12^{TH} EUROPEAN CONCURRENT ENGINEERING CONFERENCE 2005

ECEC'2005

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PREFACE

Since 1994 onwards the European Concurrent Engineering Conference has functioned as a vessel to highlight, Concurrent Engineering as a research topic, which, has been considered within the European community of researchers and practitioners as a way of exchanging ideas and working together in a highly technical distributed high end industrial environment.

Concurrent Engineering has gained in maturity, and every day experiences and business are conducted today. Novel methodologies are drawn, and new ways of working are emerging. Information and Communication Technologies allow virtual teams to engineer virtual products by accessing virtual collaborative workspaces and launching new business applications and processes. Virtual organizations are built in a multi domain context where a trans-organizational distributed information system should be enabled.

In its 12th edition, the ECEC is hosted by the Institut de Recherche en Informatique de Toulouse on the campus of Université Paul Sabatier. It is aimed at industrial enterprises, industrial associations, universities and research institutes, and features a variety of interesting contributions to the following major topics:

1. Simulation in Business Games
2. Simulation in Business and Economics
3. Simulation in OR and Knowledge Management
4. e-Business in CE
5. Supporting Technologies
6. Engineering Data Management and Information Modeling
7. Engineering Process Management
8. Collaborative CE Environments and Virtual Teams

The selected papers, included in this volume, cover on the one hand many industrial areas such as the Aerospace, Automotive, Metallurgical plants, Maritime and Construction sectors. They will provide an accurate view on the Concurrent Engineering deployment in the Industry.

On the other hand, new insights in conceptual approaches, processes, methods and modeling are considered. They will allow the assessment of the Concurrent Engineering within organizations and business.

We would like to take this opportunity to thank the general and local organizers of the conference, and especially Philippe Geril from EUROSIS in Ghent for his efforts and work, and to all Session Chairs, Members of the Technical Program Committee and Reviewers for their efforts to make this Conference a success.

We hope that this event will lead to further CE activities, which will also bring people from industry, research and education closely together. As General Chairman and Program Chair of the 12th European Concurrent Engineering Conference, the Organizing Committee of the Conference joins us in thanking all of you for supporting this event and in wishing you a pleasant and rewarding stay in Toulouse.

Dr Jean-Claude HOCHON
Program Chair

Professor Abdelmalek BENZEKRI
General Chairman ECEC'2005

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Management of Technology Using a Modular Open System Strategy

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ABSTRACT

The need to rapidly insert new technology, develop new systems, reconfigure existing systems in real time, and protect intellectual property and resources require an adaptive modern network of systems capable of accommodating evolving needs and technologies. What is needed is a flexible and agile technology management approach built upon a secure, integrated network of modular open architectures. Adherence to such an approach is necessary for creating an open and adaptive organization and for deterring competition and expanding business. This paper proposes an archetype for developing a robust and flexible Technology Management Approach (TECHMAP) built upon integrated networks of modular open architectures.

INTRODUCTION

International presence in the global market is no longer a luxury afforded by a few, but a necessity for all kinds of organizations that want to grow and sustain. Expanded international presence will demand capability to effectively deal with the economic fluctuations, technological, and other risks associated with heavier reliance on foreign customers. Satisfaction of foreign customers' needs demands the ability to effectively develop and integrate various E-commerce and other technologies, deploy the systems resulting from such integration rapidly and efficiently, and modernize the systems as needs and technologies change (Azani and Khorramshahgol, 2001).

There is little doubt that future organizations must be less costly and more adaptive (Nutt 1992). Moreover, the organizational infrastructure must possess inherent capability to adapt to the gigantic paradigm shift brought about by the massive rate of technological advances and the pervasive globalization of economies, markets, and conflicts. The new pattern of change has business and engineering dimensions reinforcing each other and creating a paradigm shift greater than the sum of its parts. Let's identify some of the fundamental ingredients of these business and engineering paradigm shifts and review their implications in greater details.

BUSINESS PARADIGMS

The new way of doing business is rapidly being shaped by the following major changes:

1. **Immense technological big bang.** The technological breakthroughs that occurred during the last century and the ones that will emerge in the near future are rapidly and drastically changing our lives and the way we will manage organizations. In our opinion, the floodgate of this massive change is about to be fully opened and its accelerating speed, enormous intensity, and impacts will soon overwhelm us. The emerging paradigm of technological change will be at least 1000 times more powerful than the mechanization technology breakthroughs that happened during the

industrial revolution. This paradigm – or Technological Big Bang – will ultimately free us from dependence on this planet and throw human species into the unbounded possibilities of the heavens. For this reason, we chose to call this massive shift in know-how and capability to harness the fruits of human intelligence, a technological big bang.

2. **Drastic proliferation of scientific and technological knowledge.** Unlike the past, scientific information is no longer a secured and privately owned secret. Knowledge has become a public good and is readily available to everyone around the world. The rapid advance and integration of telecommunication and computer technologies, and the standardization efforts within the newly emerged industries has created suitable conditions for proliferation of technologies. With the advent of the Internet, wireless handheld technologies, and mushrooming of Internet cafe shops around the world, we will witness a drastic increase in the speed of proliferation and a shrinkage of time needed to respond to emerging market needs and technologies.

3. **Shift in values and priorities.** The era of salvation by government is very rapidly coming to an end. The welfare state is being replaced by interdependent enabling states. Geographic and cultural boundaries are gradually being removed by telecommunication and Internet technologies. Disappearance of such boundaries will result in convergence of thoughts and values and adoption of common views regarding quantity and quality of life. Consequently, the citizens of the world now seek freedom and democracy to enjoy life as they wish to, demand access to the same high quality products that others have, and expect higher level of service from private and public institutions. Convergence of values will necessitate higher degree of standardization of products and services and the ability to quickly and effectively respond to rising needs and expectations. They demand proactive prevention of wars and support peacekeeping efforts that are technological rather than labor intensive, and destroy property rather than people. The public also demands a smaller government and a higher access to public services.

4. **Shrinkage of response time.** There is little doubt that the time span for product development, production of goods and services, and the overall managerial decision making is approaching real time. Real time decision making requires dominant knowledge base systems capable of reconfiguring and effectively integrating different technologies, deploying the systems resulting from such integration very efficiently, and continually modernizing those systems as needs and technologies change.

5. **Ever increasing reliance on outsourcing.** No single organization is the engine of change for new technologies. Rather than being a developer, most of organizations have become integrators and consumers of commercial technologies. As a result of globalization of competition and the prospect of making more profit in the global market, various industries have shifted their focus away from internal production to outsourcing and integration of commercial goods and services that others have a better comparative advantage. Also, as a result of brain drain, highly skilled and specialized employees have become very scarce, like endangered species, and a large number of functions performed by these people are being outsourced to contractors.

6. **Shift in strategy:** The above-mentioned changes will collectively result in pressures to revise the corporate and government strategies. The new strategy will definitely result in a dramatic reduction in number of people employed while increasing the use of technologies that can plan, monitor and control from long distances. Such a historic shift would reduce the vulnerability of organizations to labor unrest and provide them with enormous flexibility to respond to new initiatives. The new government and corporate strategies will have to be less dependent on very old and obsolete legacy systems. In today's situation, the life-cycles of the constituent technologies of which systems are built turns over several times inside the design cycle of traditional systems. If it takes 3 to 6 years in auto

industry to design and field a new car system, the technologies available in the early stages will have run their life cycles and be not merely obsolete, but unavailable at any price.

ENGINEERING PARADIGMS

The engineering of future systems essentially faces the same set of realities. It is quite possible to "go it alone" and develop unique systems that meet no standards other than those created specifically for a program by a company. But such an approach not only eliminates the tremendous engineering and business leverage that is available in the commercial marketplace, but it is also economically infeasible. Successful engineering of modern complex systems will be influenced by the following paradigm shifts:

1. **Need for developing technologies before developing systems.** Industry and government are full of examples of massive resources that were wasted developing systems that did not originally have proven technologies. Time-phased requirements and evolutionary development will become the dominant acquisition strategy. The tremendous cost of technology development will be shared by a large number of interested parties, each acting in its own self-interest. Interactions among all of these stakeholders will drive the marketplace towards convergence in a mainstream that meets the requirements of many stakeholders. If you are in the mainstream, then you can dip into the technologies created and marketed by others any time they are needed.

2. **Shift in role of the system designer.** The role of the systems designer shifts to that of architect and integrator, rather than detailed designer. The systems designer who can depend on the stability of interfaces that are typically found in open systems solutions is able to select products from a wide variety of competing sources. These products are selected with due regard for the architecture required to solve the problem at hand, and then integrated to form a functional product for the user. Consequently, the role of the builder of a system also changes from that of a designer to that of an architect and an integrator.

3. **Shift toward more standardized interfaces.** Designers can provide viable solutions only when the interface is known. In closed proprietary systems the interface and access is controlled by the owner of the specification or standard, . Others wishing to develop systems must reverse engineer, or depend on poorly understood publicly released information. The result is that systems that are not purchased entirely from a major vendor are typically sub-optimized designs of often doubtful integrity. The essential characteristic of standards usable in the open system context is that they be available to all either at no cost or for a reasonable fee. By designing a product based on open interfaces, the vendors will be able to protect their intellectual property rights and at the same time increase the exposure of the market to their product.

   Products with closed interfaces will practically limit the marketplace to only one or at best, a few vendors with profound negative effects on ability to insert new technology and reduce total cost of ownership (Meyers and Oberndorf, 2001). These effects are created mostly by the lack of competition. Three of the most common are detailed below:

   - The vendor is under no pressure to maintain prices. Even if a vendor must buy into a project with a low initial bid to secure subsequent sales, the buyer is locked into that single vendor for years to come and cannot easily migrate to a more reasonable pricing structure (Rauch, 1996).
   - The technology that is available is determined not so much by market demand, but rather by what the major vendor believes is warranted and in their own best interest.
   - Other commercial items may not be readily available, or may not integrate well into the existing system. This situation occurs because the proprietary interface standards are not published, so only those sub-vendors favored by the major players are provided with information.

In addition, developers and systems designers must also understand the standards development process and participate in it to ensure that their organizational needs are met by the standards that are released. The goal is to influence the specifications of standards that will most likely be widely accepted and become stable. When standards are reasonably stable, as well as widely distributed, then competent vendors can create compliant products that work together with related products of other vendors to form a viable system.

4. **Need for flexible and modular architecture.** Modular design tenets such as encapsulation, self-containment, cohesiveness, and decoupled-ness are essential design considerations for development of contemporary systems. These principles will facilitate future insertion of new technology, ease repair and maintenance, and mitigate integration risks.

THE MODULAR OPEN SYSTEM STRATEGY

A Modular Open Systems Strategy (MOSS) is an integrated business and technical strategy that employs a sound systems engineering process and continuing market research to develop modular and flexible architectures characterized by widely supported and consensus-based interface standards published and maintained by recognized standards organizations. MOSS is an effective enabler for achieving integrability (the ability to quickly and affordably interconnect and assemble existing platforms, systems, subsystems, and components). Modular open system strategies are also effective enablers for achieving rapid acquisition with demonstrated technology, evolutionary and conventional development, interoperability, life-cycle supportability, and incremental system upgrade without redesign of entire system or large portions thereof. MOSS will also enable continued access to cutting edge technologies and products from multiple sources, and prevents the buyers from being locked into proprietary technology (Firesmith and Henderson-Sellers, 2002).

MOSS is an effective approach for adapting to current patterns of change brought about by the business and engineering paradigm shifts identified earlier. It is an effective strategy for adapting to the massive rate of technological advances brought about by the immense technological big bang. The permeable boundary and the plug and play capability of an open system enable access to scientific and technological know-how available at the global market. MOSS is also compatible with public demands for leaner and more affordable systems than could more effectively interact with their surrounding environment and rapidly adapt to it. It will make an organization capable of rapid reconfiguration and affordable modernization as needs and technologies change. Finally, MOSS is also compatible with the outsourcing trends and shifts in strategies. It will enable effective integration of different technologies and rapid deployment of the systems encompassing such technologies (Azani 2000).

TYPES OF MODULAR OPEN SYSTEM STRATEGIES

One can follow three strategies for designing and implementing open systems: top-down, bottom-up, and balanced. Traditional practice in the development of systems has been to develop systems from the top down, where high level requirements were analyzed, partitioned, and allocated to hardware and software elements. By following a top-down MOSS, the organization establishes an overall implementation/deployment plan for MOSS implementation, sets priorities for applications, constitutes an enterprise-wide policy for development, and establishes a list of preferred key interfaces that must remain open to enable exchange of information and products. This strategy integrates complex development efforts with uniformity and economy of scale, but constrains rapid development and local innovation at the end-user level.

A bottom-up MOSS is based on inputs and wisdom at the lower level to develop and deploy open systems throughout the organization. The driving force for adoption of a bottom-up MOSS is common sense and an immediate-felt need by experienced system engineers. Bottom- up MOSS may be proven to be more robust than top-down strategies, especially if the architects/engineers at the lower organizational levels possess sound systems engineering skills and have adequate understanding of the MOSS concept. A bottom-up approach encourages rapid and innovative development of open architectures at the subsystem or user level. While fast and effective for users, this approach leads to duplication of effort and lack of uniformity among similar subsystems. Moreover, the subsystem/component level implementers may not share the same strategy as the enterprise level architects who have a broader understanding of the mission, open systems constraints, and the required system of system interoperability.

By following common sense and sound systems engineering principles, acquisition planners and executives will soon recognize the need to follow a balanced strategy (Azani 2001). Such a strategy is built upon the advantages of both a top-down and a bottom-up strategy. Inputs from the lower levels as well as from the suppliers and customers are gathered and analyzed to create a shared open systems vision and a well-thought deployment plan for the organization. A balanced MOSS will take advantage of prior lessons learned and will establish organization-wide policies and processes to implement open systems. Because a balanced MOSS is based on full participation by all the stakeholders affected, it will be more effectively bought into and more quickly implemented. Figure 1 shows the upward and downward flow of information in a balanced MOSS strategy.

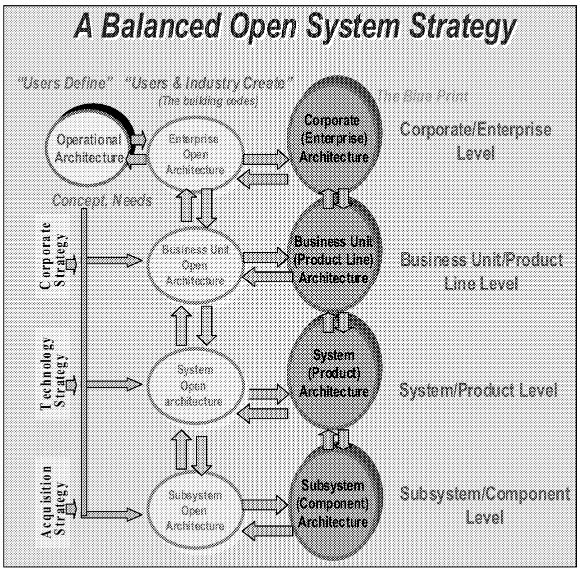

Figure 1: Balanced Modular Open System Strategy

THE BUILDING BLOCKS OF A SUCCESSFUL TECHNOLOGY MANAGEMENT STRATEGY

Modern organizations are in need of developing, acquiring, and integrating a variety of complex systems and technologies. Such an important task can not be undertaken haphazardly through trial and error. Organizations need a systematic and purposeful approach to effectively guide them in assessment, selection, development, transfer, deployment, and integration of new technologies. They also need a robust infrastructure that makes it easier, faster, and more affordable to insert and sustain the portfolio of technologies utilized by the organization. The authors of this paper believe that by adherence to their proposed Technology Management Approach (TECHMAP) the executives of organizations will be in a better position to lead their organizations in the path of lower total ownership costs and rapid assessment, development, deployment, and integration of technologies.

