given. Design for deconstruction should always be adopted for its wider economic, social and environmental benefits rather than any initial cost saving.

Current economic barriers to design for deconstruction and re-use of reclaimed materials and products include: the additional time involved for deconstruction and the difficulty of costing this against re-used materials which will be used on a different project, the damage caused by poorly designed assemblies and connectors as well as the limited flexibility of reclaimed elements. Reuse is not subsidised in the same way that manufacture is in terms of energy, infrastructure, transportation, and economies of scale, all of which have hidden environmental costs.

5. Establishing a conduct for successful deconstruction process

Advanced planning for deconstruction or salvage before demolition is crucial for its success. The first step is to assess the deconstruction potential:

- Conduct a walk-through with the owner's representative and a deconstruction contractor to determine the feasibility and level of salvage possible. Identify materials and job phases where recovery, recycling and salvage opportunities are the greatest. The walk- through also can identify materials that could be salvaged and reused on-site;
- To compare costs, require estimates for full deconstruction of the structure, targeted salvage prior to demolition, and traditional demolition; and
- Based on the walk-through and cost comparison, it should be determined if full deconstruction of the structure is an option or if salvage prior to demolition would be more effective.

After that, one should be establish goals for deconstruction salvage and recycling and include these goals in the specifications.

Based on the walk-through, a list of materials to be salvaged should be developed. Identify materials to be reused on-site. For materials that will be sold or donated off-site, salvage companies that accept reused building materials should be contacted.

It is important to use specification language in the construction waste management specifications to address deconstruction or salvage prior to demolition. The language should include goals or measurable standards for the level of salvage and/or a list of materials to be salvaged.

Deconstruction and salvage prior to demolition are usually more time-consuming than traditional demolition. It is important that sufficient time is allowed to dismantle the building or to salvage reusable items before demolition. For that, it is recommendable to take the following measures:

- Determine in advance how much time is available to complete the demolition phase of the project. The bid and contract process is the best place to assure that adequate time is available. Contracting mechanisms include decoupling demolition from the design/build phase of construction contracts. The demolition aspect of the project can be delayed while the terms of the larger design/build agreement are worked out, thus allowing time for deconstruction and salvage prior to completing demolition;
- Other alternatives to ensure enough time to complete deconstruction and salvage include issuing an early notice to proceed for the demolition phase of the project or creating a separate request for proposal or bid and contract for deconstruction and demolition.

It also is important for the architect to identify and remove barriers to salvage and reuse by eliminating language in contracts that prohibit rather than control activities such as on-site salvage, storage of salvaged materials, or processing operations that might create noise pollution like on-site concrete crushing.

Require the contractor to develop a reuse and salvage plan as part of the waste management plan for the project by including this requirement in the specification language. The reuse and salvage plan should include a list of items being reused in place or elsewhere on-site; a list of items for reuse off-site through salvage, resale or donation; a plan for protecting,

dismantling, handling, storing and transporting the reused items; and a communications plan describing the salvage plan to all players.
Finally, the contractor should be also required to provide clear and consistent communication at the job site to be sure the crew is informed of the salvage plans, procedures and expectations. Careful removal and handling of the reuse and salvage materials is crucial to their usability and marketability - the key to success is communicating the priorities, making detailed plans and carefully monitoring the progress to insure success.

6. Suggestions to impel the deconstruction process in Portugal

In Portugal the construction sector is still very traditional, so new practices and attitudes are difficult to implement. New challenges like refurbishment and waste management have been systematically prorogued. In order to improve the construction waste management by impelling the deconstruction process it will be necessary to implement some few strategic actions:

- To improve the efficiency of the authority control;
- Training all construction intervenients;
- Diffusion of benefits by workshops;
- To consider environmental factors in contractors selection;
- To increase the disposal taxes; and
- To increase the penalties.

7. Conclusions

Nowadays, few measures have been carried out to improve the relationship among construction site activities, the environment and the citizens. Maybe due to the mobility of the construction activity, it is difficult to make the construction companies – especially the smallest ones – keep the law. There are some good examples but they are still insufficient. The production of legal documents that encourages a more environmentally positive behaviour, that is, that arouse and force the construction industry to handle its debris and by-products more carefully, is of vital importance to the contribution of this sector for sustainable development for the which all must contribute. In this context, special mention must be made to the mandatory, in public projects, of a waste management plan, which must be made during the design stage. It seems to be a correct and effective way to highlight the importance of waste management and to get all the participants involved, from the design to the construction stage. This change, however, must be accompanied by public awareness campaigns. It is not enough to stress that the plan is mandatory. The plan's importance must be addressed too. It will be easier to reach our goals if all kwon the advantages and importance of such a plan.
Due to the need for adaptation and improvement of existing buildings taking into account the new standards of quality and comfort, the works involving demolition of buildings or parts of buildings are becoming increasingly frequent in Portugal. Thus, the study of practical solutions that point to the reuse of building materials and components, will contribute to decrease the urban problem created by illegal landfills – bringing

environmental improvement – and introduce new materials into the market which have potential for use. The deconstruction process appears as an adequate answer for these challenges and with a significant potential for exploitation in Portuguese building refurbishment. In this sense, it is very important to carry out an effort to overcome the barriers to the increased use of deconstruction methods as an option for building demolition.

Therefore, a greater engagement and a new attitude from all practitioners is absolutely necessary in order to implement new and more adequate waste management rules and new selection demolition processes so as to increase the results of the construction waste management.

It is very important that National authorities and construction practitioners understand the benefits of the deconstruction process and look at it as an advantageous way to improve waste management, thus following other European countries' practices.

8. References

Bowes, H. & Golton, B. (2000). The maximization of net resource recovery from demolition, *Proceedings of BRE Conference: Deconstruction closing the loop conference,* Watford, May 2000

Bossink, B. & Brouwers, H. (1996). Construction waste: qualification and source evaluation, *Journal of Construction Engineering and Management,* Vol. 122, No 1 March, 1996

CEPA - California Environmental Protection Agency, Integrated Waste Management Board (2001). *Deconstruction Training Manual: Waste Management Reuse and Recycling at Mather Field*, California Environmental Protection Agency, Integrated Waste Management Board, California

CIRIA – Construction Industry Research and Information Association, (1997). *Waste minimisation in construction – Site Guide.* Ciria Special Publication 133

Couto, A. (2002). Environmental impact of construction sites in historic cities centres, MSc dissertation, University of Minho, September

Couto, A. & Couto, J. (2007). Why deconstruction is not adequately considered in Portuguese building refurbishment, *Proceedings of the ARCOM 2007: 23rd ARCOM Annual Conference*, Belfast, Northern Ireland, 3-5 September 2007

Couto, A. & Couto, J. (2006). Desconstrução – Uma ferramenta para a sustentabilidade da construção, *Proceedings of the NUTAU`2006, Technological Innovation – Sustainability, VI Brazilian seminary of design management process in building projects*, School of Architecture and Urbanization, University of S. Paulo, São Paulo, Brazil

Couto, J. & Couto, A. (2009). Strategies to improve waste management in Portuguese construction industry: the deconstruction process. *Int. J. Environment and Waste Management*, Vol. 3, Nos 1/2, pp. 164-176

Couto, J. & Couto, A. (a) (2007). Construction sites environment: establishing measures to mitigate the noise and the waste impact, *Proceedings of Portugal SB07. Sustainable Construction, Materials and Practices – Challenge of the Industry for the New Millennium, Part 1,* pp. 76-81, ISBN 978-1-58603-785-7, Lisboa, 12-14 September 2007, IOS Press, Amsterdam

Couto, J. & Couto, A. (b) (2007). Reasons to consider the deconstruction process as an important practice to sustainable construction, *Proceedings of Portugal SB07. Sustainable Construction, Materials and Practices – Challenge of the Industry for the New Millennium, Part 1,* pp. 56-62, ISBN 978-1-58603-785-7, Lisboa, 12-14 September 2007, IOS Press, Amsterdam

EnviroSense – Delaware Department of Natural Resource and Environmental Control, 1996. A pollution Prevention Guide for Building Construction and Demolition. Available at: http://es.epa.gov/program/regional/state/delaware/del-cnst.html

Resource Venture (2005). *Construction Waste Management Guide for Architects, Designers, Developers, Facility Managers, Owners, Property Managers & Specifications Writers'*, Resource Venture, Third edition, Seattle

Hagen, K. (2008). Deconstruction as an Alternative to Demolition – Helping the Environment, Creating Jobs, and Saving Resources. Available at: http://www.associatedcontent.com. Accessed September 2008

Hurley, J. & Hobbs, G. (2004). Report 9: TG39 – UK Country Report on Deconstruction

Hurley, J., McGrath, C., Fletcher S. L. & Bowes, H. M. (2001). *Deconstruction and reuse of construction materials*, BRE – Building Research Establishment, ISBN 1 86081 478 6, Watford

Kasai, Y. & Lindsell, P. (1988). Outline of various demolition methods and their evaluation, *Proceedings of RILEM International Symposium on Demolition and Reuse of Concrete and Masonry*, Vol. 1: Demolition methods and practice, Chapman and Hall, London

Kibert, C. (2000). Deconstruction as an essential component of sustainable construction, *Strategies for sustainable building environment*, Pretoria, 23-25 August 2000

Kibert, C. & Chini, A. (2000). Deconstruction as an essential component of sustainable construction, *Proceeding of CIB conference on Overview of Deconstruction in Selected Countries*, pp. 6-14, ISBN 0-9643886-3-4, USA, August 2000, Edited by Charles Kibert and Abdol Chini, University of Florida, Gainesville

Morgan, C. & Stevenson, F. (2005). *Design and Detailing for Deconstruction: SEDA Design Guide for Scotland*, Nº1, SEDA – The Scottish Ecological Design Association

Moussiopoulos, N.; Papadopoulos, A. Iakovou, E.; Achillas, H.; Aidonis, D; Anastaselos, D. & Banias, G. (2007). Construction and Demolition Waste Management : State of the art trends, *Proceedings of 10th International Conference on Environmental Science and Technology*, pp. A-1009-A-1016, Greece, September 2007, kos island

Storey, J. & Pedersen, M. (2003). Overcoming the Barriers to Deconstruction and Materials Reuse in New Zealand, *Proceedings of 11th Rinker International Conference : Deconstruction and Materials Reuse*, USA, May 2003, Edited by Abdol Chini, University of Florida, Gainesville