The proposed framework has been developed based on authors' years of experience in government and industry, and has successfully been tested and proven to be useful, especially in technology intensive and high-tech organizations. The main focus of TECHMAP is on modular open system strategy which enables an organization to effectively respond to technological change by developing flexible and adaptable integrated networks of secured modular open architectures. The proposed TECHMAP comprises of four major strategies (Figure 2):

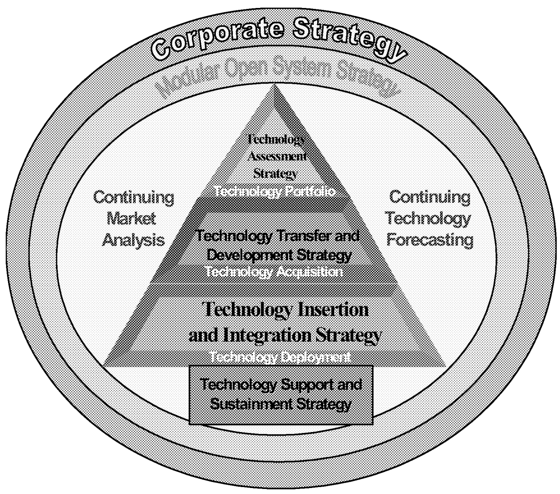

Figure 2: The Technology Management Approach (TECHMAP) Framework

1. Technology Assessment Strategy

2. Technology Transfer and Development Strategy
3. Technology Insertion and Integration Strategy
4. Technology Support and Sustainment Strategy

These strategies are formulated in congruent and based on the overall corporate strategy of an organization, and will be facilitated and enabled by adherence to a balanced modular open system strategy. In a way, the overall corporate strategy establishes the framework and guidance, and the balanced modular open system strategy establishes a collaborative environment and an effective infrastructure for selection, assessment, and deployment of an organization's portfolio of technologies. Continuing market analysis and technological forecasting are other essential ingredients for the establishment of a viable and adaptive TECHMAP. Market analysis is needed to gather intelligent information on existing and emerging technologies, products, and standards. Market analysis is supplemented by application of various technological forecasting tools to discover technology trends and predict timing and availability of scientific breakthroughs.

The proposed framework operates in a versatile and open environment. It receives inputs from other organizational entities and provides them with the means to operate more efficiently and effectively. Organizational systems such as production, finance, marketing, and R&D will become transparent to the TECHMAP by agile open infrastructure comprised of integrated network of secured modular open architectures (Figure 3).

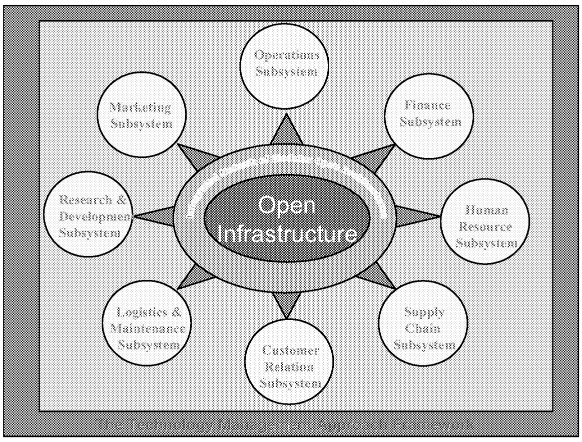

Figure 3: The Encompassing Nature of a Technology Management Approach

As the acronym depicts, TECHMAP is a map that shows the position of the organization with respect to market conditions and the life cycle of various technologies impacting or have the potential to impact the well being of the organization. In other words, TECHMAP maps the whereabouts of the organization with respect to key technologies needed and guide the organization to effectively correct its path. An effective TECHMAP could be regarded as the center of the nervous system in an organization. As such, it will provide real time planning, control, communications, intelligence, and integration capabilities with respect to assessment, selection, development, and deployment of an organization's technology portfolio.

As is shown in Figure 3, the integrated networks of secured modular open architectures will provide the necessary linkage among the main subsystems of an organizational system infrastructure. Such network is characterized by enduring interoperability, integrability, affordability, adaptability, and supportability throughout the life cycle of a technology and its encompassing system(s). These attributes are realized by employment of open interface standards for key interfaces used in various system and subsystem architectures. Key interfaces are common boundaries or connections between modules that are subject to rapid technology turnover and/or increased failure, or have requirement for commonality and/or interoperability (Azani 2001). When such interfaces are defined by open standards, they permit: (1) quick and effective communication among subsystems and technologies; (2) rapid configuration and reconfiguration of systems and technologies; (3) affordable development and supportability through continuous access to multiple sources of supply; and, (4) increased adaptability to upgrade and change as new technologies become available or requirements evolve (Azani 2002).

GUIDING PRINCIPLES FOR MANAGEMENT OF TECHNOLOGY

This paper recommends the following guiding principles as a means to expedite the TECHMAP development process and achieve its technology plug and play capabilities:

1. Create a shared vision among all the stakeholders to create a viable and adaptable TECHMAP greater than the sum of its constituent technology strategies.

2. Create a balance between ease of integration, affordability, performance, and interoperability.

3. Delegate decision authority to the lowest possible organizational levels to cut unnecessary bureaucracy and speed up the decisions needed for developing and deploying the required technologies.

4. Institute appropriate incentives to expedite the overall technology management process. These incentives must address how to reward people and organizations (e.g., program executive officers, program managers, systems engineers, and acquisition logisticians, contractors) for thinking beyond the boundaries of their departments/programs to achieve the necessary attributes.

5. Maintain flexibility through management processes that leverage the natural cycle rates of the underlying technologies, architecture-driven modularity, and sufficient control over interfaces and design. To enable and maintain flexibility, channel resources to leverage commercial products and technologies.

6. Use modular partitioning principles (e.g., maximum decoupling and synergism) to identify and select interfaces that must be defined by open standards. Be mindful that not all the interfaces within a subsystem have to be open. The attributes of TECHMAP can be best realized by suitable modular partitioning of systems. If the interfaces are controlled at an appropriate level, then modularity consistent with the best economic and engineering requirements can be achieved. Partitioning and modularity can be attained with minimum effort and cost by applying an open system strategy. Methods must be developed for assessing not only the degree of openness, but also the quality of the choices made. There must be an understanding that practical openness requires adherence to MOSS, but after due and diligent consideration of MOSS, a closed system design may be preferred if it meets the performance and life-cycle cost goals.

7. Utilize specific milestone reviews and performance measures to ensure that the system design and support conform to the open system strategy and standards. Particularly, we need to pay special attention to the selection of standards. Standards require relatively long periods to mature, and then after reaching maturity have a relatively short half-life. Some attention must be given to the nature of the standards selected. One that is too mature, despite being widely supported, may well disappear under the onslaught of superior new technologies. On the other hand, juvenile standards may not achieve sufficient support to merit consideration. Nevertheless, conscientiously selecting a youthful standard and being wrong is still usually cheaper and quicker than adopting a unique or proprietary standard. Moreover, we need to be mindful that systems may be declared open simply because it is a requirement, not because it is a reality.

8. Institute careful change management and planning. Establish plans to change the structure, processes, and the means by which technologies and systems are developed, fielded, and supported. A synergistic partnership with employees, suppliers, and customers is essential. Such partnership will require noticeable organizational and cultural changes. The acquisition strategy of each system and technology must be derived from an overarching acquisition strategy. The acquisition process must concentrate on interrelationships among systems and technologies being acquired rather than on acquiring systems in isolation from each other. The acquisition process must also shift the emphasis from short term cost of system development to total cost of ownership; from requirements frozen early in the acquisition cycle of a system to flexible and evolving capability for system of systems; from unaffordable supportability to Just in Time (JIT) supportability enabled through modularity, economies of scale and, continuous access to multiple suppliers. The cultural and structural changes will result in organizational resistance and passive behavior in the beginning. But, a new

organizational equilibrium will soon be reached based on the quality of plans and the degree of empowerment and involvement of various stakeholders.

CONCLUSION

The MOSS strategy is among a few options available to organizations to eliminate threats from obsolete technologies, closed systems, and budget constraints; and to rapidly and effectively exploit the technological opportunities. By following the MOSS strategy an organization has at its disposal efficient and effective means to leverage the investment made by the commercial sector in new products, technologies, and scientific know-how , and effectively integrate them into highly advanced and efficient systems.
The proposed archetype will enable an organization to:

- Attain capability to more effectively reconfigure systems and applications;
- Integrate commercial and indigenous technologies more effectively;
- Insert new technology quickly across various system platforms;
- Improve effectiveness of collaborative systems and applications; and
- Reduce total ownership costs of technologies and systems through commonality, software and hardware reuse, reduced development cycle time, and increased access to multiple sources of supply.

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SIMULATION IN BUSINESS GAMES

A BUSINESS GAME FOR THE MARITIME SECTOR

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KEYWORDS

System dynamics, Shipping, Shipbuilding, Business Game, Maritime Economics

ABSTRACT

This paper presents a system dynamic approach for the creation of an extensive Maritime Business Game, which stems from a close cooperation between two universities, each with its own specialisation. In the first place, this model has been developed for educational purposes. As it is not easy to familiarise students with all the workings in the maritime world, this game is meant as a new instrument for education. Participants are confronted with several aspects of the maritime business such as strategy deployment, financial planning, interpreting market changes, etc. The first results were promising. Students were eager to understand the principles of the game in order to outperform their competitors in gaining both market share and profits. With the accumulating experience from education as well as continuous efforts to improve and update the model, a valuable tool for teaching and academic research will emerge in the future.

1. INTRODUCTION

1.1 Introduction to the Four Shipping Markets

Shipping can be considered as one of the oldest global markets. For ages ships are sailing across the entire globe. The ever increasing integration of markets causes the seaborne trade to grow continuously.

Due to this world-wide coverage, the maritime sector is often held up as an example of a very competitive sector. There are a lot of different players involved and each one is maximising the company's result. To get an understanding of the strategies shipping companies undertake, one has to know something about the workings in this business.

The maritime sector can be divided into four shipping markets, which are continuously interfering with each other (figure 1).

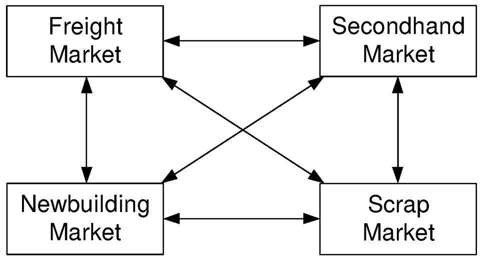

Figure 1: The Four Shipping Markets (Stopford 2002)

In essence, goods have to be transported because of the spatial differences in their supply and demand. The maritime leg of this transport service is in general done by ship owners against a freight rate. This rate is determined by the law of supply and demand of transport capacity. The demand mainly depends on the level of economic or industrial activity. The total seaborne fleet is a function of the pace at which new vessels are built and old vessels are scrapped. Used vessels can also be traded in the second hand market. This, however, only changes ownership patterns but does not affect total supply. We will investigate the market models more thoroughly later on.

The game model focuses on two main actors operating within the maritime sector: ship owners and shipyards. These participate in the game and have to optimise the performance of their company.

1.2 Application

The aim of this maritime business game is twofold. Until now, this business game has been solely used for educational purposes. By actively playing one of the parties involved in the maritime sector, students get a better understanding of the complexity of the organization of and the operation within the sector. Their participation in a realistic simulation of the business dynamics inherent in shipping and shipbuilding complements their theoretical knowledge.

Secondly, as the underlying models are being optimised, we will use the game for scientific research. Among other, it will be possible to develop and test strategies for ship owners and shipyards, and develop appropriate public policies. Also it will be possible to develop internally consistent scenarios that will enable stakeholders to discuss future directions for the maritime cluster on the basis of a rational and common platform.

1.3 Methodology

The model behind the Maritime Business Game is developed in-house by the Universities of Antwerp and Delft. By combining their knowledge and expertise, it was possible to create a new and unique management tool, which can be used for a variety of purposes. The University of Antwerp is specialised in Maritime Economics and took charge of the shipping model. The University of Delft is technologically-oriented and set up the shipbuilding model.

An extensive search made it clear that no business games yet exist treating shipbuilding and shipping as detailed as necessary for our purposes. It is worth mentioning the Tankersim model (www.tankersim.com), even though only the tanker market is presented and no yards are incorporated.

Although many general environments are available to support our domain-specific needs, we decided to use the system dynamics tool VENSIM (www.vensim.com). This tool kit includes enough features to meet future applications of the game.

At present, the game is built around two interactive models i.e. a shipping model and a shipyard model. Each model serves as part of the economic background for the other model. This happens through a lot of dynamic relations, mainly triggered by the participants. With some minor adjustments each model can be run independently allowing for a greater focus on only one market. This is useful in education, when e.g. economics students do not have to deal with the shipbuilding dynamics. The synergy we strive for is in the combination of the two models, in order to bring out the interactivity between them and to let different kind of students participate and compete against each other. This is the added value of cooperation between both universities.

This paper starts with the modelling of the different shipping markets as they form the framework in which ship owners and shipyards operate. Next, the game procedures are presented with an introduction of all major players involved. We subsequently explain the game model more in detail. The performance of the decision-making by the ship owner and shipyard will be reflected in the financial results. We continue with an evaluation of the model and pinpoint some future improvements and enhancements.

2. MARKET MODELS

At the moment of writing, only the bulk sector is fully integrated in the model. For the freight market, the main focus is on the spot market.

2.1 Freight Market

The most important thing in this market is the fixing of a freight rate in order to equalize supply and demand. The total demand is a function of industrial growth, trade elasticity and determined stochastically (Cooke 2004). The total bulk fleet is determined endogenously by interpolating representative fleet data to a monthly basis. The market clearing algorithm is based on productivity changes of the total fleet through speed adjustments as figure 2 shows (Strandenes 1999). Although system dynamics is continuous in time, it allows for some easy simultaneous equations. The calculation time may rise exponentially, though, and the computer might not find an equilibrium.

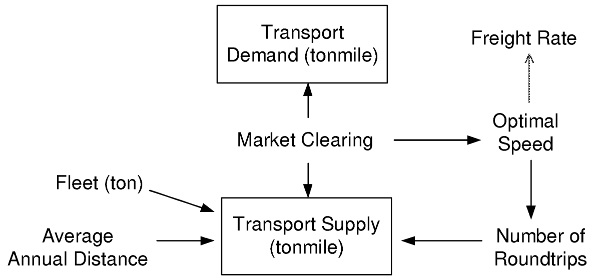

Figure 2: Market Clearing Algorithm

Besides this, the freight rate also depends on the vessel size/type (Handysize/max, Panamax and Capesize), due to scale effects, the market in which the owner is operating (grain, iron ore, coal, fertilizers) as well as the transport route. Since only the spot market is modelled, the freight rates are calculated per ton. Due to the heterogeneity in markets, each ship can have another freight rate.

Because the freight market influences all other markets (figure 1), it is necessary to compute different freight indexes (Baltic Handysize/Panamax/Capesize Index). These reflect the heartbeat of the different freight markets and the elasticity by which they influence the other shipping markets.

2.2 New Building Market

The aim of the new building market is to anticipate long term demand for transport capacity. The time lag between the ordering/demand and the delivery/supply of the vessel explains the structural inequality in shipping. This delay also triggers additional dynamic behaviour in the system. Therefore, it is necessary to model this market appropriately.

The market of building ships, notably bulk carriers, is concentrated in a limited number of countries or regions. This means that most aspects of the market can be represented by a small number of yards. Besides players operating as yards in the game, there are a number of automaton algorithms programmed in order to reflect the reality of the new building market. Among other things, these automatons yield the price and delivery time for each vessel type, which is the key to the ship owner's decision-making.

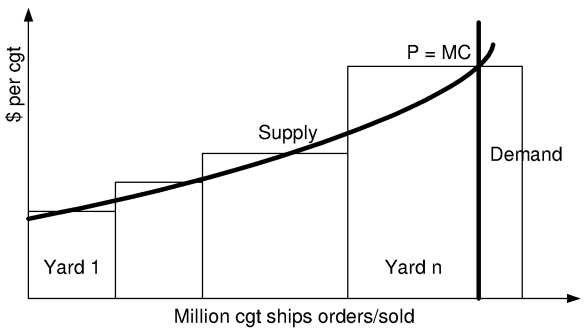

Figure 3: Equilibrium in the New Building Market

The model will generate equilibrium prices based on the total supply of new buildings and the stochastic demand. As we modelled the representative behaviour of the new building market, it is possible to apply the economic principle of price (P) equal to marginal cost (MC) in order to get equilibrium prices in a competitive market (figure 3). This price is made public and is important information for ship owners as well as shipyards to assess their negotiating power.