Teixeira, J. & Couto, A. (2002). Building Refurbishment in Historical City Centres, *Proceedings of XXX IAHS World Congress on Housing. Housing Construction – An Interdisciplinary Task,* Vol. II, pp. 223-229, ISBN 972-9027-31-5, University of Coimbra, Coimbra, 19-13 Setembro 2002, Wide Dreams – Projectos Multimédia Lda

Teixeira, J. & Couto, A. (2000). Construction Sites and Environment in Historic Portuguese Cities, *CD Proceedings CIB Symposium on Construction and Environment Theory into Practice*, S. Paulo Brazil, 23-24 November 2000

WRAP: Materials change for better environment (a). Achieving Good Practice Waste Minimisation and Management. Available in website to WRAP at: http://www.wrap.org.uk/construction . Accessed November 2009

WRAP: Materials change for better environment (b). Designing out waste: A design team guide for building. Available in website to WRAP at: http://www.wrap.org.uk/construction . Accessed September 2009

17

Establishment a Resource Management Program for Accreditation Process at the Medical Laboratory

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1. Introduction

The Laboratory Accreditation Program from the Joint Commission on Accreditation of Healthcare Organizations (JCAHO) is one of the most widely used CMS-approved accreditation program. The other two accreditation programs are the Laboratory Accreditation Program from the CAP (College of American Pathologists) (http://www.cap.org) and COLA, formerly known as the Commission on Office Laboratory Accreditation (http://www.cola.org). Testing requirements of each organization are at least equivalent to those of CLIA '88, they execute to some extent different testing standards and rationales in reaching the goal of quality laboratory testing. Since 1995, clinical laboratories surveyed using JCAHO standards have been deemed to be certifiable under CLIA '88 requirements. The purpose of CLIA '88 is to ensure that all laboratory testing, wherever performed, is done accurately and according to good scientific practices and to provide assurance to the public that access to safe, accurate laboratory testing is available [1]. Joint Commission inspect their members using performance standards that meet or exceed those of CLIA.
The current JCAHO laboratory standards include resource provision and management and mandate that the laboratory leaders plan for and provide adequate resources to meet the mission and goals of the laboratory (Joint Commission of Accreditation of Health Care Organizations, *2009 Accreditation Process Guide for Laboratories*: http://www.jcrinc.com/). The areas of resource provision and management include appropriately trained staff; space, utilities, and safety and environmental controls; appropriate equipment and supplies; and adequate systems to handle required information. The planning process by lab leaders needs to address the ability to provide these and other resources, as required. There should also be adequate education to appropriate staff about the quality management system plan and implementation. This communication delineates an execution of resource management (RSM) program and some quality assurance tools that have been developed and tailored in our laboratory to comply with the requirements for laboratory accreditation by Joint Commission International (JCI) [2].

2. Methods

The objectives of this work were achieved in accordance with the mission of the hospital, the objectives of our laboratory, any applicable laws or regulations and all relevant accreditation standards. The related policies and procedures were developed to provide guidance for workers when implementing the process. The policies were generated based on standard requirements for resource provision and management by JCI [3]. The implementation of this resource management (RSM) program is undertaken in five major sub-fields. Table 1 outlines the descriptions and intents of those pertinent standards classified in each sub-field.

Table 1. Joint Commission International standards regarding resource management.

Standard no.	Standard	Explanation
RSM.1	The leaders determine and provide adequate resources, support laboratory employees and to implement, maintain and improve the quality management program.	After planning for the services provided, the laboratory leaders are responsible for providing adequate, appropriately trained staff and other resources to meet the goals of the laboratory and to meet customer needs. In addition, appropriate resources are provided for the maintenance and improvement of the quality management system. These include the following: • Staff trained to participate in the program • Adequate time is allotted for staff to participate in the various aspects of the quality management system, as required by their job responsibilities. • Information system and data management processes required for the quality management system.
RSM.2	The clinical director (or leaders) of the laboratory provides an adequate number of qualified staff.	The number and qualifications of all staff, including the director and managers are appropriate to the laboratory's services. Required job qualifications are defined for all laboratory staff positions, as well as job expectations. Required qualifications are at least as stringent as applicable law and regulation. An adequate number of technical and support staff are provided for all required functions. There is also provision for an adequate number of supervisory staff with training and experience to oversee laboratory testing and reporting activities.
RSM.3	Basic facilities, including adequate space, utilities, and equipment are sufficient for the efficient	The laboratory can provide consistent test results of acceptable quality only when there is provision of appropriate facilities the laboratory environment. These include adequate

Standard no.	Standard	Explanation
	and safe performance of laboratory work.	buildings, space within the laboratory, appropriate utilities, and supplies and equipment for performance of laboratory tests. In addition, communication systems within the laboratory and between the laboratory and customers are adequate for the size and complexity of the organization, and for the efficient transfer of information and messages.
RSM.4	Laboratory leaders assure that resources required for the provision of services are adequate and available. Such resources include materials required for specimen collection, preparation and processing, examination, and storage, such as • Laboratory instruments; • Reagents; • Consumables; and • Analytical systems.	Adequate resources must be provided for the laboratory to meet goals and customer requirements. The laboratory director is responsible for defining the process of selecting and using equipment, reagents, and other supplies that affect the quality of services. As part of this process, the director defines performance criteria for test methodologies, equipment, and quality control. Criteria are also defined for the inspection, acceptability, and storage of consumable materials.
RSM.5	The laboratory designs a safe, accessible, effective, and efficient environment consistent with its mission, services, and law and regulation.	Laboratory leaders address safety. Adequate safety devices are provided.

3. Results

3.1 RSM.1 – RSM.1.1

The qualifications and responsibilities of laboratory personnel should include the requirements of CLIA relating to competency assessments in the clinical laboratory [4-6]. The laboratory director and managers and/or other leaders have the appropriate training and experience to perform all responsibilities.

Table 2 and 3 summarize the requirements for laboratory director and technical supervisor, respectively. Those qualifications are described in CLIA’88 under Subpart M – Personnel for Nonwaived Testing §493.1351-§493.1495. A complete description of the requirement is located at http://www.cms.hhs.gov/clia or http://www.phppo.cdc/clia.

Ensure that prior to testing patient's specimens, all personnel have the appropriate education and experience, receive the appropriate training for the type and complexity of the services offered, and have demonstrated that they can perform all testing operations reliably to provide and report accurate results. Ensure that policies and procedures are established for monitoring individuals who conduct pre-analytical, analytical, and post-analytical phases of testing to assure that they are competent and maintain their competency to process specimens, perform test procedures and report test results promptly and proficiently, and whenever necessary, identify needs for remedial training or continuing education to improve skills. Specify, in writing, the responsibilities and duties of each consultant and each supervisor, as well as each person engaged in the performance of the pre-analytical, analytical, and post-analytical phases of testing. This should identify which examinations and procedures each individual is authorized to perform, whether supervision is required for specimen processing, test performance or result reporting and whether supervisory or director review is required prior to reporting patient test results.

Table 2. Summary of responsibilities of laboratory director

“The technical supervisor is responsible for identifying training needs and assuring that each individual performing tests receives regular in-service training and education appropriate for the type and complexity of the laboratory services performed.” "The technical supervisor is responsible for evaluating the competency of all testing personnel and assuring that the staff maintain their competency to perform test procedures and report test results promptly, accurately and proficiently. The procedures for evaluation of the staff must include, but are not limited to— 1. Direct observation of routine patient test performance, including patient preparation, if applicable, specimen handling, processing and testing. 2. Monitoring the recording and reporting of test results. 3. Review of intermediate test results or worksheets, quality control records, proficiency testing results, and preventive maintenance records. 4. Direct observation of performance of instrument maintenance and function checks. 5. Assessment of test performance through testing previously analyzed specimens, internal blind testing samples or external proficiency testing samples. 6. Assessment of problem solving skills."

Table 3. Technical Supervisor Responsibilities

3.2 RSM.2 – RSM.2.1, 2.2, 2.3, 2.4

Every individual employed in the laboratory need to be oriented to required duties before being allowed to perform them unsupervised. The orientation program is provided for each employee, regardless of job duties. Employee orientation and competency assessment activities are accomplished through a number of training and measurement of performance once a year [7]. Another reason for performing competency assessment with laboratory personnel is that it is also a requirement of the College of American Pathologist (CAP) for accreditation. CAP General Inspection Checklist indicate that the manual that describes training activities and evaluations must be specific for each job description. Those activities requiring judgment of interpretive skills must be included. The records must make it possible for the inspector to be able to determine what skills were assessed and how those skills were measured. Retraining and reassessment of employee competency must occur when problems are identified with employee performance. The training and assessment program must be documented and specific for each job description [8].

The CAP and the JCAHO have guidelines that include several items dealing with initial training and competency assessment of laboratory personnel as a requirement for laboratory certification/accreditation.

Trainings include department policies, job-related tasks, patient safety and Employees Occupational Safety and Health Program (EOSHP). During the first year that an individual is performing such patient testing, competency must be assessed every six months [9-16].

Figure 1 shows a checklist developed in our laboratory to assess the competency of a medical laboratory technician who performs point of care (POC) urinanalysis. Records of documented personnel information including certification or licensure, summary of training and experience, references from previous employers, job description, initial orientation and any retraining, continuing education and achievement, competence evaluations, applicable health records such as immunization status, monitoring for exposure to hazardous chemicals and radiation and untoward incident or accident reports are also maintained for each staff member.

3.3 RSM.3 – RSM.3.1, 3.1.1, 3.1.2, 3.1.3, 3.1.4, 3.2, 3.3, 3.4, 3.4.1, 3.4.2, 3.4.3

The laboratory facilities are designed and organized to provide adequate space and allow personnel to perform required work with optimal accuracy, precision, efficiency, timeliness and safety. Specimen collection facilities are designated to respect patient's privacy, security, comfort, and disabilities. In addition, provision is made for optimal specimen collection and/or processing conditions.

Sufficient and appropriate storage space is provided for specimens, reagents, control materials, equipment, laboratory supplies, manuals, slides, histology blocks, and files. Manufacturer or other authoritative storage requirements are met, such as for temperature, ventilation and humidity. Storage areas are kept clean and well maintained. A policy covering security issues concerning patients, visitors, other customers, personnel, and property is established. Equipment (software and hardware), reference materials, consumables, reagents, and analytical systems are safeguarded from adjustments or tampering which would invalidate test results.

Laboratory areas for which space and design should be addressed include areas where clerical functions are performed. Because this function is often critical to reporting the correct result on a patient or maintaining specimen identity, consideration should be given to providing areas where interruptions are uncommon and individuals can give full concentration to the transcriptions or data entry being completed.

One of the fundamental processes is to develop an Employees Occupational Safety and Health Program (EOSHP) to address all types of hazardous materials and wastes in the laboratory [17]. Our EOSHP project was introduced as a reference case and published in the source book entitled “Understanding Health Care Facility Safety” by Joint Commission [18]. The EOSHP puts a system in place that employees have both the right and the need to know about the

CLINICAL CHEMISTRY LABORATORY
EMPLOYEE ORIENTATION/COMPETENCY ASSESSMENT CHECKLIST

Part 1: Identifying Information (Typed) DATE:

1. Employee's Name:
2. Position Title: Medical Laboratory Technician
3. Job Description : POC test : UA Multistix/ Chemstrip
4. Organizational Location (Dept/Office/Section): Urinanalysis

Part 2: Signatures

	Rater's Signature/Date	Reviewing Official's Signature/Date	Employee Signature/Date
a. Competencies & Plan Discussed & Developed by Rater & Employee*			
b. Initial Competencies Assessed			
c. Progress Review**			
d. Final Review**			

* Signatures Indicate That Expectations Are Understood
**Discussion and Signatures are Required - Narrative is Optional Except When Performance is Unacceptable

I - INITIAL ORIENTATION (NEW EMPLOYEES)

A- New Employee Orientation program : The New Employee Orientation program is designed to familiarize new staff members with their jobs, the hospital and work-site environment before an employee begin laboratory work and related other activities. This is a mandatory training requirement for all new employees.

	DATE	Training Method	Assessment Method
1. Date attended new employee orientation			
2. Date completed departmental orientation			
3. On the job orientation and training			
4. Evaluate and establish initial competencies			

B- Position/Job Specific Orientation: Supervisor or designated staff member (preceptor) provides new employee orientation and initial training to his/her job responsibilities, reviews position description, establishes and discusses performance standards, competencies, behavioral indicators, training requirements, and the performance evaluation process.

Competency Assessment :	**EMPLOYEE ACK (INITIALS)**	**VALIDATOR CHECK**
1. For initial validation, reads entire Policy/Procedure (SOP)		
2. Completes and passes written test (Passing criteria is 100%)		
3. Performs ONE unknown (patient specimens from Clinical Chemistry)		
a. Observes universal precautions		
b. Checks expiration date of strips		
c. Closes vial of strips after removal of strip for test		
d. Mixes specimen 10 times by inversion		
e. Dips appropriately, blots off excess		
f. Matches up strip to reagent pads successfully		
g. Differentiates between positive vs negative test results		
h. Reads reagent pads correctly - achieves passing grade on unknown		
4. Knows storage requirements of specimen if not immediately dipped and read		
5. Understands quality control requirements		
! CRITICAL POINTS — STAFF PLACES INITIALS BY EACH ONE		
a. Interfering substances: Glucose- High oncentrations of Vitamin C (ascorbic acid) and moderately high amounts of ketones (40 mg/dl) may cause false negatives for specimens containing small amounts of glucose (100 mg/dl).		
b. QC: Two levels of liquid QC must be run and documented every day.		
c. Reading results: Must read pads within indicated times, else blood and glucose may give false positives.		

Fig. 1. An employee competency and assessment checklist to assess the competency of a medical laboratory technician who performs point of care (POC) urinanalysis.

hazards they are exposed to while working and the identities of the chemicals that pose the hazard. It is essential to communicate the hazard information and protective measures required to use these chemicals safely to exposed or potentially exposed employees who may use the chemicals. The implementation of EOSHP incorporates the establishment of a Chemical Hygiene Plan, description of a Hazard Communication Quality Standard (HCQS), development an Employee's Guide to Handle the Hazardous Chemicals to assist the laboratory staff in complying with the EOSHP HCQS, identification of the staff who will be responsible for the initial set up of the EOSHP and the day-to-day activities necessary to comply with each aspect of the HCQS, construction an inventory of all hazardous chemicals used in the laboratory and a written list comprising the hazard descriptions of chemicals. In this respect, guidelines of NFPA (National Fire Protection Association, USA) provide comprehensive source to delineate hazard symbols and classifications [19]. In accordance with the EOSHP HCQS, the Material Safety Data Sheets (MSDS) for the specific hazardous products or chemicals should be supplied. In addition, a guide should be published to explain the terms and definitions in the MSDS. Appropriate signs and labels are prepared as hazard warnings to convey the hazardous effects of the materials. Labeling guidelines are published. Storage conditions and groups are identified for chemical substances. Special areas and cabinets are designated based on the hazard identifications. Safety equipments need to be acquired to ensure the protection of laboratory staff [20]. Guidelines are determined in the event of a chemical spill, incident, or leak from a sealed container. Initial and refresher trainings are provided with all laboratory staff. A copy of the Employee's Guide to Handle the Hazardous Chemicals is handed out as training source document. The primary policies for managing biological hazards should define the mechanisms for oversight for controlling exposures to biological materials in the workplace and include the bloodborne pathogens and exposure plan [21-25]. The related policies and procedures for handling biohazardous materials need to be developed to provide guidance for worker safety when handling or exposure to biological agents and included in the new employee orientation and annual update training programs (Fig. 2) [26,27]. The administration and supervision of patient exposures to and infection with biological agents is the primary responsibility of organization's Infection Control Unit. Assessments of risk for the biological safety management activities are accomplished through a number of audits and data collections on a semi-annual basis. All occupational exposures to or injuries from biological materials are to be reported by employees to the EOSHP coordinator. Biological safety posters including the information, reporting and reduction of exposures to bloodborne pathogens and tuberculosis [28] are posted in all major areas of the laboratory facilities.

A Laboratory Waste Management program should be established to safely control hazardous chemical and biological waste from receipt or generation through use or final disposal in the laboratory. Orientation training must include hazardous waste management (Fig. 3). Chemical waste is characterized as non-hazardous or hazardous in accordance with the rules and regulations specified by OSHA (The federal Occupational Safety and Health Administration, USA) [29,30]. With this regard, a substance, which exhibits one of the four hazardous characteristics (corrosivity, ignitability, reactivity, toxicity), is delineated as Hazardous Chemical Waste. Chemical waste that does not exhibit any of the hazardous characteristics as defined above is considered non-hazardous chemical waste. Any waste that is potentially biohazardous, infectious, or pathological is described as Biological Waste. A Waste Characterization Checklist needs to be developed to determine whether the waste is hazardous or non-hazardous (Fig. 4).

Bloodborne Pathogen and Other Infectious Agents

Record of Training

Please Print

Name: ____

Department & Division: ______________________________

Job Title: ____

Training Date: ______________________________________

Length of Training: __________________________________

Instructor(s) & Job Title: _____________________________

I was informed about:

- the Bloodborne Pathogen Standard;
- the epidemiology and symptoms of bloodborne and other pathogens;
- the mode of transmission of bloodborne and other pathogens;
- the Hospital's exposure control plan;
- a review of the use and limitations of methods that will prevent or reduce exposure, including
  - engineering controls;
  - work practice controls, and
  - personal protective equipment;
- selection and use of personal protective equipment including gloves, gowns and eye protection;
- visual warning of biohazards including labels, signs and color-coded containers;
- information on Hepatitis B Vaccine;
- the procedure to follow if an exposure incident occurs;
- sharps disposal;
- handwashing;
- proper work practices.

This is to certify that the employee named above has completed the above training.

______________________	______________________
Employee's Signature	Date
______________________	______________________
Supervisor's Signature	Date

Keep this record for at least three years. Store in Department Office with other training records. This record must be made available upon request by County, Hospital or Environmental Health and Safety Inspectors.

Questions: Call the Biosafety Officer.

Fig. 2. Record of training for bloodborne pathogen and other infectious agents

Hazardous Waste Generator Record of Training

Please Print

Name of Employee: ____

Department & Division: ____

Job Title: ____

Training Date: ____

Length of Training: ____

Instructor(s) & Job Title: ____

- Use of the EOSHP *Hazardous Chemical Waste Management Guidebook*
- Hazardous waste definitions
- Labeling of hazardous waste storage containers
- Completion of the waste packing forms
- Contacting the Chemical Waste Manager for waste collection
- Closure of containers
- Container inspections (weekly)
- Secondary containment for free liquid wastes
- Storage of incompatible wastes (separate by tray, cabinet, room, etc.)
- Storage of lead-acid batteries (indoor, curbed, impermeable)
- No hazardous waste allowed in trash or salvage dumpsters
- Who to call for hazardous waste information
- Who to call for approval to sewer non-hazardous chemicals
- Evaporation of chemical residues is not allowed
- Management of problem wastes (unknowns, shock-sensitive, etc.)
- Emergency chemical spill response procedures
- Pollution prevention techniques
- Self auditing procedures
- Other (list): ____________________________

This is to certify that the employee named above has completed the above training.

______________________________ ______________________________
Employee's Signature Date

______________________________ ______________________________
Supervisor's Signature Date

Keep this record for at least three years beyond the termination date of the employee. Store in Department of Human Resources with EOSHP Laboratory Safety - Chemical Hygiene Plan training records. This record must be made available upon request by County. Hospital or Environmental Health and Safety Hazardous Waste Inspectors.

Questions: Refer to your EOSHP *Hazardous Chemical Waste Management Guidebook* or call the Chemical Waste Manager.

Fig. 3. Hazardous waste generator record of training. Adapted from http://www.dehs.umn.edu/hazwaste_chemwaste_umn_cwmgbk.htm.