2.3 Second Hand Market

The market for used ships is not modelled explicitly because it can be considered as an auxiliary market. The second hand price for a vessel is determined by the age of the ship, the current exchange rates and the prevailing market conditions on the freight market. Increasing freight rates e.g. cause the prices of second hands to rise consequently.

2.4 Scrap Market

The scrap market is still a very labour-intensive sector. Most vessels are being scrapped in developing countries like Pakistan, India and Bangladesh. Scrap yards are not modelled in the game. It is more important to find a scrap equilibrium price.

On the one hand, the demand for scrap depends on the situation on the steel market. The decision to demolish a vessel is based on the earning potential of that vessel. If the operational costs of a ship systematically exceed the freight rate, the probability that a vessel is being sold for demolition will increase. We incorporated this for the endogenously generated fleet by computing this probability using a normal distribution. It is clear that the level of scrapping will be highly correlated with the age of the fleet, as this influences the operational cost of a ship. Besides the freight rates, the imposed regulation may also result in a quicker demolition of vessels. The phasing out of single hulled tankers is a good example to illustrate such a scenario.

3. GAME PROCEDURES

3.1 Overview of the Structure

Next to the interactions between the different shipping markets, there is also interaction between the elements in the game. We highlight each of them as they are depicted in figure 4.

The most important elements are the participants, who represent the shipyards or the ship owners. Their interaction is threefold. During the contract negotiations, the ship characteristics, the price, the payment schedule as well as the delivery time are agreed upon. Once a contract has been concluded, the construction of the vessel can start. In this second phase the shipyard will send bills to the ship owner according to the contract. Eventually, the new ship will be tested and delivered to the ship owner.

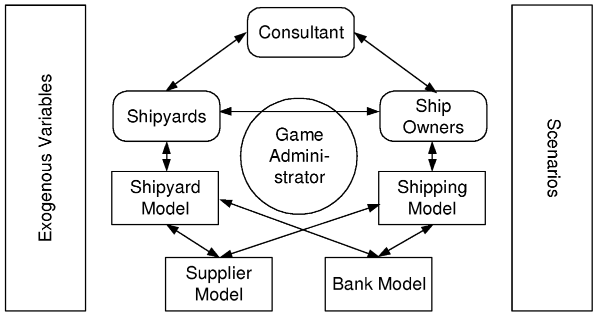

Figure 4: Game Model Set-up

The role of the consultant is to supply participants with additional information on the market. The consultant can be played by one of the staff members. The participants can turn to him to buy additional information about the current market or predictions about the evolution of various exogenous variables.

Exogenous variables cannot be influenced by the participants. Examples abound: the steel price, the fuel price, port and canal tariffs, wages, interest rates, exchange rates. We postulate that these variables follow a geometric Brownian motion (Tvedt 2003). Thus, Y_t makes stochastic movements.

$$dY_t = \mu Y_t + \sigma Y_t dZ_t \qquad (1)$$

The incremental change in Y_t is given by equation (1) where μ is the instantaneous expected growth rate, σ is the standard deviation of the incremental relative change in Y_t and dZ_t is the increment of a standard Brownian motion, that is, $dZ_t \sim N[0,dt]$.

Sometimes, it might be more appropriate to set these values according to their historical values. To enable this, it is always possible to input exogenous variables as time series in order to represent certain scenarios. Such a scenario could be the re-enacting of the oil crises.

The participants can directly influence the course of the game. By defining different parameters, shipyards can take decisions about the labour pool, the priority for ships, the selling or buying of equipment, the credit loans, etc. Once these decisions are made, the model will communicate with the supplier model for e.g. new equipment, or with the bank model for new credit loans.

The same system exists for ship owners. They can choose routes and cargos for their vessels, set insurances and flags, take credit loans, etc. Here the supplier model provides port services for example. The reason for presenting the supplier and bank model as individual models is to allow participants to represent these elements in future versions of the game.

The last element to consider is the Game Administrator. He/she has no direct connection with any of the other elements, but needs to be present in order to run the game smoothly. The Game Administrator will enact the next game step and is available to correct unintentional mistakes of the participants.

3.2 Game Set-Up

The game is developed as a system dynamic model and is connected with an SQL Database to regulate the input and output. This approach has a lot of advantages. The participants are able to input there data or decisions simultaneously and from whatever location they want. Moreover, the whole game can be played over the internet, without face-to-face meetings, where negotiations take place by e-mail or instant messengers. Moreover, it passes the responsibility for accurate input onto the participants, making the Game Administrator available for useful tasks such as involvement in the educational process.

The creation of a system dynamic model also allows for a greater flexibility regarding the number of participants. The game can be played with almost any number of participants. The automatons can play the other yards or ship owners. The introduction of automatons not only increases the competition between players, but also facilitates the comparison of the performance of automatons and players to a larger extent. Also in a setting with relatively few players, adding automatons provides a realistic intransparency to the game.

Another benefit of using system dynamics deals with the very detailed treatment of 'time'. The game takes steps of one month, while the calculation step used in the model is 1/32nd of a month or almost a day. This detailed way of calculation is important, e.g. to follow the cash flows properly. Especially in shipping, where the cash position can be as important as profits or losses, this is worth dwelling on.

The game time determines when the players are provided with different sources of information. After each month of gaming time, they get a cash flow overview of the past month. For the shipyards, information is provided about their equipment, assets and work in progress. For the ship owners, the location of the vessels is communicated.

Every three months a more detailed review of the company's cash flow over that period is reported. Once a year a balance sheet and the year's results are presented, together with some additional information on their assets.

Next to these yard or owner specific information sources, a more general information source, the monthly news bulletin, is issued. Among other things, the requests for quotation are published as well as information about the contracts concluded over the past month. Other items are the raw material prices, the freight rates, regional oil prices, port tariffs, the weather forecast and exchange rates for the different currencies.

Apart from these regular news items, there is also a general heading providing information on expectations for transport volumes, piracy attacks, tax and subsidy changes or the availability of sailors. The newspaper is generated automatically from the game output.

Each company, i.e. each group of students, has to react within a certain time period. Yards have to deliver their bids for the open tenders, while at the same time negotiations with ship owners will take place.

The role of the game administrator is to inform the players when the game moves one time step ahead and when the necessary information is available. There is a slight delay between these two events. The Game Administrator will first read out the input entered into the model, after which the model is run. Once the calculations are done, the information will automatically be made available to the players.

4. GAME MODEL

4.1 Shipping Model

Each ship owner has a fleet. The initial configuration of this fleet is different for each player. Throughout the game, they have to take decisions to maximise the performance of the company. On the one hand, there are strategic decisions like buying and selling vessels, the market in which to operate or the way a ship is financed. On the other hand, a lot of tactical decisions have to be taken like the speed of the vessel, the flag, the conscript of a P & I option, the call for a consultant to gather crucial market information and the possibility to lay up the vessel. The time at which a decision is taken can be as important as the decision itself, hence, the importance of time in the game.

The shipping model is based on roundtrips so as to get dynamic loops. A ship owner can trade along a number of routes, which are combined to roundtrips. To be able to anticipate market events as best as possible, ship owners can change roundtrips each month.

Two overall trips stand out. The first trip starts in the East coast of the US, goes through the Panama Canal to the Far East and rounds Cape Hope to Europe and eventually ends back in the US. This maritime leg covers different trading blocks, which explains the higher exposure towards risk or some events that can take place. The second roundtrip conversely does not circumnavigate the world but is restricted to the Atlantic region. Ships then ply between the US and Europe. Because ship owners can choose the goods they transport, not two but six (goods) roundtrips can be distinguished. An example could be the transport of grain from the US to Europe and back with fertilizers.

Because undertaking trips is the key point in the shipping model, we elaborate this more technically in figure 5.

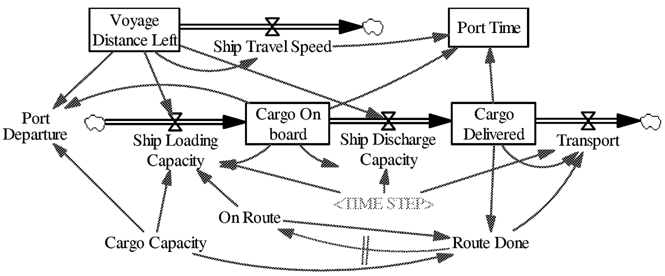

Figure 5: Simulation of Roundtrips

Each route starts with the loading of the vessel. When the cargo is on board, the vessel starts sailing to another port where the vessel is unloaded. Once the cargo has been delivered, another route can be initiated. Figure 6 illustrates the idea for an arbitrary voyage trip.

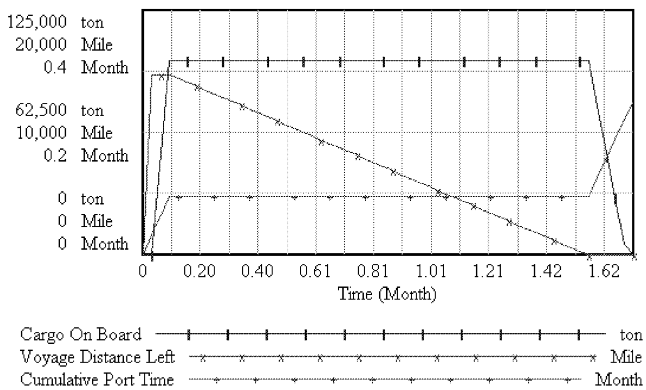

Figure 6: Simulation of Voyage Trip between US and FE

The benefit of using system dynamics is that it allows tracking the vessel's position at every moment. As a result, ship owners, aware of this, can better evaluate the situation of each vessel and they can e.g. adjust the speed in light of future market developments. Moreover, the idea of vessel tracking makes it easier to relate costs to particular shipping activities.

When undertaking trips, ship owners incur different kinds of costs which need to be managed as well as possible. We distinguish between operational, voyage costs and capital costs.

The operational costs consist of stores, crew, insurance, administration and maintenance costs. The crew costs are determined by the tension in the labour market of sailors and officers. These manning costs can be influenced by a different choice of flag. This choice will affect the level of insurance costs in a reverse way, though. The insurance costs are fixed by a compulsory Hull & Machinery and an optional P&I insurance. The latter protects the ship owner for additional risks like war and port state control. As with the insurance costs, the maintenance costs and stores are also affected by the age of the ship and by the ship size but to a different extent. We assume the administration costs to be fixed albeit imposed on each ship.

The voyage costs consist of bunker costs, port and canal dues. The bunker costs are a function of the actual and the design speed, the design consumption, the vessel age and the fuel cost, which is dependent of the geographical region the ship bunkers. We assume that bunkering is performed each time the ship has been unloaded. The port and canal dues are determined by the gross tonnage of the ship and the port time. Furthermore, we impose the fact that port authorities will adjust their tariffs to the current freight market condition. As for now, ports are linked with routes. Every port or route has a certain loading and unloading capacity, which can change in course of the game due to a situation of over- or undercapacity. This may also affect port tariffs.

The importance of port time is handled by adjusting for the laytime through demurrage and despatch. If there is a difference between the contracted (laytime) and effective port time, the owner will be rewarded (demurrage) or charged an extra cost (despatch) by the charterer. This has to be placed next to the extra income a vessel may earn if sooner/later open to undertake a new trip.

The capital costs mainly originate from the financing of ships. Ships are written off linearly over an arbitrary period, currently set at of twenty years.

When a ship becomes too expensive e.g. due to age, the ship can be sold or scrapped. The ship owner formulates a selling price and the model examines whether the market can accept this offer or not. When a ship owner wants to buy a ship, he goes along the second hands or enters into negotiations with the shipyards as to order a new ship.

4.2 Shipyard Model

In shipbuilding the work is divided in 5 different stages (Bunch et al. 1988). The work can to a certain extent be executed in parallel lines, as table 1 depicts. At each sequential phase, different activities can be performed. Prefabrication is the stage where materials are prepared for use in the construction. This phase typically contains actions such as cutting and bending steel plates, profiles and pipes. In this model it also includes the creation of panels from plates and profiles.

Table 1: Work Flow in the Shipbuilding Process

Sequence	Parallell Work		
1	PF-Steel	PF-Pipe	
2	SA-Steel	SA-Pipe	
3	A-Steel	A-Pipe	
4	A-Paint		
5	A-Elec	A-Equip	
6	HE-Steel	HE-Pipe	
7	HE-Paint		
8	HE-Elec	HE-Equip	HE-Cabling
9		Launch	
10	Of-Elec	Of-Equip	Of-Cabling
11	Commissiong & Testing		
12	Sea Trials		
13	Extra Work		

PF: Prefabrication SA: Sub-Assembly
A: Assembly HE: Hull Erection Of: Outfitting

Sub-Assembly is the next phase, where the different plates are assembled in three-dimensional construction blocks. The weight of these blocks is in the range of 50-80 tons. In modern shipbuilding these blocks are also outfitted with pipes.

This is followed by Assembly. In this stage a number of Sub-Assembly blocks together with extra plating and stiffeners are assembled into large blocks weighting as much as 250-300 tons each. These blocks are outfitted as far as possible. This means that not only piping, but also the machinery and the electric equipment are being installed. Before the installation of these items, the steelwork is conserved by applying the first layers of paint.

The most important stage in the building process is Hull Erection. The actual ship is built using the large blocks from Assembly. This construction takes place in a dock or on a slope. The time in the dock is expensive. As long as a ship is occupying the dock, no other ship can be built. In this stage the main engine is installed as well as all the other large machinery and electric equipment items. When all steelwork is completed together with the majority of the other tasks, the ship is launched.

The installation of the last items and the completion of the vessel are performed in this last construction phase, called (Quay-side) Outfitting. During the sea trials afterwards, the performance of the ship is tested vis-à-vis the contracted values. This is mostly followed by a short period of corrections and small adjustments, after which the ship is delivered to the owner.

In shipbuilding, each yard has its own vision on the best method to build ships, but the one presented above is mainly accepted. Only the amount of outfitting can differ significantly. The players are therefore free to assign the amount of outfitting performed within certain limits. Each building block has to go through all these activities and production is limited by the availability of these blocks from previous phases. Another important restriction for production is the availability of production facilities. This can range from completely automated panel-lines to simple forklifts for the transport of goods from the storage to the production area. The number of facilities is limited and the players set priorities for their allocation, both for ships and building stages.

Besides facilities and equipment, a shipyard needs a lot of personnel. Shipbuilding is still a labour-intensive industry, requiring highly specialised craftsmen. This specialisation is represented in the game by the use of different kinds of labour sources: metalworkers, welders, electricians, mechanics, painters and operators for the facilities. Different activities require different combinations of specialists. Because the labour pool is limited, the shipyards can call in temporary labour, although at a higher cost.

The scarcity of floor space can also be a restriction. As pointed out, three-dimensional blocks are constructed in the Sub-Assembly stage and require a certain floor area. In shipbuilding, the construction is carried out in halls and docks. The size of these halls is limited. Moreover, the facilities will also need room to move and handle their contents. This further restricts the floor space available for building blocks, causing a bottle-neck in production.

The last item to stem production is the availability of materials (steel, piping, etc) for production.

These are not the only aspects participants have to handle. As time goes by, the facilities in use will show the effects of wear and tear. Production will drop and the costs will rise. At some point the facilities will just wear out. It is up to the participants to decide on the best time for their replacement.

The players can influence all these restrictions, not only by setting priorities for working within them, but also by acquiring new facilities, enlarging halls, hiring more people, material management, etc. All these changes have costs associated with them and the amount of money available depends on their success in securing profitable contracts. For these contracts, payment scheduling is an important issue for the yards. The majority of the expenses are incurred in the beginning of the production, while the income flows are mostly collected in the end. Credit loans are available to overcome this gap, but again at a certain cost.

4.3 Financial Model

All choices of the players will affect the performance of their company. This performance will be computed in the financial model. It is crucial to understand the difference between costs and expenditures on the one hand and receipts and revenues on the other hand. The difference between expenditures and receipts determines the cash flow, while the difference between costs and revenues stipulates the result of the company. This result forms the basis for yearly taxation.

Because different accounting principles exist to book the down payments with respect to the progress of a new building, we shall explain this more thoroughly. Not only are the payment moments crucial, they also demonstrate one of the links between the shipping and shipyard model.

If a ship or a piece of yard equipment is ordered and a long term credit loan is taken to finance this, the corresponding loan is directly deposited as cash. Down payments are taken up in the balance as such, reducing to zero when the ship is delivered. With the receipt of materials a bill is presented. These costs are put on the balance as a creditor, until payment has taken place. Payment will take place as soon as possible, provided there is enough cash available.