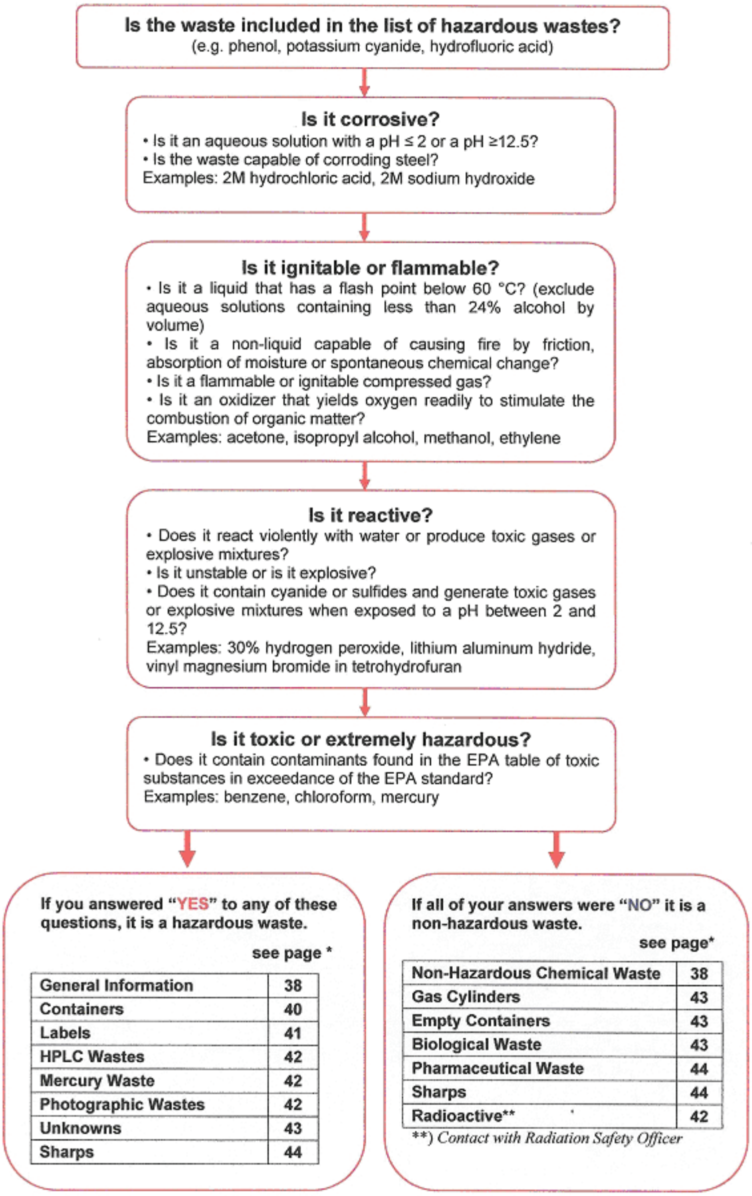

Fig. 4. Waste characterization checklist. Adapted from http://www.uri.edu/safety/old_website/data/LabWasteGuide.pdf.

Policies and procedures for managing and handling radioactive materials and waste should be well defined. The ALARA program [31] and associated work practices are put in practice to reduce risks to workers by keeping doses well below the limits. All procedures and practices for radiation safety must comply with law and regulations by the Atomic Energy Authorities.

3.4 RSM.4 - RSM.4.1, 4.2, 4.3, 4.4, 4.5, 4.6, 4.7, 4.8, 4.9

The guidelines should be generated to perform initial validation for new instruments and analytical systems to verify that the method(s) will produce accurate and reliable results [32-34]. Laboratory instruments and analytical systems are tested upon installation, and prior to use to assure their capability of meeting performance expectations. For new analytical methods, the laboratory verifies, at a minimum, accuracy, precision and the reportable range, as well as confirming that the reference range applies to its patient population. If the laboratory has modified the test or if the method is very complex with many steps, the laboratory also verifies analytical sensitivity and analytical specificity.

The laboratory leaders provide for a program to regularly monitor and demonstrate proper calibration and function of instruments, reagents, and analytical systems. The program also includes preventive assessments through periodic inspection, testing and maintenance for the temperature of water baths, and/or heat blocks, paraffin baths, refrigerators and other temperature dependent equipment, mechanical timers, pipettors and dilutors, volumetric glassware, thermometer and microscopes.

Calibration, calibration verification, function checks, and preventive maintenance are performed on instruments and analytical systems, as needed, and at least according to manufacturers' recommendations. Criteria for calibration verification include at changes of reagent lots; when indicated by quality control data; after major maintenance or service; as recommended by the manufacturer and at least every six months [35]. All required verification checks are documented, along with remedial action when instruments or test methods did not meet performance expectations. A maintenance log for the instruments and analytical systems is kept up to date. Maintenance and inspection ensure that equipment is safe. Equipment is used only by personnel who are competent and authorized to do so.

The historical records are maintained for each instrument. A historical record should include identity of the equipment; manufacturer's name, type identification, and unique identifier such as a serial number; manufacturer's contact person and telephone number, if appropriate; date received and placed into service; current location, where appropriate; condition when received (e.g., new, used, reconditioned); manufacturer's instructions or recommendations, if available, or reference to their location; equipment performance records that confirm the equipment's suitability for use; maintenance carried out to date and what maintenance is planned for the future; damage, malfunction, modification, or repair to the equipment; remedial actions carried out because of unacceptable performance tests.

Detailed records identifying daily, weekly, or monthly performance tests and function checks must be retained for at least two years. Records of major repairs, parts replacement, and semiannual or annual calibration checks and preventive maintenance must be retained for the life of the instrument.

Procedures should be determined to check periodically the validity and quality of reagents and water quality used in laboratory testing. Labeling protocols are defined for all reagents, controls, kits, and solutions. Processes are defined for validating and maintaining computer software and information.

3.5 RSM.5 - RSM.5.1, 5.2, 5.3

Policies and procedures should be developed to provide a safe physical environment where hazards are controlled and personnel activities are managed to reduce the risk of injuries [36]. The details of environmental conditions and supporting safety utilities are represented in Table 4. The laboratory's safety processes should include adequate fire detection and prevention policies. Adequate safety devices such as emergency eyewash, safety cans, puncture-resistant containers for discarding all waste sharps [37], fire extinguishers and blankets are made available and training should be provided to all laboratory staff. Figure 5 presents a laboratory safety self-audit checklist.

Table 4. The details of environmental conditions, supporting safety utilities and tools

Entrances, Exits, Hallways and Stairways	All entrances, exits, hallways and stairways must be clear and unobstructed.
Showers/Eye Operative -	Monthly inspections are required. Any area which deals with corrosive, flammable or otherwise hazardous material is required to have immediate access to eyewash and drench shower facilities. All showers and eye wash equipment must be in full operational order and unobstructed. Eye wash bottles are not adequate equipment.
Personal Protective Equipment	Personal Protective Equipment such as goggles, masks, gloves and cover gowns must be readily available and not worn outside the immediate work areas. Lab coats and appropriate shoes shall be worn to avoid any contact with harmful materials. Respirators shall be used when applicable. Evidence of respirator training and certification must be readily available.
Fire Extinguisher/Inspection and Location	All fire extinguishers must be inspected monthly. Extinguishers must be properly mounted, unobstructed and be properly labeled for the intended use. Training classes should be offered through the Fire Marshal.
Pressurized Cylinders	All cylinders must be stored in proper locations. All cylinders must be secured in an upright position and properly restrained to prevent falling. Containers must be labeled for contents and usage. Cylinders of all gases having a Health Hazard Rating of 3 or 4 shall be kept in a continuously mechanical ventilated hood or other ventilated enclosure. Maximum number of cylinders of a flammable gas shall be not more than 3 (25 x 127cm) 45 square meter in an unsprinkled space or not more than 6 (25 x 127cm) in a sprinkled space of 45 square meter. Liquefied Gas Cylinders in laboratory work areas shall not exceed 3 cylinders (23 x

	76cm) in a sprinkled space or exceed 2 cylinders (23 x 76cm) in an unsprinkled space.
Room Use Identification	All access doors must be marked when rooms or areas are being used for chemical, biological or radioactive purposes as outlined in the Chemical Hygiene Plan. All doors must remain closed and the vision panel must remain unobstructed. Unattended labs shall be locked at all times.
Fume Hood Operation	Face Velocities should be between 80 and 120 FPM at the working sash height with an optimum level of 100 FPM. The sash should never be higher than 30 cm **except when accessing equipment.** Hoods should not be located in high traffic areas or under air supply vents. The hood must have user spill protection and cup sinks must have spill guards.
Biological Safety Cabinets	Certification is required annually or any time the hood is moved or has had maintenance performed. Cabinets must not be located near high traffic areas or air supply ducts.
Hazardous Chemicals	All chemicals must be appropriately labeled and shall not be placed near or over floor drains. Flammable liquids must be stored in appropriate containers. 0-35 liter must be stored in shipping containers. 40-75 liter must be stored in specific safety containers, 75 and over must be stored in a safety cabinet.
Hazardous Waste Disposal	Hazardous waste training is required for all employees who handle hazardous material.
Equipment and Utility Labeling	All utility and plumbing lines need to be labeled and indicate the product contained; i.e., gas, water, etc
Location of Cut-off Valves/Circuit Breakers	All cut off valves and breakers must be properly labeled.
General Safety (Dress, Eating, Smoking, etc.) -	Eating, drinking, smoking and applying cosmetics is not permitted in a wet lab. Refrigerators, ice machines and microwaves must be labeled for intended use. Food, personal medication and hazardous materials shall not be housed in the same refrigerator. Smoking is prohibited throughout all facilities at the organisation (with the exception specially designed

	"designated smoking areas"), Lab Personnel shall not wear loose (e.g. saris, dangling neckties, overly large or ragged lab coats), skimpy (e.g. shorts and/or halter tops), torn clothing, or unrestrained long hair. Perforated shoes, sandals, or cloth sneakers are not to be worn in labs.
Use of Flame and Heat	No heat generating devices should be left unattended.
Ventilation	Air flow in most labs should be "negative" with respect to the corridor. Laboratory doors shall be kept closed when laboratory procedures are in progress. Volatile hazardous materials shall not be used on the open bench top.
Housekeeping/Drains Flushed	All unnecessary material, boxes, and containers must be disposed of in the appropriate manner. All drains, including floor drains and cup sinks should be flushed with water on a weekly basis to eliminate sewer odors. Proper housekeeping must be maintained to provide adequate clearance of sprinkler systems and emergency equipment.
Sharps (Glass, Scalpel, Blades, Syringes, Etc.)	All sharps, needles and glass must be disposed of in an approved labeled container. Glass containers and other potentially sharp objects shall not be disposed of in common office refuse. Containers must not be overfilled and must be labeled and sealed for proper handling and disposal.
Emergency lighting	Where necessary, emergency lighting units shall be properly mounted and obstructed. If emergency lighting exists, it should be checked periodically to ensure it is functional.
Emergency Plans/Posted Numbers	All emergency and contingencies plans and evacuation routes shall be clearly posted in conspicuous places. A list of emergency numbers and contacts must be kept updated and posted alongside the emergency plans.
Safety Manuals	Manuals must be current and readily available for all employees.
Accidents Reported/Investigated	All accidents must be reported to the immediate supervisor for the completion of the appropriate form. File copies of reported incidents and accidents must be on hand, as well as the action taken to alleviate the safety hazard in the future.
Safety Training	This area is designated for either the orientation and annual update training which is required by EOSHP.