According to the contracted payment schedule bills are sent to the ship owner and put on the balance as debtor until the payment is received. The accounting costs of the materials are ascribed to the vessel at delivery after the product has left the yard stock.

Another major influence on the financial model is exercised by the exchange rates. All the financial reporting is stated in dollars, while not all expenditures are notified in this manner. The people that work at the yards are paid in local currency. Other items like the purchase and selling of facilities, the variable facility costs, the storage costs, the equipment and electric purchases are also subject to exchange rates fluctuations. Players will get information on the exchange rates in the monthly newspaper they receive.

The possibility of getting subsidies can also have a strong impact on the financial results and cash flows. There are two kinds of subsidies: investment and operational subsidies. The first are provided to give an incentive for investments and are represented by a fraction of the investment value that will be paid to the owner. The operational subsidies are paid to the shipyard and not to the ship owner in order to allow for a non-level international playing field. This subsidy is a fraction on top of the receipts of the yard, enabling the yard to ask for a lower price for its products.

The depreciation of facilities and vessels is linear. The book value of a ship can be important for ship owners when they consider selling a vessel on the second hand market. If they succeed in getting a price outstripping the book value, they realise a surplus value, which is booked as revenue.

Finally the interest rate is of importance. For the financing of ships or buying of equipment, shipping companies have an incentive in securing the lowest interest rate possible. We calculated the interest rate as a variable mark up on LIBOR. This mark up is determined by the bank model and depends on different ratios derived from the balance sheet. This represents the importance of a healthy financial position.

5. EXPERIMENTS AND RESULTS

During the first application of the Maritime Business Game, there was healthy competition between the groups. Many demands for the services of the consultant concerned the performance of their company compared with the others. This proved the eagerness to influence the own performance.

All groups created their own cost calculation sheets. In the beginning not all calculation sheets were accurate, but as these were under continuous improvement, in the end everyone had a pretty good idea about their costs and revenues. As the game continued and the students got a better grasp of the business dynamics, some inventive strategies were followed. One involved hedging on the steel price, another followed the strategy of offering extremely short delivery times.

Table 2: Results Maritime Business Game

	Participant	ROE
Owner1	Player	19%
Owner2	Player	25%
Owner3	Player	26%
Owner4	Player	28%
Yard1	Automaton	-4%
Yard2	Automaton	-1%
Yard3	Player	16%
Yard4	Player	15%
Yard5	Player	xxxx
Yard6	Player	11%
Yard7	Automaton	xxxx

ROE: Annual Average Return on Equity

Some results of the first game are presented in table 2. Two yards have gone bankrupt. Yard 1 is still supported by government aid, whereas the others are surviving. There was a significant difference in the performance of shipyards and ship owners. Certainly in the first game, the ship owners had an easier task than the shipyards.

6. FUTURE DEVELOPMENTS

6.1 Ship Owner

The first expansion is the integration of the tanker sector in the model. This goes together with the development of a time charter market, as many tankers are hired for a certain period rather than for a single voyage on the spot market. This does not only result in a reordering of responsibilities between charterer and ship owner but also brings out the link between time charter and spot contracts.

In order to create a model that covers the most important merchant shipping sectors, the container sector will be incorporated as well. This requires another approach as the liner sector is totally different from the dry bulk or tanker sector.

Other enhancements consist of the modelling of a port-auctioning process, the possibility of computer-guided negotiations between charterer and ship owner, and the possibility of hedging with respect to bunker prices.

6.2 Shipyard

At this moment players can choose from a series of standardised ships. In the near future it will be possible to order tailor-made ships, with the size of the vessel being based on certain trend lines. This will widen the negotiation possibilities between owners and shipyards.

Outsourcing part of the construction work to other yards will be another option to develop. This is quite common practice, certainly for the Dutch yards. It will allow for different forms of cooperation between the different yards in the game. One yard can for instance solely focus on hull construction at places where cheap labour is abundant, while the other yard will specialise in outfitting, with a highly trained work force. This focus can make certain facilities redundant, creating a less capital intensive yard.

6.3 Other

The elaboration of a stock market is also under consideration. Participants can then buy parts of other yards or shipping companies. Thus mergers and acquisitions are incorporated in the model. The incentive is not only the possible increase in cash flow, but also controlling a company by obtaining a majority stake.

In the slightly longer term, other players like suppliers and banks will be added. This calls for an endogenous model for both players, and would enhance the scope of the game as well as the level of player's interactions to a larger extent.

An important direction for development is research, where the model can be used to model the behaviour of existing shipping companies or yards. These can be used for strategy development or scenario testing. In both cases different forms of strategy are tested against different economic and technical scenarios (e.g. the economic consequences of fast bulk ships). Moreover, it will be possible to allocate a "success" rate to certain strategies. Simulations can help for instance with policy development, since greater insight into the effects of decisions is already gained before implementation.

7. CONCLUSIONS

The Maritime Business Game is unique in the simultaneous approach of the different markets. It provides a detailed level of interaction between participants and covers many of the strategic and tactical decision-making inherent in maritime companies. With the experience gained from education a valuable research tool for policy development will emerge in the future. Continuous efforts from the Universities of Antwerp and Delft, will ensure a business game that is kept up to date and founded on extensive research and experience in all fields covered in the game.

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STEVE ENGELEN studied Applied Economics at the University of Antwerp in order to get his master's degree in 2001. Afterwards, he also got a master's degree in Maritime Sciences as well as in Law of the Sea and Inland Navigation. Since 2002 he has been working for the Department of Transport and Regional Economics, starting as a junior researcher and to become assistant in 2004. He designed the shipping model, under supervision of Professors Hilde Meersman and Eddy Van de Voorde.

JEROEN F.J. PRUYN is specialised in the application of system dynamics in shipbuilding problems. Graduated for his master's degree in Marine Engineering in 2003, he currently holds the position of researcher at Delft University of Technology. He is responsible for the development of the yard model behind the Maritime Business Game, under supervision of Professor Ubald Nienhuis.

SIMULATION GAMES AS AN EXPERIMENTAL BASIS FOR TESTING THE EFFICIENCY OF FREE MARKETS

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KEYWORDS
Simulation, business games, experimental method

ABSTRACT

This short paper describes with the use of an example how business games, originally devised as pedagogical tools, can also be used as an experimental basis for testing assumptions regarding some aspects of managerial behaviour and economic efficiency.

Introduction

In a previous paper (Dion 2004) we suggested that the potential range of use of Business Games extended their usual and historical -purely pedagogical- function. Since then, we have conceptualised and put into practice an experiment that shows how the general context of a business game can be used to test various assumptions regarding the behaviour of participants and the efficiency of their decisions (Cohen and Rhenman 1964, Faria 1998, Keys and Wolfe 1990, Swanson and Holton 1999, Wolfe 1993). Although the global underlying issue is extremely broad, since it suggests a possible change of category –from teaching to research, of a well known and widely used tool –business games, we have restricted our experiment to a specific question, yet essential to the principle of open economy: how do free non centralised markets and theoretically perfect markets compare in terms of efficiency.

Our methodology finds its sources in the vast corpus of research undertaken as early as the 1950s and 1960s in the field of experimental and social psychology. In many cases, the subjects of those experiments -mostly students, were not aware of the actual topic of the research, and in some instances they were intentionally misguided in order not to let their consciousness interfere with the research findings. We have been able to reproduce a similar scheme in the case of business games, since during the experiment, participants were simply involved in the game as players, and hence tried to maximize their profits, while some experimental measures were conducted without them knowing it. The fact that the game was very taking made students particularly unaware of the research dimension of the process.

Methodology

The experiment took place at the end of a course about strategic marketing which itself already used a business game as its core pedagogical tool and involved 20 graduate students. During the last session, that lasted 3 hours, students were presented with a new game, called Mercato, that focuses on negotiation skills. This game was especially devised for the purpose of the experiment. The complete set of instructions for the game is given in Appendix A. In short, it consists in a series of exchanges of objects that bear various utilities for the 8 teams in competition, without the teams knowing precisely the set of utilities of their partners/competitors. Exchanges are free and therefore only happen –unless there is a mistake, if both partners of a transaction find a mutual benefit in the process, which causes in turn an increase in the total utility of the game universe (e.g. the addition of all the utilities of all teams). A measure of this total utility increase gives an indication about the global efficiency of the market constituted and driven by the teams.

At the end of the game, various measures can be made to assess and explain the players' individual and collective performances.

Results

The first results that need to be presented, although they have no intrinsic interest outside of the pedagogical context, reveal the performance of each team. Those data, that will be needed for further investigation, are given in table 1.

Immediately after the end of the game, a classic questionnaire was submitted to participants, which brought the information given in table 2.

Plotting the data from table 1 against the data from table 2 allows a simple calculation of linear correlations between teams' performances and the various possible explaining factors extracted from the questionnaire (table 3).

	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8	Average
Number of transactions as a seller	4	0	8	4	2	1	1	6	3,25
Number of transactions as a purchaser	3	5	1	6	2	3	5	1	3,25
Number of pure barters	0	0	0	0	0	0	0	0	0
Total number of transactions	**7**	**5**	**9**	**10**	**4**	**4**	**6**	**7**	**6,5**
Number of objects in initial set	12	9	10	10	6	4	4	9	8
Total number of objects sold	10	6	10	10	3	3	4	8	6,75
Total number of objects purchased	7	6	9	9	5	5	7	6	6,75
Number of objects in final set	9	9	9	9	8	6	7	7	8
Average number of objects sold per sale or barter	2,50	0,00	1,25	2,50	1,50	3,00	4,00	1,33	2,01
Average number of objects purchased per purchase or barter	2,33	1,20	9,00	1,50	2,50	1,67	1,40	6,00	3,20
Average number of objects per transaction	**2,43**	**2,40**	**2,11**	**1,90**	**2,00**	**2,00**	**1,83**	**2,00**	**2,08**
Average transaction time for sales	9,75	0,00	12,25	13,75	13,50	2,00	4,00	16,67	8,99
Average transaction time for purchases	14,00	15,80	2,00	15,83	1,50	13,33	11,60	6,00	10,01
Average transaction time for barters	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Average overall transaction time	**11,88**	**15,80**	**7,13**	**14,79**	**7,50**	**7,67**	**7,80**	**11,33**	**10,49**
Number of transactions with Team 1	0	1	2	1	1	0	2	0	0,875
Number of transactions with Team 2	1	0	1	2	0	0	0	1	0,625
Number of transactions with Team 3	2	1	0	2	1	2	0	1	1,125
Number of transactions with Team 4	1	2	2	0	1	0	2	2	1,25
Number of transactions with Team 5	1	0	1	1	0	0	1	0	0,5
Number of transactions with Team 6	0	0	2	0	0	0	0	2	0,5
Number of transactions with Team 7	2	0	0	2	1	0	0	1	0,75
Number of transactions with Team 8	0	1	1	2	0	2	1	0	0,875
Number of different partners	**5**	**4**	**6**	**6**	**4**	**2**	**4**	**5**	**4,5**
Initial utility	**2857**	**2792**	**2787**	**2815**	**2862**	**2915**	**2796**	**2817**	**2830**
Utility gained on sales (a)	2215	336	309	803	570	514	1375	686	851
Standard expected performance on sales (b)	413	356	495	566	319	271	422	515	420
Performance ratio on sales ((a)/(b))	**536%**	**94%**	**62%**	**142%**	**179%**	**189%**	**326%**	**133%**	**208%**
Utility gained on purchases (a)	-946	336	556	492	567	641	1294	391	416
Standard expected performance on purchases (b)	634	749	621	519	720	716	680	565	651
Performance ratio on purchases ((a)/(b))	**-149%**	**45%**	**90%**	**95%**	**79%**	**89%**	**190%**	**69%**	**63%**
Final utility	**3794**	**3810**	**3643**	**4341**	**4212**	**4170**	**3824**	**3904**	**3962**
Rank	**7**	**6**	**8**	**1**	**2**	**3**	**5**	**4**	

Table 1 – Teams' performances

Assessments									
Average assessment from others	**Team 1**	**Team 2**	**Team 3**	**Team 4**	**Team 5**	**Team 6**	**Team 7**	**Team 8**	**Average**
Easy to get in touch with	3,14	3,29	4,00	3,00	2,83	3,43	4,29	4,00	3,50
Kindliness, friendliness to others	3,14	3,14	3,71	3,86	4,29	3,71	3,71	3,71	3,66
Precision in initial deal propositions	3,14	3,29	3,57	3,00	3,57	3,71	4,00	3,43	3,46
Flexibility in negotiation, apparent ability to concede	3,29	3,43	3,57	2,57	3,00	3,29	3,71	3,57	3,30
Ability to consider a wide number of topics to negociate	3,33	3,67	3,50	3,29	2,67	3,17	3,83	3,50	3,37
Ability to include more than one partner in a deal	3,29	3,71	3,57	4,00	3,43	3,57	3,14	3,86	3,57
Ability to come back several separate times to discuss deals	4,00	4,00	3,50	3,29	3,67	3,71	3,86	3,71	3,72
Quick to decide	3,57	4,33	3,43	4,00	3,83	3,57	3,57	3,57	3,74
Seem to talk more	3,29	4,17	2,43	4,00	3,57	3,29	3,57	3,71	3,50
Frequent use of Auctions as a seller	3,80	3,50	3,60	3,33	2,80	3,33	2,80	3,80	3,37
Frequent participation in Auctions as a purchaser	3,67	3,67	3,67	3,17	3,17	3,43	3,00	3,67	3,43
Promptitude to initiate contact, organize things	3,50	2,86	3,33	3,67	3,00	3,83	3,83	3,50	3,44
Ability to act as an intermediary, a trader, to be opportunistic on the market	3,43	2,86	3,43	2,57	2,29	2,17	2,33	2,17	2,65
Show their utilities	2,57	3,29	3,00	2,67	2,43	2,83	3,29	4,00	3,01
Likely performance on sales	3,60	3,50	3,33	3,80	4,00	4,00	3,20	4,00	3,68
Likely performance on purchases	3,60	3,20	3,60	3,40	3,20	3,00	3,80	3,50	3,41

Table 2 – Teams' behaviour assessed by their partners/competitors

Linear correlation between performance (Final utility) and various possible explaining factors (measured though their Average assessment from others)	**Correlation**	**Rank**
Easy to get in touch with	-0,63	11
Kindliness, friendliness to others	0,59	1
Precision in initial deal propositions	-0,22	6
Flexibility in negotiation, apparent ability to concede	-0,83	13
Ability to consider a wide number of topics to negociate	-0,66	12
Ability to include more than one partner in a deal	0,40	3
Ability to come back several separate times to discuss deals	-0,52	8
Quick to decide	0,30	4
Seem to talk more	0,45	2
Frequent use of Auctions as a seller	-0,40	7
Frequent participation in Auctions as a purchaser	-0,56	9
Promptitude to initiate contact, organize things	0,18	5
Ability to act as an intermediary, a trader, to be opportunistic on the market	-0,61	10

Table 3 – Relative strength
of factors explaining performance

Those results seem to draw the following profile for the best negotiators : sociable, talkative, rapid. On the contrary, flexibility and complexity do not seem to serve as performance enhancers: they even seem to decrease it.

Such findings have a certain value in terms of understanding some of the explaining factors of the mechanisms of commercial success. However, the point of this paper is not so much to focus on the results of the experiment themselves. It mainly aims at showing how business games can serve as an original research tool. In this respect, it is worth noting that the investigating potential of the method goes far beyond this first set of conclusions.

Indeed, the information collected and used in this first stage were partly declarative. As such, they inevitably bear some kind of inaccuracy of subjectivity. A way to avoid such biases consists in trying to explain teams' performances by some objectively measurable factors, such as their number of partners or transactions, for instance (table 4).