Laboratory Safety - Self-Audit

Laboratory Name :

Department :

Date of Inspection:

Inspector/Auditor Name:

Responsible party :

Y or N	ITEM
	1. LAB SIGNS
	a. Primary & second contracts posted with phones
	b. Warning & restriction signs (rad, carcinogen, biohaz -if needed)
	c. Emergency phone numbers posted in lab
	d. Emergency action plan/procedures - available & up to date
	2. SAFETY EQUIPMENT
	a. Fire extinguisher available (within max 20 m)
	1. Unobstructed & mounted at designated location (1 m top)
	2. Extinguisher has annual inspection, sealed, and charged
	3. Appropriate extinguisher for hazard (Class A, B, C, or D)
	b. MSDS's available in lab or other central location
	c. Eyewash present (within 15 m or 10 sec travel)
	1. Unobstructed
	2. Checked/tested within past month (record tag)
	d. First Aid kit available & marked
	1. Stocked, up to date
	e. Exit signs & emergency lighting operating (if needed)
	3. PROTECTIVE CLOTHING (PPE)
	a. PPE (eyewear, gloves, smock) readily available in lab
	b. Proper eye protection use (safety glasses/goggles/face shield)
	c. Visitor glasses readily available
	d. Proper chemical resistant/heat resistant/cryogenic gloves
	e. No shorts/skirts/sandals/cosmetics (when chems in use)
	f. Rubber apron available (if concentrated acid/base)
	4. GENERAL HAZARDS
	a. Walkways & doors unobstructed
	b. Adequate lighting and switches
	c. Excess trash, boxes, & paper removed promptly
	d. No eating, drinking, smoking or food storage in lab
	5. SPILL PROCEDURE
	a. Spill kit available - proper size & type
	b. Spill procedures established - written & available
	6. ELECTRICAL
	a. Proper power cord use (good housekeeping, no trip hazard)
	1. Extension cords- temp, use, single only (no daisy chains)
	2. Powerstrips (w/surge protection)- computer equip, only
	3. No cording through walls, floors or ceiling
	b. Electrical cords not frayed & good insulation
	c. 3-pronged plugs not altered
	d. GFCI (Ground Fault Circuit Interrupter) near sinks / rubber mats on floors in wet areas
	e. Electrical panels and disconnects unobstructed
	7. GAS CYLINDERS
	a. Properly secured (individual chain/cable recommended)
	b. Storage bottle with empty or full labels
	c. Cylinder labeled as to contents
	d. Caps on cylinders not in use

Y or N	ITEM
	8. REFRIGERATOR/FREEZER
	a. "No Food or Drink" sign
	b. Food/drink not stored in unit
	c. Flammables stored in approved flammables refrigerator
	d. "Food or Drink Only" sign in separate refrigerator
	9. CHEMICAL STORAGE
	a. Chemicals stored by reactive class (flamm, acids, bases, etc.)
	b. Incompatible chemicals physically separated
	c. Chemicals properly labeled (original or secondary label inplace)
	1. Secondary containers w/ NFPA labels (filled in correctly)
	2. Storage areas labeled with hazard &/or NFPA placard
	e. Special labels & storage (carcinogens, biohaz or acute toxics)
	f. Acids/corrosives/solvents stored in compatible trays
	g. No excess chems on bench tops/in fiime hoods/under sinks
	h. Flammable &/or corrosive cabinets available (if needed)
	10. UNSTABLES/EXPLOSIVES
	a. Marked with receipt & open dates
	b. Peroxide formers have required disposal date
	11. WASTE CHEMICALS
	a. Waste form complete & located on container
	b. Containers closed (second containment if needed)
	12. VENTILATION - HOODS
	a. Exhaust hood & alarm (if approp.) working
	1. Annual inspection sticker within year (80-120 fpm)
	2. Sash kept 2/3 closed except for adjustment
	b. Cert, biosafety hood in use for BSL2 (Laboratory Biosafety Level 2)
	c. Hood housekeeping - properly maintained, no excess storage
	13. MECHANICAL
	a. Belts, pulley drives, rotating parts guarded
	b. Stop switch is easily accessible
	c. Equipment is secured (i.e., bolted to floor)
	d. Electrical disconnect unobstructed
	e. Unattended operating equipment labeled
	14. CHEMICAL INVENTORY
	a. Annual inventory -available at EOSHP* office
	1. Up to date and complete
	2. Copy to EOSHP* coordinator within year
	b. MSDS readily available for all chemicals (within 10 minutes)
	15. TRAINING
	a. HazCom Training - training docs & users understand regs.
	b. Lab Standard - training docs & users understand CHP (Chemical Hygiene Plan)
	1. Departmental Chemical Hygiene Officer (designated)
	2. Chemical Hygiene Plan (available, current)
	c. Annual Bloodborne Training (if approp.) - documentation
	1. Exposure control plan (available, up to date)
	d. Hazardous waste training (if regular waste stream)
	e. Radiation, Laser, & other training as appropriate

*) Employees Occupational Safety and Health Program

NOTES :

Fig. 5. Laboratory safety self-audit checklist

4. Conclusion

Resource management for accreditation process at the medical laboratories applies to many aspects of quality management including personnel, basic facilities, equipment, security and safety. Preparation is key to the success of a resource management program. A comprehensive program that includes management commitment, effective training, regular audits of critical functions to identify potential problems, implementation of corrective action and establishment of priorities for improvement benefits the laboratory in many ways.

5. Acknowledgements

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6. References

[1] US Department of Health and Human Services. Clinical Laboratories Improvement Amendments of 1988. Code of the Federal Register, Title 42, part 493. Washington, DC.1988. Available at: http://www.cms.hhs.gov/clia/. Accessed November 16, 2009.

[2] Joint Commission International Accreditation Standards for Clinical Laboratories. 1st ed. Oak Brook Terrace, IL. 2002.

[3] Yenice S. Implementing a resource management program for accreditation process at the medical laboratory. Clinical Biochemistry 2009; 42:266-73.

[4] College of American Pathologists. Criteria for the clinical laboratory director. Appendix O in: Policies and Guidelines Manual. Northfield,IL,1993.

[5] College of American Pathologists. Commission on laboratory accreditation. Laboratory accreditation program. Team Leader Assessment of Director and Quality Checklist. Available at: http://www.cap.org/apps/docs/laboratory_accreditation/checklists/team_leader_assessment_sep07.pdf. Accessed November 16, 2009.

[6] Code of practice for clinical biochemists (chemical pathologists) and clinical biochemistry services. Available at: http://www.rcpath.org. Accessed November 16, 2009.

[7] National Committee for Clinical Laboratory Standards. 1995. Training verification for laboratory personnel. Approved guideline GP21-A. National Committee for Clinical Laboratory Standards, Wayne, PA.

[8] College of American Pathologists. Standards for laboratory accreditation. Available at: http://www.cap.org/apps/docs/education/competency_assessment/Specific_Observation_Checklists.pdf. Accessed November 16, 2009.

[9] Boone DJ. Assessing laboratory employee competence. Arch Pathol Lab Med. 2000;124:190-1.

[10] Howanitz PJ. Employee competence and performance-based assessment: a College of American Pathologists Q-Probes study of laboratory personnel in 522 institutions. Arch Pathol Lab Med. 2000;124:195-202.

[11] McGovern MM, Benach M, Wallenstein S, Boone J, Lubin IM. Personnel standards and quality assurance practices of biochemical genetic testing laboratories in the United States. Arch Pathol Lab Med. 2003;127:71-6.

[12] Sharp SE, Elder BL. Competency assessment in the clinical microbiology laboratory. Clin Micro Rev 2004; 17:681-94.

[13] Smith BR, Wells A, Alexander CB, et al. Curriculum content and evaluation of resident competency in clinical pathology (laboratory medicine): a proposal. Clin Chem 2006; 52:917- 49.
[14] Hemmer PR, Karon BS, Hernandez JS, Cuthbert C, Fidler ME, Tazelaar HD. Leadership and management training for residents and fellows. A curriculum for future medical directors. Arch Pathol Lab Med. 2007; 131:610-4.
[15] Quality Laboratory Practice and Its Role in Patient Safety: The American Society for Clinical Pathology Policy Statement (Policy Number 06-01).2006.
[16] Joint Commission on Accreditation of Healthcare Organizations. 2008 National Patient Safety Goals Laboratory Services Program. Available at: http://www.jointcommission.org/PatientSafety/NationalPatientSafetyGoals/08_lab_npsgs.htm. Accessed November 16, 2009.
[17] Furr AK. CRC Handbook of Laboratory Safety. 4th ed. Boca Raton, Florida: CRC Pres, Inc., 1995.
[18] Working with Hazardous Chemical Materials. In: Understanding Health Care Facility Safety. International Edition. Joint Commission International, 2006. p.149-52.
[19] Available at: http://www.nfpa.org/. Accessed November 16, 2009.
[20] Roder MM. A Guide for evaluating the performance of chemical protective clothing (CPC). Cincinnati, OH, US Department and Health and Human Services Public Health Service Centers for Disease Control and Prevention. 1990.
[21] Primary containment for biohazards: selection, installation and use of biological safety cabinets. 2nd ed. Washington: US Department and Health and Human Services Public Health Service Centers for Disease Control and Prevention. US Government Printing Office; 2000.
[22] Sehulster L, Chinn RYW. Guidelines for environmental infection control in health-care facilities. Recommendations of CDC and the healthcare infection control practices advisory committee (HICPAC). 2003; 52(RR10):1-42.
[23] NCCLS. Protection of laboratory workers from occupationally acquired infections; approved guideline, 3rd ed. Wayne, PA: NCCLS; 2005 (publication no. M29-A3).
[24] Guideline for Hand Hygiene in Health-Care Settings.Recommendations of the Healthcare Infection Control Practices Advisory Committee and the HICPAC/SHEA/APIC/IDSA Hand Hygiene Task Force. Available at http://www.cdc.gov/mmwr/PDF/rr/rr5116.pdf. Accessed November 16, 2009.
[25] Biosafety in microbiological and biomedical laboratories. 5th ed. Washington: US Department and Health and Human Services Public Health Service Centers for Disease Control and Prevention. US Government Printing Office; 2007.
[26] CDC. Exposure to blood: what healthcare personnel need to know. Atlanta, GA: US Department of Health and Human Services CDC; 1999. Available at http://www.cdc.gov/ncidod/hip/BLOOD/Exp_to_Blood.pdf. Accessed November 16, 2009.
[27] CDC. Preventing needlestick injuries in health care settings. Atlanta, GA: CDC; 1999. Available at http://www.cdc.gov/niosh/pdfs/2000-108.pdf. Accessed November 16, 2009.
[28] Mycobacterium tuberculosis: assessing your laboratory. The association of state and territorial public health laboratory directors and US Department and Health and