Relation between performance (Final utility) and various possible explaining factors (measured through their actual value)

	Correlation	Rank
Final utility and Total number of transactions	-0,11	2
Final utility and Average number of players per transaction	-0,48	4
Final utility and Average overall transaction time	0,11	1
Final utility and Number of different partners	-0,23	3

Table 4 – Relative strength
of other possible factors explaining performance

Those results partly confirm the previous conclusions: one-to-one simple transactions seem more efficient than complex exchange schemes. However, a slight contradiction seems to arise regarding the effect of time on the process. Through the questionnaire survey, we could get the feeling that promptitude is an asset to reach high performance. But Table 4 shows that a -slight- correlation exists between performance and time: in other words, the later a given transaction occurs, the higher gain in utility it brings. A possible explanation lies in the distinction between speed and time. Some exchanges can happen close to the end of the game, ans still be hastily concluded. This explanation would be in coherence with the strong negative correlation of performance with the item "Easy to get in touch with" (-0,61).

A last methodological perspective offered by this experiment consists in the study of the overall dynamics of the exchange process throughout the game. Unfortunately, time has not allowed a comparative test of a free "wild" market with, for instance, a structured auction selling system or a centrally administrated exchange platform. One could assume that auction selling would have lead more quickly to a higher degree of performance, but this assumption has not been checked.

However, it is still possible to compute and compare the actual observed performance with the theoretical optimum. An optimal situation would indeed have been reached at the end of the game if –and only if- each object finally belonged to the team for which it has the highest value. This situation could be attained in many ways, and with an infinite number of benefit distribution between players. But it corresponds to a single global score which is given in table 5. This allows the computation of an efficiency ratio between the actual and ideal performance.

	Total
Actually Observed Gain in Utility	**9057**
Maximum possible utility in case of optimal allocation	**10692**
Efficiency ratio	**85%**

Table 5 – Relation between actual
and optimal performance

Moreover, it is possible to examine how this actual performance evolves with time. This is easily done by plotting the total utility reached at the end of each transaction (see Appendix B for details). The observed curve can be adjusted by a second degree polynomial curve with an excellent fitting index, which accounts for the existence a law of the diminishing returns (figure 1).

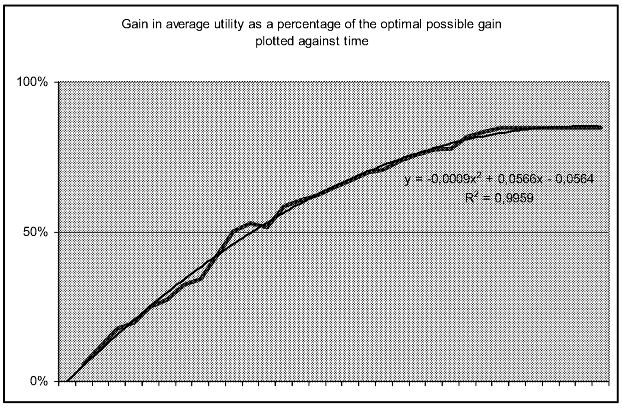

Figure 1 – Evolution of global performance with time

This general trend can be observed similarly by examining each team's course, only with a much more erratic evolution over time (figure 2). It is also worth noting that some teams accept a temporary decrease in their performance as long as a given losing transaction allows them to prepare a future exchange which profit will exceed the initial loss. It is also interesting to observe that, although the global performance oscillates around 85%, some teams finish much higher and some much lower: this is only due to their relative negotiation ability and the consequences on the distribution of benefits between partners throughout the game.

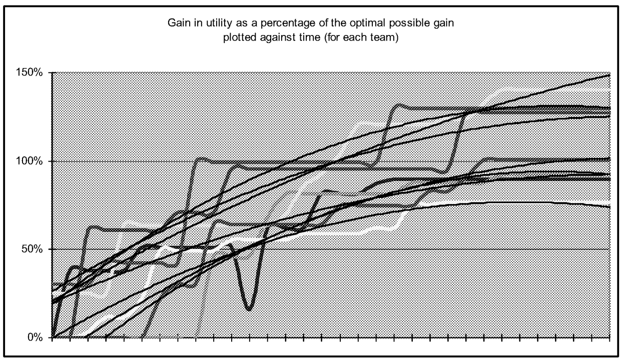

Figure 2 – Evolution of performance
with time (for each team)

Conclusion

The purpose of this paper is not so much to insist on the results of the experiment, but rather to defend, through it, the principle of a possible use of business games as valuable experimental devices. We believe that this objective has been partly achieved through the described experiment.

The next step can be either to replicate the research on a wider basis to assess the validity of the method and consolidate the findings, or to set up a comparative study of various trade organisations in terms of efficiency, by testing the most obvious schemes (centralised market, free market, market with intermediary agents, auction selling) against one another.

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APPENDIX A – SIMULATION'S INSTRUCTIONS

Mercato

Football Players' Transfers Simulation Game

A simulation game about two fundamental concepts of economics :Utility and value

Mercato is a simplified simulation game about the difference between utility and value. The purpose of the game is to simulate and understand the development of an exchange process between team managers for which players have various utilities and no fixed price. Although a reference is made here to the market of sports transfer, the same type of simulation could be set in numerous and various economic environments:

- Bartering of natural resources at the early colonial stage
- Collections of trading cards
- Modern art market, etc.

In *Mercato*, the class is split into 8 teams of 1-4 players. All teams have an identical goal: maximise their utility. This goal should be achieved by buying and selling players to other teams at a price that ensures a gain in utility (transportation costs and taxes are neglected) . Exchanges can be anything between pure buy/sell processes and barters, that can include a maximum number of 5 players on each side plus a possible money compensation.

At the beginning of the game, each team is provided with a number of players (printed on a set of cards) and a certain amount of money. By definition, the utility of money will be equal its face value. Its function in the game is to ease the transaction process in case strict barters are less interesting than buy/sell processes.

Each player has a different utility for each team, depending on the team's organization, needs and structure, and the local demand of supporters. Each team has a precise knowledge of their own set of utilities, but only a few indications about the set of utilities of others. Teams have no interest in telling others what their true utilities are, since this might put them in a weak situation in the price negotiation process. Moreover, the documents on which their set of utilities is printed are easy to forge, so that any showing of those documents is always questionable. Please note that the utilities used in the game have nothing to do with what they could be in reality, and have only be attributed randomly to all the players, for the sake of the game.

The total initial utility of each team is about the same, and so is the final utility that they can reasonably hope to reach at the end of the game. The maximum possible utility for the entire game is approximatively 50% higher than the initial internal utility. This maximum utility will be obtained in case the series of exchanges leads to a situation where each player belongs to the team where its utility is maximum. However, it is unlikely that a perfect optimisation shall occur, and it is all the more unlikely that it shall occur on the basis of an equal gain in utility for all teams. Thus at the end of the game, all teams will have different utilities and the team with the highest utility will be the winner. An increase in utility ranging around 40-50% will correspond to a good performance, and an increase lower than 25% will correspond to a poor performance.

Although it is easy to perform exchanges that bring a small increase in utility, players have no interest in under-selling to other teams players that could reach a higher value by other purchasers. Therefore, the key factor of success lies in the speed and high number of contacts that teams will be able to make in a short time span rather than on the depth of argumentation within the negotiation process.

Teams will be free to move around the room or stand still, ask or answer, try to buy or try to sell, quote prices overtly or not, call for tenders, or even engage in auction selling. They will also be free to try to achieve their goal directly (by trying to buy players of high utilities and selling players of low utilities) or act as traders between other teams. However, to prevent potential traders from jamming the game, a penalty of 2% will be taken off their total utility for each player in their hand exceeding 15 (eg. their total utility will be decreased by 2% if they hold 16 players, by 4% if they hold 17 players, and so on). Any player in excess of 30 will be ignored. The lack of cash should prevent the game from becoming too speculative anyway, knowing that there is no possibility to borrow money from financial institutions, and that all transactions have to be paid for cash.

Documents provided :

- *Set of 64 cards (players)*
- *Set of bank notes to serve as cash*
- *Transaction agreement sheets*
- *Utility cards showing the precise set of utilities for each team*
- *Example of complete utility set (to give an idea of the possible values)*

Appendix B – Detail of transactions observed throughout the game

Order	Utility of objects sold for seller	Utility of objects sold for purchaser	Utility gap between seller and purchaser on sales by seller	Utility of objects purchased for purchaser	Utility of objects purchased for seller	Utility gap between seller and purchaser on purchases by seller	Total profit to share	Total gain for seller	Total gain for purchaser	Share of profit for seller	Share of profit for purchaser	Profit for seller on his sales	Profit for seller on his purchases	Profit for purchaser on his purchases	Profit for purchaser on his sales	New utilities for teams 1	2	3	4	5	6	7	8	Barter index	Pure seller index	Pure purchaser index	Pure barter index (1)	Pure barter index (2)	Number sold	Number purchased	Id. code	Gain in average utility as a percentage of the
0	15	393	**379**	286	75	**210**	589	271	318	46%	54%	174	97	205	114	2657	2792	2787	2815	2862	2915	2796	2817	0	4	5	0	0	1	1	405	0%
1	54	374	**321**	452	120	**332**	652	398	254	61%	39%	196	202	125	129	2657	2792	2787	2815	2862	2915	2796	2817	0	1	7	0	0	2	1	107	0%
2	18	269	**252**	616	229	**387**	639	599	40	94%	6%	236	363	16	24	2657	2792	2787	2815	2862	2915	2796	2817	0	6	3	0	0	1	1	603	0%
3	29	241	**213**	120	120	**0**	213	91	121	43%	57%	91	0	121	0	2657	2792	2787	2815	2862	2915	2796	2817	0	3	5	0	0	1	0	305	0%
4	42	484	**442**	192	61	**130**	572	149	423	26%	74%	115	34	326	96	2657	2792	2787	2815	2862	2915	2796	2817	0	7	4	0	0	1	1	704	0%
5	600	381	**-220**	718	243	**475**	255	117	138	46%	54%	-101	218	-119	257	2657	2792	2787	2815	2862	2915	2796	2817	0	3	1	0	0	1	2	301	0%
6	155	435	**280**	456	202	**255**	534	301	233	56%	44%	158	144	122	111	2657	2792	2787	2815	2862	2915	2796	2817	0	3	8	0	0	1	1	308	0%
7	3	199	**196**	100	100	**0**	196	97	99	49%	51%	97	0	99	0	2657	2792	2787	2815	2862	2915	2796	2817	0	8	6	0	0	1	0	806	0%
8	171	643	**472**	763	412	**351**	823	593	231	72%	28%	340	253	132	98	2657	2792	2787	2815	2862	2915	2796	2817	0	5	7	0	0	1	1	507	0%
9	101	714	**613**	463	203	**259**	872	362	511	41%	59%	254	107	359	152	2657	2792	2787	2815	2862	2915	2796	2817	0	8	2	0	0	2	2	802	0%
10	558	856	**298**	626	612	**14**	312	68	244	22%	78%	65	3	233	11	2657	2792	2787	2815	2862	2915	2796	2817	0	3	6	0	0	2	1	306	0%
11	381	872	**491**	12	643	**-631**	-140	-369	229	264%	-164%	1294	-1663	-803	1032	2657	2792	2787	2815	2862	2915	2796	2817	0	1	7	0	0	1	1	107	0%
12	12	558	**546**	494	317	**177**	723	482	241	67%	33%	364	118	182	59	2657	2792	2787	2815	2862	2915	2796	2817	0	1	2	0	0	1	1	102	0%
13	2	161	**159**	69	14	**55**	214	67	147	31%	69%	50	17	109	38	2657	2792	2787	2815	2862	2915	2796	2817	0	4	2	0	0	1	1	402	0%
14	299	373	**74**	334	209	**126**	200	36	164	18%	82%	13	22	61	103	2657	2792	2787	2815	2862	2915	2796	2817	0	3	4	0	0	1	2	304	0%
15	2	118	**117**	206	39	**166**	283	204	79	72%	28%	84	120	33	47	2657	2792	2787	2815	2862	2915	2796	2817	0	1	4	0	0	1	1	104	0%
16	13	141	**128**	132	11	**120**	248	119	129	48%	52%	61	58	66	63	2657	2792	2787	2815	2862	2915	2796	2817	0	8	4	0	0	1	1	804	0%
17	375	638	**264**	550	550	**0**	264	175	88	66%	34%	175	0	88	0	2657	2792	2787	2815	2862	2915	2796	2817	0	4	7	0	0	1	0	407	0%
18	269	360	**91**	309	302	**6**	98	39	58	40%	60%	37	3	54	4	2657	2792	2787	2815	2862	2915	2796	2817	0	3	1	0	0	1	1	301	0%
19	363	489	**126**	681	464	**217**	343	318	25	93%	7%	117	201	9	16	2657	2792	2787	2815	2862	2915	2796	2817	0	5	1	0	0	1	2	501	0%
20	152	156	**4**	297	84	**212**	217	145	72	67%	33%	3	142	1	70	2657	2792	2787	2815	2862	2915	2796	2817	0	3	2	0	0	1	1	302	0%
21	33	196	**163**	120	120	**0**	163	87	76	53%	47%	87	0	76	0	2657	2792	2787	2815	2862	2915	2796	2817	0	8	7	0	0	1	0	807	0%
22	2	57	**55**	20	20	**0**	55	18	37	33%	67%	18	0	37	0	2657	2792	2787	2815	2862	2915	2796	2817	0	3	4	0	0	1	0	304	0%
23	435	493	**59**	519	180	**338**	397	84	313	21%	79%	12	72	46	267	2657	2792	2787	2815	2862	2915	2796	2817	0	8	6	0	0	1	1	806	0%
24	244	362	**118**	350	269	**82**	199	106	93	53%	47%	63	43	55	38	2657	2792	2787	2815	2862	2915	2796	2817	0	8	4	0	0	1	1	804	0%
25	118	205	**87**	205	158	**47**	134	87	48	65%	35%	56	30	31	17	2657	2792	2787	2815	2862	2915	2796	2817	0	4	2	0	0	1	1	402	0%

Order	Gain in utilities for teams as a percentage of their expected performance 1	2	3	4	5	6	7	8
0	0%	0%	0%	0%	0%	0%	0%	0%
1	0%	0%	0%	0%	0%	0%	0%	0%
2	0%	0%	0%	0%	0%	0%	0%	0%
3	0%	0%	0%	0%	0%	0%	0%	0%
4	0%	0%	0%	0%	0%	0%	0%	0%
5	0%	0%	0%	0%	0%	0%	0%	0%
6	0%	0%	0%	0%	0%	0%	0%	0%
7	0%	0%	0%	0%	0%	0%	0%	0%
8	0%	0%	0%	0%	0%	0%	0%	0%
9	0%	0%	0%	0%	0%	0%	0%	0%
10	0%	0%	0%	0%	0%	0%	0%	0%
11	0%	0%	0%	0%	0%	0%	0%	0%
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21	0%	0%	0%	0%	0%	0%	0%	0%
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SIMULATION IN BUSINESS AND ECONOMICS

MODELLING AND SIMULATION OF ENTERPRISE BUSINESS PROCESSES FOR CONTINUOUS IMPROVEMENT USING PETRI NETS

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Abstract: The paper presents the modelling of interlinked business processes using Petri Nets and a case study in the light metal industry. We believe that the integration of business processes has been raised to an important problem for development of quality management systems following the process approach to management, which aims to enhance the performance of an organisation. The utilisation of Petri Nets allows the creation of models for the different processes, in different levels, which can be combined in order test, through step by step simulation. Through global simulation, the coherence of the model may be evaluated, as well as the processes' performance.

Keywords

Generalised Stochastic Petri-Nets, Quality Systems, Enterprise modelling.

1. Introduction

1.1. Initial conditions and problems

The markets' requirements for sophisticated high quality products in small amounts and quick response to the demand necessitate production and support processes with tight control limits and high flexibility (Womack and Jones, 1996). Quality management techniques are used to ensure that the products conform to the customer's requirements and further to guide the organisations to performance improvement. For the Quality Systems, ISO's management system standards provide the companies with a model to follow in setting up and operating the quality management system (International Standard Organisation, 2000a). The company's procedures have to be documented which means established, written down, implemented and maintained. Common practice is the representation of the procedures by using flow-charts.

According to ISO's standards, quality management systems should be considered as means for continual improvement of processes that contribute to the satisfaction of an organisation's customers and other interested parties (International Standard Organisation, 2000b). Measurements for the efficiency of processes include throughput, people utilisation, equipment utilisation and cost reduction.

The process approach to management necessitates the systematic identification and management of the various processes employed within an organisation and particularly the interactions between such processes. The set of measurements which should be thus established should not encourage actions that optimise local performance, as the result achieved by a single individual or function is really valuable only at the proportion of affecting the overall result (Lepore and Cohen, 1999).