Human Services Public Health Service Centers for Disease Control and Prevention. Atlanta, 1995.
[29] Available at: http://www.osha.gov/OshDoc/data_General_Facts/highly-hazardous-chemicals-factsheet.pdf. Accessed November 16, 2009.
[30] Available at: http://www.osha.gov/pls/publications/publication.html. Accessed November 16, 2009.
[31] Available at: http://www.ncsu.edu/ehs/radiation/forms/alara.pdf. Accessed November 16, 2009.
[32] Westgard JO. Basic Planning for Quality, Madison, WI: Westgard QC, Inc., 2000.
[33] Westgard JO. Basic Method Validation, 2nd ed. Madison, WI: Westgard QC, Inc., 2003.
[34] Guide to method validation for quantitative analysis in chemical testing laboratories. Irish National Accreditation Board. 2007. Available at: http://www.inab.ie. Accessed March 5, 2008.
[35] College of American Pathologists. Standards for laboratory accreditation. Available at: http://www.cap.org/apps/docs/laboratory_accreditation/lapstandards.pdf. Accessed November 16, 2009.
[36] CDC. Selecting, evaluating, and using sharps disposal containers. Atlanta, GA: CDC; 1998. Available at http://www.cdc.gov/niosh/sharps1.html. Accessed November 16, 2009.
[37] Laboratory risk assessment what, why, and how. US Department and Health and Human Services Public Health Service Centers for Disease Control and Prevention. Atlanta, 1998.

18

Understanding Discrepancy: A Conceptual Persistent Healthcare Quality Improvement Process for Software Development Management

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1. Introduction

This chapter illustrates a sustained conceptual service quality improvement process for management of software development within a healthcare enterprise. Our proposed process is revised from Niland's Healthcare Quality Information System (HQIS) (Niland, 2006). This process includes functions to survey the satisfaction of our supported system functionalities, describes the information system operation bylaws on-line, and provides on-demand information system training. To achieve these goals, we integrate five information systems at the National Taiwan University Hospital (NTUH), including healthcare information system, health quality information system, requirement management system, executive information system, and digital learning system, to form a full Deming cycle (Deming, 1986). Essentially, the process can supply sufficient sources for user requirement management in a healthcare enterprise. Preliminary user satisfaction surveys have indicated that our information system development gradually promotes user satisfaction and has been accepted by the users since 2006. In conclusion, we can straightforwardly understand the discrepancy between the diverse user requirements and select the right system development methodology with our proposed process in a healthcare enterprise.

2. Background

The Healthcare Information System (HIS) in NTUH was built under an IBM/SNA (Systems Network Architecture) environment with a hierarchical Information Management System database (IMSDB) over twenty-five years ago. The HIS contains multiple components operating independently, e.g., Outpatient Information Systems (OIS), Inpatient Information System (IIS), and Emergency Treatment Information System (EIS). The client/server approach was designed and implemented in the system (Cheng, 2005; Hsieh, 2006).

As time advancing, the above built-in technologies have turned out to be obsolete. As an integrated access among HIS components has become inevitable, NTUH Information Office started to carry out developing and deploying a new HIS at the beginning of year 2004. Currently, the entire HIS architecture is committed to the Microsoft technologies: .NET platform incorporated at the HIS core as well as its ancillary systems with the invocation (method calls) expressed in Health Level 7 (HL7) and embedded in XML/SOAP (Simple Object Access Protocol) formats. The newly developed OIS, IIS, and EIS have been implemented under such architecture and become fully operational since January 2006, January 2007, and August 2008 respectively. On average, the NTUH HIS serves approximately 8,000 outpatients, 300 emergency cases, and 2,500 beds for inpatients daily. Under these circumstances, it is essential to focus on the business requirements and enhance the information systems by inspecting feedbacks from end users. Therefore, a sustained conceptual service quality improvement process for the management of software development within a healthcare enterprise is critical.

3. Related work

Wang stated that “in order to increase productivity, organizations must manage information as they manage products,” and proposed a Total Data Quality Management (TDQM) methodology for improving the data entry quality in information systems (Wang, 1998). Although the data quality can be improved by the TDQM methodology, chameleonic user requirements can make the information systems less satisfactory. Therefore, it is substantial for us to continuously refine the information systems to unite users' exact demands.

Niland proposed a robust Healthcare Quality Information System (HQIS) in 2006 which has the potential to address this deficiency through the capture, codification, and analysis of information about patient treatments and credibly concerned results (Niland, 2006). Niland proved that HQIS would be a feasible method for system implementations, maintenance in a healthcare enterprise environment. However, it is necessary for a healthcare organization to construct an environment for solving and processing requirements effectively.

From the perspective of software engineering, software development has a life cycle, and it is advised to follow a set of administrative steps such as system requirements, system analyses, system designs, system developments, system tests, and system maintenance (Sommerville, 2007). In particular, we aim at the software development that has to satisfy the requirements of healthcare professionals in a mission-critical healthcare enterprise. Ravichandran and Rai suggested that software quality goal is best attained when top management purposely appoints an administration infrastructure that promotes improvements in process design and rallies stakeholders to expand the structure of the development processes (Ravichandran and Rai, 2000). Furthermore, Higgs stated that a point to remember when implementing information management systems is that doctors and nurses must genuinely be involved in decision making and risks. The key phrase is `open and honest` (Higgs, 1997). In other words, problems and opportunities must be shared by all parties in an organization.

In 2002, Califf provided an alternative view by presenting a model that integrates quantitative measurements of quality and performance into the development cycle of managing and future therapeutics (Califf, 2002). He proved that the migration from quality management to HIS is feasible; however, it did not disclose the evaluations about system performance related evidences. Therefore, we proposed a conceptual persistent healthcare

quality improvement process for software development knowledge management which can be implemented in a healthcare enterprise.
The services for healthcare enterprise are diverse and difficult to restrict users to handle their routine processes within an information system under rough functionalities. Therefore, the healthcare environment that implicitly buries some requirements or problems should be concerned and solved. Based on the above illustrations, there are problems that ought to be resolved for the engineering requirements between developers and staffs in a healthcare enterprise. For example, user requirements need to be effectively collected, analyzed, and migrated with legacy information systems in order to implement an `open and honest` environment that assists to promote organization requirements, and to meliorate the software requirement engineering processes and outcomes.

4. Methods

We proposed a conceptual process for the circular healthcare quality promotion, which can be integrated with the healthcare enterprise software development and the Deming cycle (also known as PDCA cycle) (Deming, 1986). First, we simplified the informatics blueprint of HQIS (Niland, 2006); afterwards, we defined a circular process to upgrade the healthcare quality and system satisfaction. Finally, we collected some exploratory surveys as quantitative evaluation information from all users, including doctors, nurses, technicians, clerks, and engineers, and persistently fine-tuned our system functions based on the latest major user requirements.

4.1 Revising informatics blueprint

Our research revised Niland's HQIS into a circular process where the obtained outcome is in-turn automatically fed back to the process. Meanwhile, we simplified HQIS by ignoring the socio-technical part in order to rapidly collect the effective, on-line data. In other words, our HQIS solely emphasizes on service quality, organizational feedback, as well as knowledge management perspectives. Regardless, the knowledge management platform is not connected with our previous process yet, but the platform is under-production and will be incorporated in the near future (Cheng, 2008). We designed a circular process in our software development compliant with the Deming cycle of four traditional stages: Plan, Do, Check, and Act. Figure 1 illustrates the Deming cycle within four designated sectors which are enclosed by dash-lines from left to right and form a counter-clockwise cycle.
The right-most dash-line frame presents the 'Plan' stage in the Deming cycle. The Plan stage embraces at least two systems: the requirement management system and the executive information system. Both systems coupled together will expressly feed specific information with each other. The decision making will be postponed to the subsequent 'Do' stage after a thorough information analysis is conducted.
The left-most dash-line frame is a simple screen example which contains the 'Do' stage of the Deming cycle. In our HIS execution environment, users can recognize at least four types of icons to retrieve further information in a designated process. These icons can be hidden at first and can be visible later while the mouse navigating over the specified area. The purposes of these four-icon representations are: "q" to carry out an on-line function satisfaction survey, "%" to inspect the on-line survey statistics, "?" to activate the on-line function description helper, and "b" to redirect users to the related on-demand information system courses.

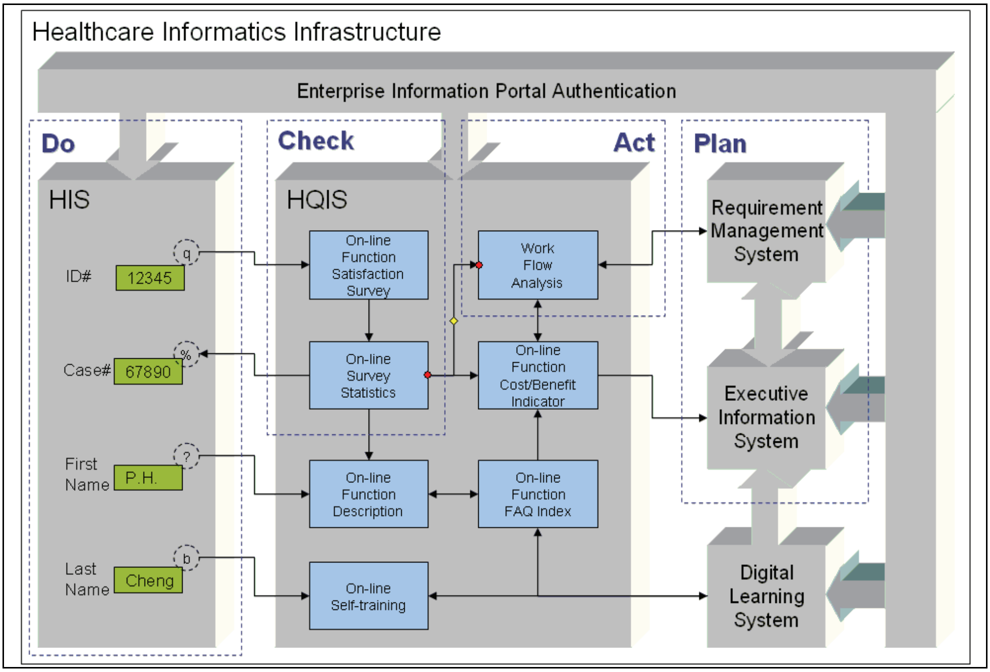


Fig. 1. Deming (PDCA) cycle managing the service quality of user requirements and software development

The above four icons are mapping to the corresponding modules such as, function satisfaction survey module, survey statistics module, function description module, and self-training module, in our HQIS. The former two modules execute the “check” operation of the Deming cycle and obtain on-line support survey results for the defined functionality. The third module receives the results of survey statistics module and is integrated with the functions of frequently asked question indexes (FAQI) module. The last module can be combined with FAQI module in HQIS and connected with an additional digital learning system within the healthcare enterprise environment.