1.2 Objectives and methodology

Objective of this study is to develop a suitable *business model* for the functional view of the company, in order to assess the existing customer order process as included in the ISO9001 manuals against specific measures, support the re-design and facilitate the integration with the rest of the quality system's procedures.

In addition, the output of the customer order process under consideration will be, directly, the input of the production order process and further the production and delivery of the products.

Since the described business process is mainly an *event-driven* decision-making process, the emphasis is given to the functional view. The quality management system has initially be modelled using Flow-Charts. which are then transformed to Generalised Stochastic Petri Nets (GSPN). GSPN have the ability to model concurrent events and represent systems at various levels of abstraction which make them especially valuable for representing the company's procedures as well as the physical detailed operation of the production system (Leopoulos, 2003, Proth et al, 1993).

Generalised Stochastic Petri Nets (GSPN) contain both immediate and stochastic transitions. They can model activities that occur almost instantly, along with processes that take a longer and random amount of time (Desrochers and Al-Jaar, 1995, Torster Licht et al, 2004). The latter is useful for modelling arrivals of customer orders. They are also appropriate to model activities with non deterministic duration (Tatsiopoulos et al., 1999).

This procedure leads to an accurate model of the customer order process, which can be furthermore used to perform qualitative or quantitative analysis by simulation in order to

increase confidence. Qualitative analysis checks the absence of deadlocks or overflows, the presence of certain mutual exclusions in the use of shared resources, etc. Quantitative analysis looks for performance, responsiveness and utilisation properties along with a better understanding of the variation of the process. Simulation supports the assessment of the process, the identification of the bottlenecks and the evaluation of corrective and preventive actions (Tudor Niculiu et al, 2004).
In addition, taking into consideration the linked processes, an evaluation of the due dates promised is possible. As a result, the sales department gains a tool that may enhance confidence in the due dates promises and thus, avoid customer's complaints.

1.3. Structure

The paper is organised as follows: In Section 2, the case study is presented with a brief presentation of the company under consideration. In Section 3, the model is presented at the higher level. Furthermore, one module from each process is further detailed modelled as a Petri-Net using the ARTIFEX tool (ARTIFEX-FABER, 2004). Section 4 is consisted of the research results. In Section 5, the conclusions are presented and opportunities are identified for further research in this area.

2. The case study

The company under consideration has been in the aluminium business since 1965 with the first production line for collapsible tubes. In the years that followed the company developed the manufacturing capabilities by successively installing production lines for aerosol cans and monoblock bottles. Close to the city of Athens, the company operates a full and completely specialised unit that covers the needs of the Greek market as the principal target and also exports to neighbouring countries.

Table 1: Operations and Equipment

Operation	Equipment
Extrusion	Press
Cut	Burr remover
Annealing	Annealing furnace
Internal lacquering	Sprimag
Polymerisation	Polymerisation furnace
Buffer	Moving shafts
Printing	Printing drum
Color heating	Printing furnace
Buffer	Moving shafts
Stoppering	Cap screw machine
Rubber jointing	Rubber jointing machine
Handling	Conveyor
Quality control	Optic
Packaging	Packaging machine

The Greek market of collapsible tubes remains under the control of the big multi-national companies of the cosmetics and pharmaceutics sectors. The supplier's flexibility is an important incentive for the customers, as it makes possible for them to avoid the maintenance of high-level inventories, in a market characterised by instability.

The plant operates a slugs operation and lubrication unit, a collapsible tubes production section, a monoblock aerosol cans production section, a monoblock bottle production section and a quality control laboratory.
The production line of the collapsible tubes section, the operations and the equipment used, is presented in **Table 1**.

3. Development of the enterprise models

3.1 Customer order

In order to evaluate the efficiency of customer order processing, the production and the delivery to the customer process of the Company under investigation, a Petri - Nets model was set up. These processes were selected as their efficient management is one of the basic requirements of the ISO 9001:2000 standard. Customer order processing, production and delivery are serial processes which are initiated by an order coming from the customer as it can be seen in **Figure 1**.

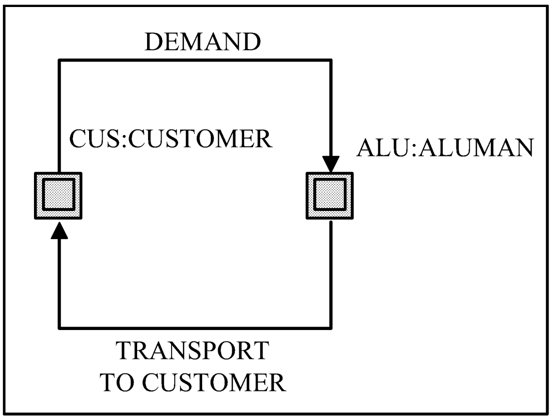

Figure 1: Customer order

3.2 Resources management

Table 2: Roles involved in processes under examination

Model codification of resources	Job Description
M_COMER	Commercial Manager
S_COMER	Commercial Staff
M_PROD	Production Manager
S_PROD	Production Staff
R_PRINT	Printing Responsible
R_CLICHE	Cliché Responsible
R_PRESS	Responsible of press machine
R_INT_DYE	Responsible for internal dyeing
M_STUDY	Engineering Studies Manager
M_QUAL	Quality Manager
S_QUAL	Quality Staff
WARE_KEEP	Warehouse Keeper
Note: Staff refers to ONE individual in this article.	

Since the order has been placed on behalf of the customer, there are several people involved in the processes under examination, that can be seen in **Table 2**.

The human resources that have been used in the model (**Table 2**) are those specifically stated by the ISO standard that is maintained by the Company. Each one of these resources is "committed" by any process that uses it. After the work that each resource has to execute is over, the resource is released from this process in order to be available for another process of the system.
The utilisation of the aforementioned human resources can be seen in **Figure 2**.

3.3 Handling of customer order and production

Having received a request for products from the customer, the Commercial Staff (S_COMER) may start the process named Demand Placement (DEM_PLACE - refer to **Table 3** for abbreviations). The main goal is to distinguish between spot or blanket orders as well as the product type requested.
The specific demand of the customer is forwarded by the Commercial Staff successively to the Cliché Responsible (R_CLICHE), the Quality Manager (M_QUAL) and the Commercial Manager (M_COMER) in order them to make any remarks that should be discussed with the customer (REPLY_DEM). When everything has been clarified, the demand is accepted and a contract is signed.
Since the contract has been signed, the order is placed (ORDER_PLACE) and the Commercial Staff informs the Production Staff (S_PROD). The production Staff examines and finally accepts the order.
The next step of the procedure is the process of scheduling the production of the customer order (ORD_SCH). Each specific order is followed up by the Production Staff who classifies the order according to product type and technical characteristics. The Production Manager (M_PROD) defines the production planning, after determining the duration for the production of each order, and notifies the Commercial Staff. The Commercial Staff after working out the information gathered from the production department suggests the possible shipping day to the Commercial Manager.
Having set the production plan, a production order is issued (PROD_ORD) by the Production Staff and it is distributed to the Commercial Manager, the Responsible for internal dyeing, the Production Manager, the Responsible for the press machine, the printing Responsible, the Quality Manager the Warehouse Keeper and the Quality Staff. These human resources are "committed" by the process in order to comment the production order and right afterwards they are released.
The pure production phase (PLINE7) has been modelled through the use of an Erlang distribution with mean production time and standard deviation that are calculated in relation to the size (quantity) of the order.
After the production order has been issued, the Production Manager and the Commercial Manager are informed for the evolution of the production process (ORDER_TRACK) by the daily-issued production report sheet.
The two remaining processes concern the Shipping scheduling and the checking and shipping the order to the customer. The Shipping scheduling is taken care by the Warehouse Keeper, while the Commercial Staff calculates the delivery time and provides any other information required to the Warehouse Keeper in order the last mentioned person to be able to schedule the shipment.
Before shipping (CHECK_SHIP), the orders are separated to those referring to local clients and clients based abroad. The accounting department is informed, as well as the Production Staff and the Warehouse Keeper. If everything is in place the transportation Company is asked to make the delivery to the customer.
The succession of the processes described above is visualised in **Figure 3**. Each one of the processes depicted in **Figure 3** is thoroughly described through analytical modelling (page) such as the one offered in **Figure 4.** The process described in **Figure 4** is the "Reply to specific Demand (REPLY_DEM)". The model describes the process starting from the Demand Placement and ending up to the Order Placement. **Figure 4** shows how the human resources involved are "committed" and released by the process, as well as the intermediate steps before the contract is finally signed, such as the interaction with the customer, when issues that need to be clarified are spotted.
After the modelling of each process, the Petri – Net model was ready to start the simulation.

Table 3: Model processes abbreviations

Model codification of processes	Process Description
DEM_PLACE	Demand placement
REPLY_DEM	Reply to the specific demand
ORDER_PLACE	Order placement
ORD_SCH	Preparation of order scheduling
PROD_ORD	Production order issuing
PLINE7	Production line 7
ORDER_TRACK	Order tracking
SHIP_SCHED	Shipping scheduling
CHECK_SHIP	Checking and shiping

4. Results

The simulation achieved two main goals. First of all, through step by step simulation, inconsistencies between the physical system and its description through the model have been spotted. There are quite many instances where the flowcharts, or other modelling techniques used, fail to describe the physical system accurately, although they seem to do so. Inconsistencies among interlinked processes are very well hidden and only a model capable of performing simulation can reveal them. Indeed, more than 10 "dead end" places where identified and the model was restructured in order to achieve coherence. The results have been included in the quality system's documentation.
Second goal, through global simulation, process was to evaluate the efficiency of customer order process and further the production and the delivery to the customers of the Company under investigation. Finally, global simulation revealed the ability of the Company to satisfy certain demands in time.
Global simulation revealed nineteen problems, concerning mainly delays occurred due to unavailability of certain human resources. These delays are presented in **Table 4**.

Table 4: Delays due to lack of human resources

Process place	Problem	Reason

	description	
Warehouse	Great delay	M_PROD not available
Production Manager Action	Short delay	M_PROD not available
Production Manager Briefing	Short delay	M_PROD not available
Commercial Manager Action	Short delay	M_COMER not available
Commercial Department 71	Delay	M_COMER not available
Production Planning Office	Delay	M_PROD not available
Production Planning	Delay	S_COMER not available
Production Completion	Delay	S_PROD not available
Shipment Scheduling	Delay	WARE_KEEP
Place Demand	Delay	S_COMER

An interesting result stemming from the simulation is that the delays are not due to equipment capacity constrains but due to human resources unavailability. The Commercial Manager, the Production Manager, the Commercial Staff, the Production Staff and the Warehouse Keeper seem to be unable to respond to their workload. The average rate of orders that can be handled by the Company has been estimated at one order per day. However, the Company may have the ability to improve its "order handling capacity" by increasing the availability of human resources that seem overloaded, by (for instance) hiring more people, or cross train and empower other people to fulfil the same roles. This would be a step forward towards the continues improvement process described by the ISO 9001:2000 standard, as well as the improvement of the satisfaction of the customer (shortening of delivery time).
Moreover, the approach proposed in this paper would offer a tangible tool to measure the efficiency of any action taken to improve the operation of the Company. By doing so (measuring the effectiveness), the Company is aligned to the ISO standard request for measuring processes' improvement.

5. Conclusions and further research

We consider Petri Nets as a tool able to support not only the representation of activities, but also the evaluation of the behaviour of the customer order process, starting from the model, presenting thus clear advantages against other modelling methods like Flow Charts.
The above properties make Petri Nets suitable for modelling procedures to be included in quality management systems aiming continual improvement. The models thus created can be tested against measures for efficiency.
Further research objectives are to create generic modules modelling the basic functions included in the main processes (production order process and customer order process) which could be combined and customised for every particular case.

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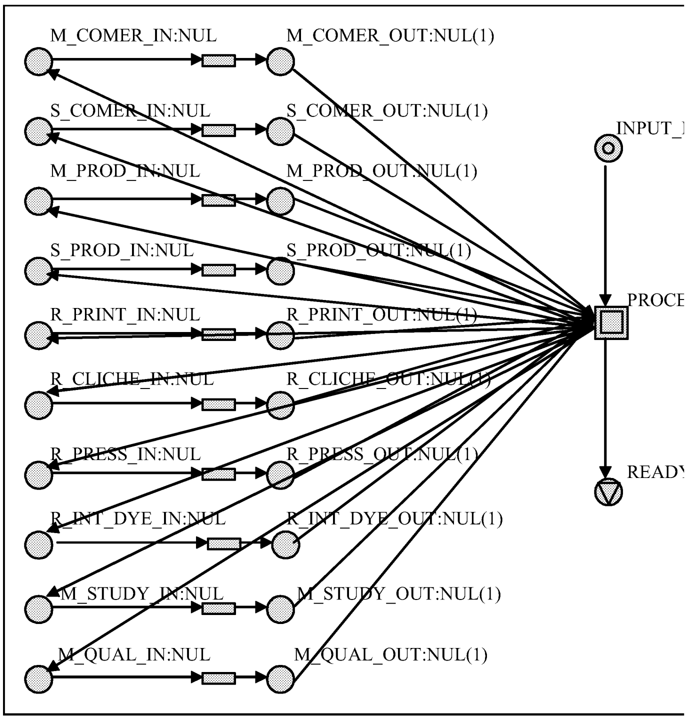