Finally, the on-line survey statistics module forwards the results to both the work flow analysis module and the function cost/benefit indicator module. The work flow analysis module represents the “act” stage of the Deming cycle and will generate relevant information to the requirement management system for further decision making. We believe that our process can induce user requirements be effectively collected, analyzed, and legacy information systems be integrated.

4.2 Continued feedbacks for outcomes

In order to constantly retrieve the most immediate user requirements, we have implemented a survey information system to communicate with majority of the enterprise users. Every registered healthcare professional can enter the cross cultural survey system through the enterprise information portal. After the authentication process, users can decide whether to attend the on-line survey. Basically, each on-line survey can be attended only once, and the time log will be maintained automatically for further statistical usages. We believe that such survey feedbacks can continuously improve the software requirement engineering processes and outcomes.

Generally speaking, most of the functionalities in HIS should follow the particular healthcare enterprise bylaws, insurance declaration rules, and/or committed work flows. Moreover, it is extremely difficult for every healthcare professional to clearly understand how computer functions ought to be performed. In consequence of their heavy duties and tight schedules, it is nearly impossible for them to participate in all of the system requirement discussion meetings. According to these reasons, we try to utilize an Asynchronous On-Line Survey (AOLS) system to identify whether the developed functions are favored or not. Meanwhile, our research anticipates that most of the surveys can statistically represent the preferences of major users in a healthcare enterprise environment, and the software engineers in the information technology department can approach and achieve the preferences.

Disciplinarily, people/users in an educational department or organization have to be well trained in every related system function before that function can be put into use. However, the system function training may imprudently ignore some ambiguous flows which can cause mistakes during the complicated healthcare enterprise work flow processing, where most of the work flows are hybrid flows that intermix computer flows with manual flows . If flow analysts do not predefine clearly, mistake may happen during the execution time.

5. Results

The more organized the system modules in a healthcare enterprise are, the higher is the resulting quality of care. In our revised version of HQIS, there are seven modules designed: function satisfaction survey, survey statistics, function description, self-training, FAQI, functional cost/benefit indicator, and work flow analysis. The former six modules are on-line services, and the last one is manually performed by system analysts in the information technology department.

5.1 Semi-anonymous survey system

The satisfaction survey module of our HQIS is an on-line semi-anonymous survey which can be executed by all enterprise staffs. Each survey result will be passed on to the on-line survey statistics module. This module will generate statistical information automatically, and the information can be readily extracted by the on-line users. Figure 2 shows the screen snapshot of one of the specific survey results in the on-line survey system. The survey data listed in the survey log can be accessed by authorized users. Note that some users will complete the survey with their comments which is indicated in the lower section of Figure 2. These useful comments will be collected, classified, and forwarded to related departments for further references; the process matches Higgs' “open and honest” key phrase (Higgs, 1997).

After a predefined survey period, HQIS can create useful statistical graphs to be shared with all users. The statistical graph creation is implemented through computer programming to provide quantitative measurements of quality in the development cycle (Wang, 1998), which can even be used to improve the quality of future therapeutics (Califf, 2002). However, the experiences of decision of statistical graph selection sometimes are subjective, and we believe that we will learn experiences from implementations.

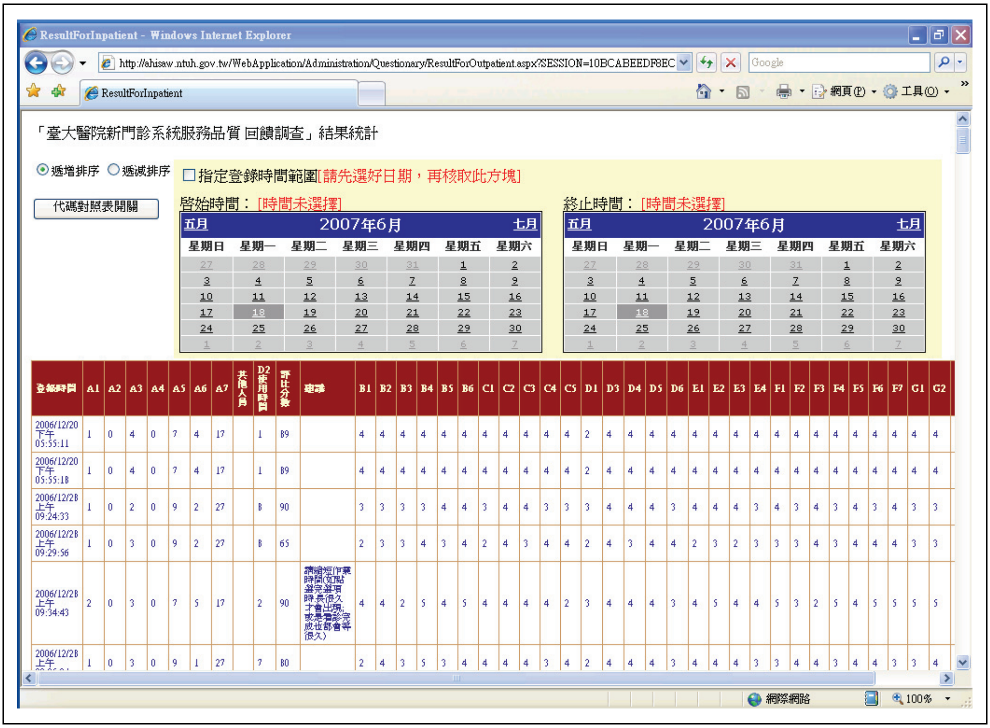
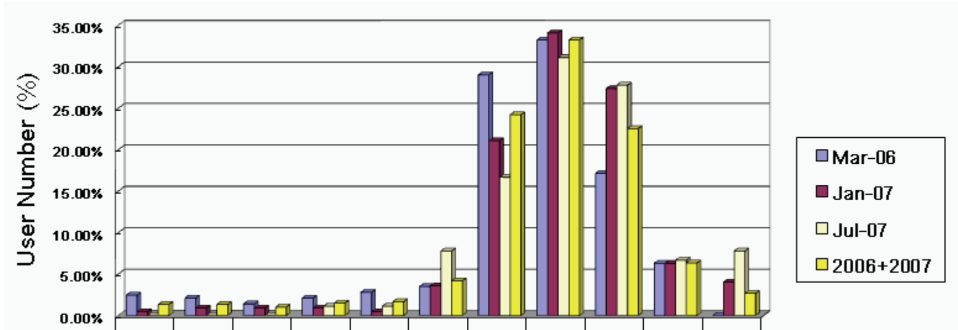


Fig. 2. A screen snapshot of the survey data in the on-line survey system

The information technology department conducts survey actions in NTUH. Figure 3 demonstrates a high-assurance service promotion phenomenon that our health information systems received average scores of 65.87, 71.31, and 71.98 in March 2006, January 2007, and July 2007, respectively. Note that the satisfaction scores of the information system service quality are slightly increased within six months from January 2007 to July 2007. The Cronbach's α is 0.897 and the effective samples are 286, 223, and 90 for these three surveys respectively. Actually, we acquired 36 questionnaires in each survey except the seven fundamental attribute questions. The following figure only provides total scores of individual surveys; the variances of the scores are 18.18, 14.10, and 12.07 for these three surveys respectively. Note that the first survey is accomplished manually, not by our survey system.

In our HQIS, the function description module can supply outline illustrations for a specific function. In other words, the system will explain which system analyst is responsible for a certain function, why the function has to be performed, which committee is decided to carry out the function, and when is appropriate to execute the function. All the explanations will be extracted later into an on-line PDF document file maintained in a well constructed folder.



	0~9	10~19	20~29	30~39	40~49	50~59	60~69	70~79	80~89	90~100	No Score
Mar-06	2.45%	2.10%	1.40%	2.10%	2.80%	3.50%	29.02%	33.22%	17.13%	6.29%	0.00%
Jan-07	0.45%	0.90%	0.90%	0.90%	0.45%	3.59%	21.08%	34.08%	27.35%	6.28%	4.04%
Jul-07	0.00%	0.00%	0.00%	1.11%	1.11%	7.78%	16.67%	31.11%	27.78%	6.67%	7.78%
2006+2007	1.34%	1.34%	1.00%	1.50%	1.67%	4.17%	24.21%	33.22%	22.54%	6.34%	2.67%

Score Level

Fig. 3. Total scores of information systems from March 2006, January 2007, and July 2007

This module will possess an on-line FAQI module additionally to support the 24-hour on-line usage in our information technology department.

5.2 On-demand training

Generally, the attendance rates for medical associated education of healthcare professionals are quite high in NTUH. However, the attendance rates of HIS related education, correspondingly, sometimes are substantially low from our experiences, especially for surgical doctors. Their attendance rates approximately are 10%~20%, even for a recommended time period. Moreover, the healthcare professionals are frequently interrupted by emergency calls during the education courses.

We try to refine our education process and support extra on-demand information system education for healthcare professionals. Since the new communication links have established, the conflicts, misunderstanding among healthcare professionals and information department can be remarkably decreased. Thus, it indicates that the information technology department has successfully increased its customer satisfactions.

Some enthusiastic users offer their subjective opinions in order to improve the enterprise work flow. However, most of them do concern about their own work flow and do not outright familiarize the entire work flow in a healthcare enterprise. Therefore, the on-line self-training module of our HQIS provides all the current work flows for user browsing and learning. The more the users firmly understand the entire work flow, the more smooth coordination will persist.

Anyhow, user requirements can continuously enhance the software requirement engineering processes and outcomes. Usually and relatively, fewer user ideas are practical because most of their points of view are based on the perspective of their own department, and lacking the bigger, overall pictures. If we accept a destructive criticism and forcefully integrate it into the enterprise work flow, the bottleneck will emerge from the imbalanced work flow and will inevitably be requested to modify in the near future.