Figure 2: Human Resource Utilisation

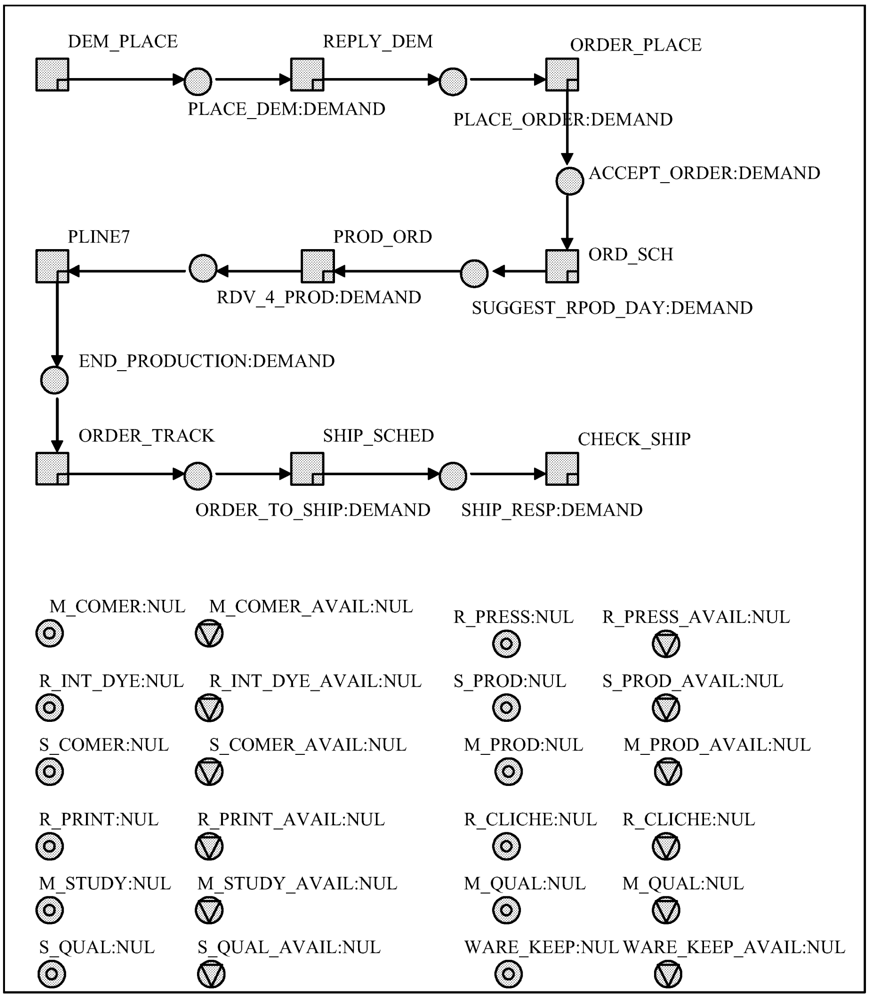

Figure 3: High level modelling of the processes under investigation

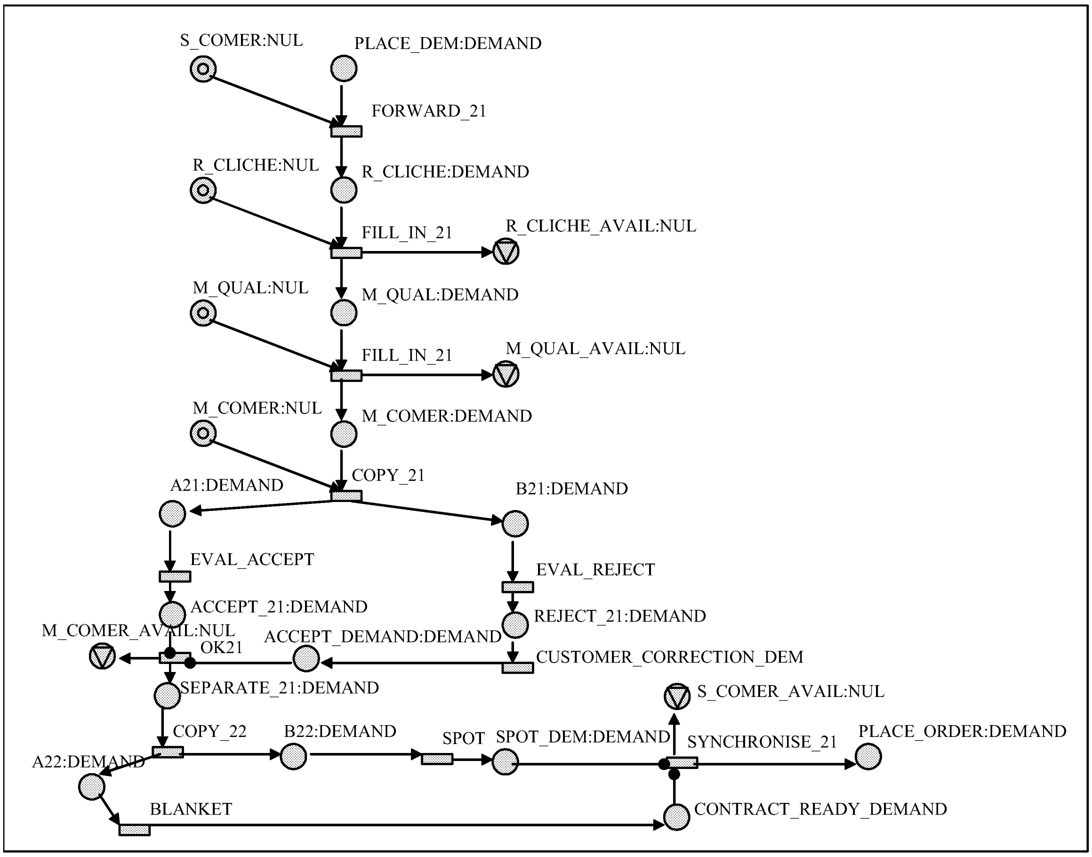

Figure 4: Analytical modelling of process “Reply to the specific demand”

CONCEPTUAL ANALYSIS FOR ROLES CONSTRUCTION

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KEYWORDS
business process, business process modeling, organize structure, formal concept analysis, cluster analysis,

ABSTRACT

The organizational structure of roles participating in business process is usually defined using the best experience. There is a minimum of neither formal nor semiformal approach involved. This paper shows the possibilities of the theory of formal concept analysis that can help to construct and to understand organizational structure of roles based on solid defined mathematical foundations. Categories of knowledge required for business process execution are main aspect.

INTRODUCTION

Business processes represent the core of the company behavior. There are many possibilities how these processes can be defined. Most of the modeling tools are focused on: *structural view*, *behavioral view* a *functional view*. Formal or semiformal specification of process is usually based on some kind of languages like UML. More sophisticated approach like Petri Nets is often used as well. Unfortunately, none of these views and modeling tools captures organization structure of roles implemented by human resources participating in processes being modeled. *Roles* define *behavior*, *competency* and *responsibility* of individual persons or groups of persons.
In previous research (Vondrak 2003) and (Kozusznik 2004) we showed how the theory of concepts might remove the gap between process models and organizational structure. This approach depends on definition of roles and their assignment to specific activities. Roles definition is ad-hoc and this is the main disadvantage. In this chapter we show how to use formal Concept Analysis to automatic or semi-automatic construction of roles from business process specification.

MOTIVATING EXAMPLE

Let's start with a small and clearly understandable example to demonstrate how the business process definition serves as a source of roles definition.
Example describes claim handling process. Some fictive insurance company C *process claims* that result from traffic accidents where customers of C are involved in.

The process starts with customer's report of a claim. Every claim is registered and after registration it is classified. There are two categories: simple and complex claims. For the simple claims two tasks need to be executed: check insurance and phone garage. These two tasks are not related to each other. The complex claims require three tasks to be executed: check insurance, check damage history and phone garage. These tasks need to be executed sequentially in the specified order. After the execution of the described tasks a decision is made. The decision is made based on the result of previous tasks and has two possible outcomes: OK (positive) or NOK (negative). If the decision is positive, then the insurance company will pay the claim. This invokes the payment task. The insurance company always sends a letter to the customer who sent the claim. Activity diagram of this process is in Figure 1.

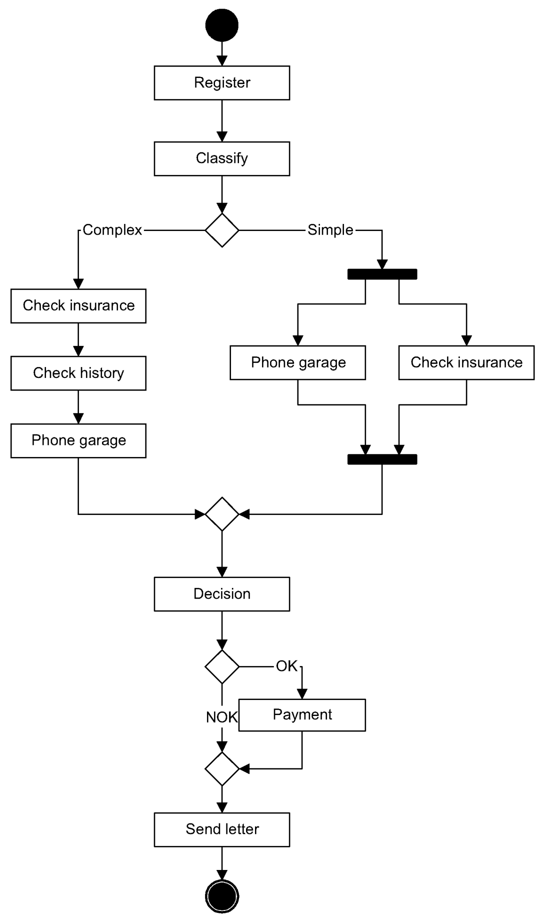

Figure 1: Claim handling process

Obviously next step is role assignment to activities defined in business process. On the other hand we may only define requirements of capability for certain activity performing. We can say that main role capabilities are knowledge and we define some categories of knowledge required for defined business process and particular activities.
For claim handling company we define these knowledge domains:

- *Administrative* – ordinary administrative ability as type writing, business correspondence etc.
- *Insurance* – special knowledge from domain of insurance
- *Financial* – knowledge of accounting
- *Management* – knowledge of management
- *Communication* – communication ability with customers, employees etc.

Following table describes the knowledge requirements for activities from our example:

	Admin.	Insur.	Finan.	Manag.	Comm.
Register	X	X			
Classify		X			
Check insurance	X	X			
Check history	X	X			
Phone garage	X	X			X
Decision		X		X	
Payment	X		X		
Send letter	X				

FORMAL CONCEPT ANALYSIS

Concept analysis theory can be used for grouping of objects that have common attributes (Ganter 1999). Concept analysis begins with a binary relation, or Boolean table, T between a set of objects O and set of attributes A. It means that $T \subseteq \mathbf{O} \times \mathbf{A}$. For any set of objects $O \subseteq \mathbf{O}$, their set of common attributes is defined as

$$\sigma(O) = \{a \in \mathbf{A} \mid \forall o \in O : (o,a) \in T\}. \quad (1)$$

For any set of attributes $A \subseteq \mathbf{A}$, their set of common objects is

$$\tau(A) = \{o \in \mathbf{O} \mid \forall a \in A : (o,a) \in T\}. \quad (2)$$

A pair (O, A) is called a concept if

$$A = \sigma(O) \wedge O = \tau(A). \quad (3)$$

The very important property is that all concepts of a given table form a partial order via

$$(O_1, A_1) \leq (O_2, A_2) \underset{def}{\Leftrightarrow} O_1 \subseteq O_2. \quad (4)$$

It was proven that such set of concepts constitutes a complete lattice called concept lattice $L(T)$. For two elements (O_1, A_1) and (O_2, A_2) in the concept lattice, their meet $(O_1, A_1) \wedge (O_2, A_2)$ is defined as

$$(O_1 \cap O_2, \sigma(O_1 \cap O_2)) \quad (5)$$

and their join $(O_1, A_1) \vee (O_2, A_2)$ as

$$(\tau(A_1 \cap A_2), A_1 \cap A_2). \quad (6)$$

A concept $c = (O, A)$ has extent $e(c) = O$ and intent $i(c) = A$. More about concept analysis can be found in (Ganter 1999), (Snelting 1997) and (Wille 1982).
Concept lattice can be depicted by the usual as a lattice diagram. It would however be too messy to label each concept by its extent and its intent. A much simpler *reduced labeling* is achieved if each object and each attribute is entered only once in the diagram. The name of object O is attached to the lower half of the corresponding object concept

$$c = (\tau(\sigma(O)), \sigma(O)) ,. \quad (7)$$

while the name of attribute A is located at the upper half of the attribute concept

$$c = (\tau(A), \sigma(\tau((A))) .. \quad (8)$$

ORGANIZATIONAL STRUCTURE MODELING

The table of knowledge requirements specified in the previous chapter corresponds with Boolean tables described in concept analysis. Objects of the relation are substituted by activities and attributes of objects are substituted by knowledge category that the activities require.

The set of concepts that can be derived consists of:

C_0= ({Send.,Clas.,Ch.I.,Ch.H.,Reg.,Pay.,Ph.G.,Dec.}, {})
C_I= ({Clas.,Ch.I.,Ch.H.,Reg.,Ph.G.,Dec.}, {Ins.})
C_A= ({Send.,Ch.I.,Ch.H.,Reg.,Pay.,Ph.G.}, {Adm.})
C_{AI}= ({Ch.I.,Ch.H.,Reg.,Ph.G.}, {Ins.,Adm.})
C_{AF}= ({Pay.}, {Adm,Fin.})
C_{IM}= ({Dec.}, {Man., Ins.})
C_{AIC}= ({Ph.G.}, {Ins.,Adm.,Comm.})
C_{AICFM}= ({}, {Ins.,Adm.,Comm.,Fin,Man.})

Concept lattice can be constructed from the set of described concepts using following rules defining a structure of the graph:

- Graph nodes represent concepts and arcs their ordering.
- The top-most node is a concept with the biggest number of roles in its extent (C_{AICFM} in our case).
- Concept node is labeled with an activity if it is the largest concept with this activity in its intent.
- Concept node is labeled with role if it is the smallest concept with this role in its extent (reduced labeling).

Resulting graph in Figure 2 provides alternate views on the information contained in the above-described table. In other words, the concept lattice enables to visualize the structure "hidden" in the binary relation.

Every concept denotes minimal set of knowledge categories required for some activities performing. Given activity is in label of concept and set of required knowledge categories is specified by intent of concept. Concept C_{AF} express that activity *payment* requires knowledge of *administrative* and *financial* domain.

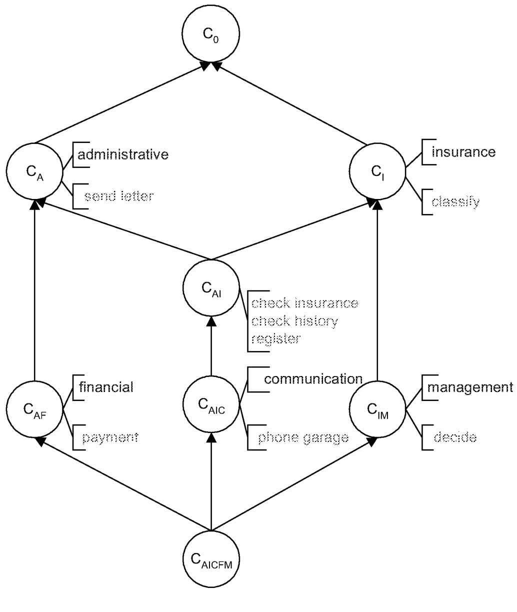

Figure 2: Result concept lattice

We can say that every concept express some role in business process in this approach. These concepts define set of required knowledge categories and set of activities that can be performed by appropriate role. There is defined some kind of inheritance between these roles. Child inherits required categories of knowledge and activities from its parents. Of course concepts like C_{AICFM} and C_0 we removed from our investigation. Concept C_{AICFM} shows role with all category of knowledge and this role can perform every activity. On the other hand C_0 doesn't contain any knowledge and cannot perform any activity. Roles C_A, C_I and C_{AI} are not necessary required because roles C_{AF}, C_{AIC} and C_{IM} can perform their activities instead. On the other hand role C_{AF} is more expensive than C_A. For decision if define roles like C_A and C_I or not we need some measure between concepts to evaluate their cost.

Such definition of roles is useful for mapping human resources to roles. If we know knowledge of concrete human and required knowledge for activities then we simply find what activities can given human perform. The question is how to provide this mapping effectively. Person with large set of knowledge can perform more activities but it is cheaper employ for it human with smaller knowledge.

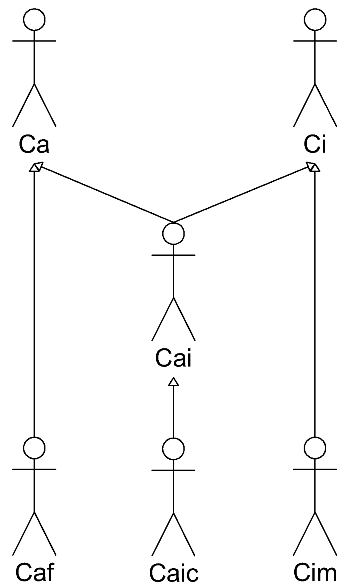

Figure 3: Hierarchy of roles

There is hierarchy of roles for our example in the Figure 3. This figure represents USE CASE diagram from UML. In this type of diagram the functionality of a system is described. There are two types of entities: *actors* and *use cases*. *Actors* describe who stands out of the system. *Use cases* represent functionality provided by system. We use this type of diagram only for describing hierarchy of roles. We omitted use cases because there is no direct mapping between them and identified activities. But we would like to do it in our future research.. Concept analysis should be able to serve as a source of UML USE CASE diagram together with the business process specification modeled using UML ATIVITY DIAGRAM.

CONCLUSION

The method of concept analysis provides exact and formally well defined way how the organizational structure can be analyzed and re-designed. The examples used in our paper were simplified but they demonstrated sufficiently the potential of concept lattices and the way that this theory can be adopted for purposes of organizational structure analysis. The problem is how to identify organizational structure itself. For that purpose the use of hierarchical aggregation seems to be a better tool because as well as the organizational structures they both employ hierarchy as the main abstraction. On the other hand the theory of concept shows better why the roles are grouped together and thus it serves as a better tool for understanding how the knowledge is shared among roles. We consider both approaches as complementary to each other and the future research is going to be focused on how they can be integrated together

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SIMULATION IN OR AND KNOWLEDGE MANAGEMENT

CROSS-CULTURAL KNOWLEDGE TRANSFER USING DYNAMIC MODELS

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KEYWORDS
Knowledge transfer, health care, dynamic models, process models

ABSTRACT

Discrete-event simulation has become an accepted tool for enabling flows of production-related knowledge associated with technology transfer across borders. Multinational enterprises based in Europe and the US often use models to convey detailed process information between engineers and plant managers who are geographically separated.

In 2003, a medical consulting organization specializing in health care improvement approached the author to determine whether dynamic models could represent processes and concepts in ways that might improve interaction with medical administrators from developing nations whose education and focus was not necessarily on process issues. Specifically, they asked if simulation could support the introduction of Western health care approaches to hospital managers in China.