6. Discussion

The following arguments will focus on three significant concerns: management by objectives, anonymous vs. signed survey, and statistical major requirements.

6.1 Management by Objectives (MBO)

Because most healthcare services are mission-critical, the service quality promotion is the most important concern in healthcare management level. Managers emphasize on particular problems and figure out the real causes. Afterwards, they propose proper solutions to solve the problems. Obviously, they will define relevant indicators to monitor the execution outcomes.

Therefore, most of the managers will utilize the PDCA cycle to track required targets and attempt to promote their objective services within a circular execution process. However, the PDCA cycle is one of the methods for promoting service quality within a short cycle process and is not quite suitable for a long cycle process. Meanwhile, MBO (Dinesh, 1998) with balanced scorecard (Kaplan, 1996) is a minimum requirement for promoting service qualities; it will restrict the scope of target. Furthermore, some of the accredited processes are not the major target for healthcare enterprise; they simply support certain methods for organization to understand their weak points and allude them for further quality promotions.

6.2 Anonymous vs. signed survey

Broadly speaking, most of the potential users favour an anonymous survey. The survey will ultimately achieve better outcomes than a signed one. Similarly, such a situation exists in our healthcare enterprise. However, the NTUH remains using signed surveys to obtain system requirements from all users. These user-replied surveys might contain description on user's system requirements more clearly. Moreover, system analysts can understand the sources of their demands and subsequently make a better system implementation decision. It is a win-win solution, and no one loses under the situation.

From December 2006 to January 2007, our research activates signed survey and anonymous survey, respectively, as depicted in Figure 4. Due to the time periods of two surveys performed are concatenated and almost overlapped, we believe that these survey outcomes are valid. The variances of signed and anonymous surveys are 9.51 and 14.10, respectively. Apparently, we learned that most of colleagues fear to fill-in the signed survey, and its scores are thus concentrated in-between 60~89. However, as the 2007 anonymous survey scores are also concentrated at the same score level, but the distribution will be more reasonable than the 2006 one; most of the colleagues honestly provide their scores.

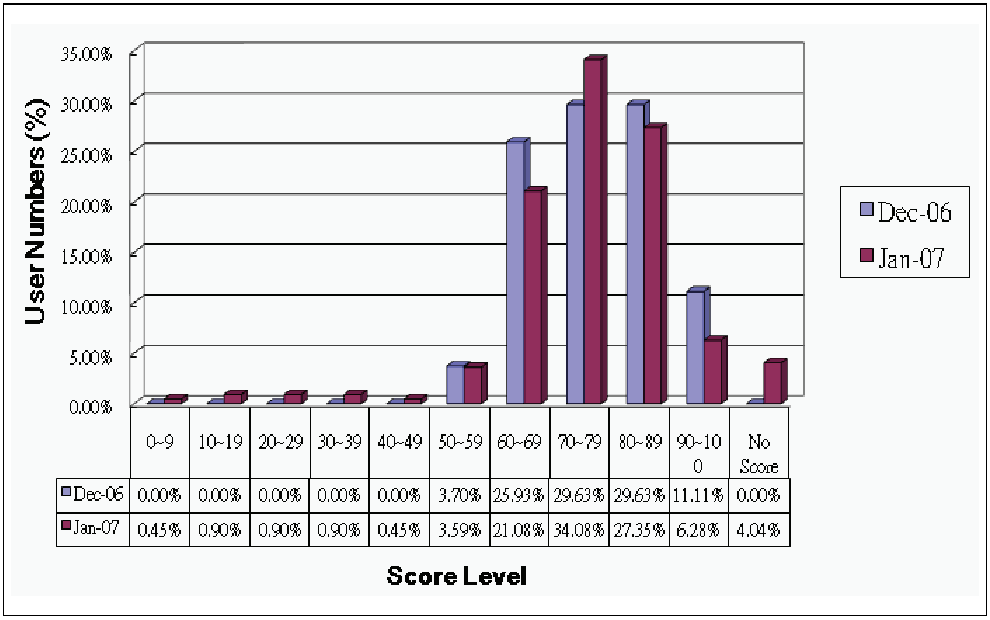


Fig. 4. Anonymous vs. signed survey: total scores of information systems from December 2006 to January 2007

Strictly, our anonymous survey is actually a semi-anonymous mechanism. That is, database administrators can trace the log to identify specific survey data, if they intended to do so. However, the Ex-superintendent, Dr. F. Y. Lin, of NTUH emphasises on the ‘open and honest’ policy and put it as the first hospital discipline. Our organization trusts every colleague and welcomes any voices. Our process implements an ‘open and honest’ environment to assist and promote organization requirements. We believe that it will be the source of innovation power. On the other hand, if the accuracy of the signed surveys increases and the satisfactions of system functions grow with continual surveys, then such results would confirm that the signed surveys are feasible. Furthermore, the healthcare professionals understand that it is another workable and acceptable way to knowledgeably communicate with system analysts.

In general, there are popular methodologies to measure the quality of medical information system management. Our process will furnish objective statistical information to assess whether the specific system functions or flows are error sources or not. Since the survey is on-line and randomly collected in NTUH with 5,360 employees at least, the statistical information would be normally distributed. Therefore, the healthcare quality management center can use the information to determine whether the systems should adopt such changes and to enhance the healthcare quality.

6.3 Statistical major requirements

Since the signed survey is acquired on-line randomly, it is appropriate for system analysts to gather the user requirements from a simple contact window. That is, the demographic information describes the voices of majority and differentiates the non-major opinions. Moreover, the statistical information can then be proposed to high-level managers to noticeably strengthen the implementation proposals and to allocate constructive budgets promptly. We believe that this system function, which is implemented based on the statistical requirement information, will become popular in our healthcare enterprise.

Despite the major requirements can strongly influence the decision in an organization, some of the specifications which would go against the organizational rules of morality should be denied by high-level mangers that also face the dilemma to make necessary decisions. On the other hand, after the healthcare quality management center receives statistical data from this process, the data can be discussed, evaluated and justified whether to alter the healthcare processes. In the meantime, system analysts can utilize the discussion decision to direct their work flows and try to obtain an optimized flow to improve the quality of services continuously.

Our research elaborates enormous challenges for healthcare quality management centre and system analysts as follows. How does one implement an optimized work flow? How does one illustrate evidence that it can improve the quality of care? Which work flow is appropriate for our colleagues in the current enterprise environment? When should one begin or terminate the work flow? Could one evaluate the quality of the new work flow before executing it? Could one observe the new work flow process status on-line? As of now, there are no complete, comprehensive answers.

7. Conclusion

Based upon the design, implementation experiences comprehended during the NTUH healthcare information infrastructure developing and deployment, we gradually achieved that brand new projects can be accomplished and integrated into the infrastructure on schedule. It is a trivial and feasible approach to retrieve the latest and principal requirements which are randomly gathered by the on-line service-oriented information systems attached with accurate time logs. The healthcare quality management centre and system analysts can utilize the statistical survey results to promote and constitute the service quality. Our proposed process provides a high-assurance service-oriented requirement mechanism that can engage the information technology department to obtain sufficient and essential demands from all users.

We are confident that, from our own experiences, the process can compass, improve the software service quality of software development and maintenance, including sophisticated patient care and security, in a healthcare enterprise environment. Before our information technology department transubstantiates most of the hard-copy healthcare records into Electronic Health Records (EHR), we strongly believe our proposed process can introduce valuable insights into the HIS evolution. By emerging the process into the software development procedures, there will be significant advantages over traditional methodologies during EHR implementations.

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9. References

Califf, R. M. ; Peterson, E. D.; Gibbons, R. J. ; Garson, A. Jr. ; Brindis, R. G. ; Beller, G. A. and Smith, S. C. Jr. (2002). Integrating Quality into the Cycle of Therapeutic Development. *Journal of the American College of Cardiology*. Vol. 40, No. 11 (Dec. 2002) 1895-1901, ISSN 0735-1097

Cheng, P. H.; Chen, S. J. ; Lai, J. S. and Lai, F. (2008). A Collaborative Knowledge Management Process for Implementing Healthcare Enterprise Information Systems. *IEICE Transactions on Information and Systems*. Vol. E91-D, No. 6, (June 2008) 1664-1672, ISSN 0916-8532

Cheng, P.H.; Yang, T.H. ; Chen, H.S. ; Hsu, K.P. ; Chen, S.J. & Lai, J.S. (2005). Codesign of a Healthcare Enterprise Information Portal and Hospital Information Systems, IEEE Healthcom 2005, pp. 446-449

Deming, W. E. (1986). *Out of the Crisis*, The MIT Press, ISBN978-0262541152, Boston, MA

Dinesh, D. and Palmer, E. (1998). Management by Objective and Balanced Scorecard: Will Rome Fall Again. *Management Decision*, Vol. 36, No. 6, (June 1998) 363-369, ISSN 0025-1747

Higgs, E. (1997). Health Informatics Blueprint: Business Needs. *Information Management & Computer Security*, Vol. 5, No. 2, (Mar. 1997) 58-62, ISSN 0968-5227

Hsieh, S.L.; Lai, F.; Cheng, P.H.; Chen, J.L.; Lee, H.H. & Tsai, W.N. et al. (2006). An Integrated Healthcare Enterprise Information Portal and Healthcare Information System Framework, IEEE EMBC 2006, pp. 4731-4734

Kaplan, R. S. and Norton, D. P. (1996). Using the Balanced Scorecard as a Strategic Management System. *Harvard Business Review*. Vol. 74, No. 1, (Jan. 1996), 75-85, ISSN 0017-8012

Niland, J. C. ; Rouse, L. and Stahl, D. C. (2006). An Informatics Blueprint for Healthcare Quality Information Systems. *Journal of the American Medical Informatics Association*, Vol. 13, No. 4, (July-Aug. 2006) 402-417, ISSN 1067-5027

Ravichandran, T. and Rai, A. (2000). Quality Management in Systems Development: An Organizational System Perspective. *MIS Quarterly*, Vol. 24, No. 3, (Sept. 2000) 381-415, ISSN 0276-7783

Sommerville, I. (2007). *Software Engineering, 8th Edition*, Pearson Educatoin Limited, ISBN 978-0321313799, England

Want, R. Y. (1998). A Product Perspective on Total Data Quality Management. *Communications of the ACM*, Vol. 41, No. 2, (Feb. 1998) 58-65, ISSN 0001-0782