As expected, dynamic models played a facilitating role in enhancing the communication of process information and new concepts. Their utility went further, however, in that the models stimulated increased participation by the nursing staff and gave them more involvement in decisions on process-related issues. Sensitive probing by the consultants allowed them to use simulations to extract background information about local practices, so that proposed approaches might be tailored to local conditions.

INTRODUCTION

A fundamental factor driving the globalization of business has been the flow of knowledge across borders. Ideas, concepts and information developed in one location may now be available almost instantaneously throughout much of the world. Although commercial organizations attempt to protect those proprietary insights that provide them with competitive advantage, their efforts to employ this knowledge in creating new markets or sourcing inputs based on lower factor costs has, if anything, accelerated the uptake of technical and process knowledge. The term "technology transfer" has acquired a broad meaning, encompassing not only exports of machinery and licensing of intellectual property, but also the conveyance of process knowledge, specifications and management approaches. Attempting to understand and facilitate these knowledge flows is a key topic in much of the current literature on international business (Foss and Pedersen 2004).

Discrete-event modeling has an established history in facilitating the conveyance of technical knowledge between engineers in different locations. Some global companies routinely send models of production operations between dispersed facilities to evaluate new process technologies or sustain a dialogue on continuous improvement. This paper describes an exploratory project in which dynamic process models were evaluated for their ability to facilitate the transfer of process-related information to individuals whose education and backgrounds lie in other disciplines, and whose cultural framework is quite different from that in which the knowledge originated. Although process simulations are generally associated with quantitative analysis, preliminary results from a project in China demonstrate that they may support other aspects of knowledge transfer that are also essential to a project's ultimate success.

THE SETTING

A health care consulting organization closely associated with a well-known US medical school was approached by a group of Chinese investors preparing to construct a private hospital near Shanghai. The mission of the new facility would be to provide a high level of care for individuals able and willing to pay for better medical services than are typically available in state-run facilities. However, the new hospital was also viewed favorably by local government officials who saw it as a potential prototype and source of ideas for existing public facilities scheduled for future privatization.

Chinese authorities recognize the need to improve the delivery of medical care, but also understand that upgrading urban hospitals to world standards will require more resources than the State can reasonably supply. The government has decided to open the health care sector to private medical providers in an effort to attract investment, just as China has done so successfully in manufacturing industries. In addition to serving as a source of new ideas for public facilities, competition from private hospitals is expected to lead to improved quality of services and lower costs throughout the health care system.

In the Shanghai project, the initial focus of medical professionals was on determining which types of treatment would be offered. Development of a facility layout that would accommodate many different types of procedures and at the same time offer adequate staff spaces was considered a high priority. The architect coordinating the consulting effort recognized, however, that patient perceptions of care quality would depend on the performance of processes through which that care would be provided. Research in the US, for example, suggests that patients frequently perceive an inverse relationship between time spent waiting and quality of care (Purnell 1991). Attracting a paying clientele to a day clinic in China would require processes substantially different from those which offered public hospital patients no more than three minutes with the doctor after a four- to six-hour wait. The consultants and leaders of the hospital staff agreed that introduction of new processes was essential to future success of the new facility.

After considering both the capabilities and limitations of discrete-event models, the consulting team agreed that simulation could potentially support the project in five key respects. First, by representing processes visually it might overcome language barriers and incongruent perceptions arising from differences in personal and cultural experience. In effect, dynamic models would present new processes using a medium that would make them more easily understandable. Second, simulations might allow the consultants to operationalize abstract concepts in ways that would allow Chinese counterparts to actually see their embodiment and impact in practice. Third, the experience of health care professionals in other project settings suggested that using models to discuss processes might encourage more input from groups or individuals who were otherwise less likely to participate in group discussions. An outgrowth of this participation could then lead to broader input in decision making, a fourth desirable outcome. Finally, the models were expected to provide a common referential frame against which local medical professionals could contrast and explain existing practices for their foreign expert guests.

PROCESS UNDERSTANDING

Some medical anthropologists have been critical of the introduction of Western medicine in China, but modern diagnostic and treatment techniques are already established and quite popular. Traditional oriental medicine is still widely practiced, however. Decisions on treatments to be made available in the new facility were generally taken as given; the models focused primarily on the delivery processes.

Three departments in the new hospital were identified as highly sensitive to process design: a multi-specialty clinic, the radiology department and a surgical center. Six other units required fewer changes and offered a basis for comparison with the three situations in which models were employed. In each of these latter cases, two models were created as overlays on architectural drawings of the proposed new facility. The first model of each pair was a "walk-through" in which the group followed an individual patient through a typical visit. Where a single facility embodied several processes for different patient types, a representative patient was shown for each. For example, the surgical center was designed to handle minor treatments, endoscopies, a range of surgeries and invasive cardiology ("cath lab") procedures. As the patient icon moved through each process, text boxes would describe the next step, as shown in Figure 1.

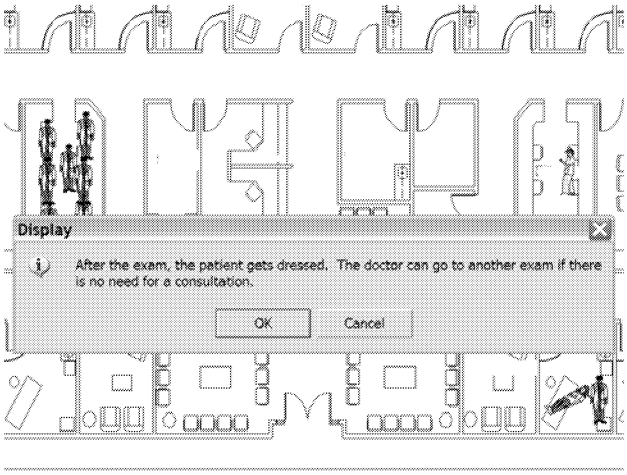

Figure 1. A Process Step in the Clinic

The second model in each pair was intended to represent a "typical day" with the facility at or near full utilization. These visualizations served to give administrators and nursing managers an overview of the activities of the staff and a sense of the resources that would be required to support a given patient census.

Although the models used representative task times provided by the consultants, the emphasis was on visualization and understanding rather than quantitative analysis. Activity durations were based on estimates of minimum, most likely and maximum times incorporated in triangular distributions. When numerical outcomes were shown to the Chinese clients, the presenter was careful to emphasize that they were representative only. For example, the radiology model showed the revenue generated for each of the different classes of studies performed (e.g. fluoroscopy, ultrasound, etc.). However, the presenter emphasized that the numbers were very general and showed only relative levels of revenue based on averages for each class. Insufficient data were available to project results based on types of imaging studies within each class.

An important exception to the team's decision to avoid quantitative analysis was comparison of the performance of existing processes in the clinic with the new patterns proposed by the consultants. Hospital administrators were particularly anxious to see whether the facility would be able to handle high patient volumes while also giving patients more meaningful time with the doctors. The response to this concern was in the form of a merged model that showed prior practice and the expert proposal running on the same screen, as in Figure 2. This comparison showed that with additional nursing support and the implementation of concepts explained in the following section, the physicians could spend more productive time with each individual and see more patients each day.

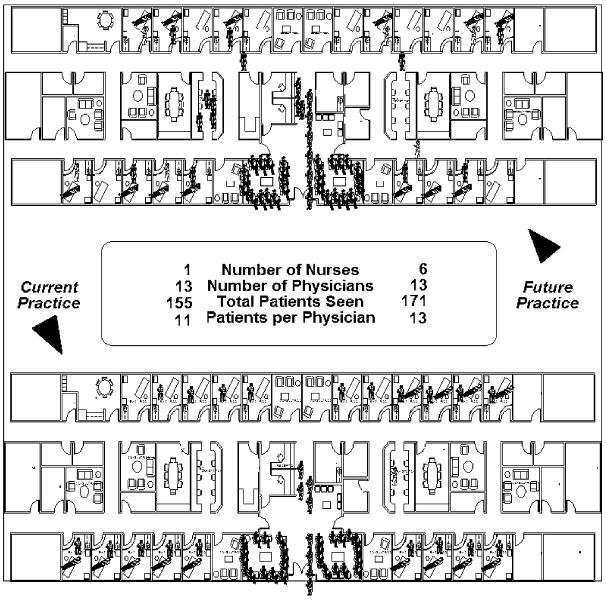

Figure 2. Comparison of Clinic Process Performance

The consultants usually explained new processes before presenting the simulations. Questions and comments were frequent during model discussions and demonstrated that participants were able to use the animation to understand what they had been told previously through a translator. Physicians, administrators, nurses and support personnel were able to point out process elements that were different from established patterns and occasionally compared them to similar processes elsewhere. Some individuals were even able to identify relatively minor discrepancies between the models and the recommendations of the consultants. The ability of these models to facilitate understanding had been almost assumed, but no one anticipated the degree to which they stimulated dialogue.

CONCEPTUAL KNOWLEDGE

The consultants planned to recommend several new concepts in each of the departments. They recognized that abstract ideas would be difficult to explain and were concerned with their ability to ensure that the Chinese participants truly understood each new approach.

Dynamic models were used to operationalize the concepts visually. For example, the clinic simulation demonstrated new patterns of staff use, based on the expectation that nurses would receive additional training to allow them to assume the taking of patient histories and vital signs. This shift would make it possible for physicians to spend more examination time with individual patients and give them a better opportunity to explain their diagnosis and plans for treatment. Another proposed change would have physicians move from room to room, while the nursing staff was at the same time preparing a subsequent patient in a nearby office.

The consultants were quite pleased when one of the participants asked to see utilization statistics for the physicians. This question led to a discussion in which the clinic staff explained that patients did not have scheduled appointments. Most usually arrived shortly before or after lunch. The door to the clinic was locked in the mid-afternoon and the staff would then hurry to see all remaining patients before the scheduled closing time. This pattern led to low utilization of doctors in the morning and very limited time for each patient later in the day. The consultants explained that a scheduling system would help to improve use of the doctors and reduce patient waiting times. Introduction of scheduled appointments would require careful attention to patient education, however.

Efficient use of machinery was an important concept in the radiology department. State-of-the-art imaging equipment is as expensive in China as it is in Europe or the US, but government reimbursements are relatively low and the ability of patients to pay is limited. The radiology model emphasized techniques to recover the cost of these machines by maximizing the number of studies performed each day. Patients were staged in a waiting and changing area, so that they would be immediately ready upon completion of the preceding study or procedure.

Although visual representations served to reinforce verbal explanations of concepts, in the case of the surgical center they clearly led to new understanding. The consultant team explained twice the use of case carts to deliver sterile surgical instruments in the appropriate sequence for each scheduled procedure, but not until the model showed this system in practice did the nursing staff realize that it would significantly change their role. Figure 3 shows these devices staged outside of the surgical suites.

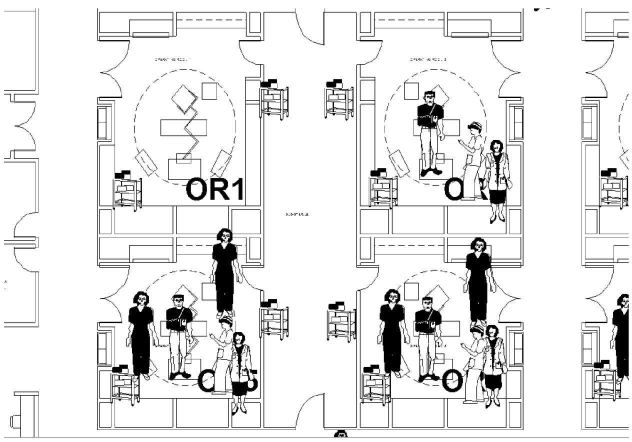

Figure 3. Staging of Surgical Case Carts

The use of a single area for both pre-operative preparation and post-operative care had a similar, though less dramatic, impact. Nurses were able to see that its use would transition over the course of the day from primarily pre-operative use to post-anesthesia recovery. No objections were raised, although the chief surgical nurse expressed concern with her ability to oversee all of the activity in what would be a large surgical center. Consultants indicated later that even they had not fully comprehended the level of activity in some of the new departments.

PARTICIPATION

In the departmental review sessions, most interaction was between physicians and the foreign consultants. Doctors asked questions about treatments and specific types of technologies. They also responded to inquiries from the consultants about the treatments typically available in China. Administrators usually deferred to physicians, but frequently commented on issues related to the quality of care and its indispensability to the financial success of the new hospital. Doctors occasionally directed questions about specific activities to the nursing staff, which often took a process orientation focusing on the movement of patients through the facility and the need for nurses to substitute for busy physicians in providing patient education.

In two of the three sessions, the atmosphere in the room changed as soon as the models were presented. Nurses immediately began talking excitedly amongst themselves. Some, who had only spoken when spoken to, started to point out how the proposed processes would change established practices. Not surprisingly, they were most vocal about shifts in their own roles. Senior nursing administrators pointed out the need for additional training if the nurses would be expected to assume some of the routine duties of the doctors. One was direct in her comments about the need to educate physicians to accept an expanded role for the nurses.

Individuals in supporting assignments also contributed to the discussion. One equipment specialist, who made only one other comment in three days of meetings, literally jumped out of his chair at one point, waving his arms excitedly. Interestingly, local architects and a construction manager, who were not necessarily attuned to patient concerns in other discussions, made comments during the model sessions that indicated a shift in their perceptions to a more patient-oriented viewpoint.

BALANCING PERSPECTIVES

Because implementation of new, patient-focused care processes would depend on the ability and willingness of the nurses to assume new responsibilities, the consultants considered increased participation by the nursing staff to be a very positive outcome of the modeling project. When nurses and nursing managers expressed apprehension about some elements of the proposed processes, other participants were often willing to make concessions to accommodate their concerns. The chief nurse raised, for example, the objection that nurses would need a sterilization area in surgery to deal with dropped instruments or items not included in the case carts. Although space was already limited, all present agreed that this request was reasonable. Nor did physicians object to working with the nursing staff to determine which elements of the traditional doctor's role could be transferred.

The ability of dynamic models to help balance competing interests had some limits, however. When discussion of the expanded nursing role pointed to the need for new hiring and additional staff training, a senior administrator simply took the issue off the table for subsequent decision among the staff, without the foreign consultants present.

LOCAL KNOWLEDGE

A common critique of technology transfer as practiced in industry has been that it displaces established local practices and too seldom adapts to conditions that differ from those where the new approaches originated. This assertion may be particularly relevant in health care, a sector in which local attitudes, culture, tradition and religious beliefs may be important considerations. Fortunately, the architect leading the consultant team was sensitive to cultural nuances and actively sought new insights that would help her team better understand the environment to which the new processes would be introduced.

She encouraged Chinese participants to use the models to describe how their existing practices differed from the Western approaches presented by the consultants. Her gentle questioning and probing continued until the consultants were comfortable that they understood the underlying rationale for traditional patterns of care. Subsequent discussions then sought to address local issues that had not been anticipated in the process proposals, whether by explaining how the new approaches would resolve the concerns or, at minimum, accommodate them.

Among the insights that emerged during presentation of the models were the limited and quite different roles of the nurses compared to counterparts in the US and Europe, the extent to which barriers to access motivated patients to seek a final resolution to their ailment on the first visit, and the number of patients who showed up requesting Western treatments simply because they would "make them feel good."

The consultants tried not to project their own value judgments or priorities on the situation. For example, during the discussions and subsequent facility tours, the team learned that patients had little privacy. Long waiting lines outside of examination rooms and the ability of patients to wander freely throughout the facility prevented physicians from holding private consultations about the needs of individual patients. It was quite common, in fact, for patients to poke their heads in occupied exam rooms to see what was happening or simply to estimate how much longer they would need to wait. The foreign experts were quite prepared to understand this lack of privacy as acceptable in the local culture, but were assured by their Chinese hosts that privacy would be highly valued as their clientele became more discriminating.

Some of the most useful insights were generated during a step-by-step review of each simulation, in a format similar to the structured walk-through that is common practice for model validation in other projects. These presentations gave the consultants an opportunity to explain their assumptions and demonstrate each element of proposed new processes. The Chinese participants were able to interject questions and make comments on the assumptions. A key factor in the consultants' success at learning about the local context was their willingness to interrupt their own presentation to carefully explore each question or comment from the Chinese medical staff.

SUMMARY

None of the project participants had used dynamic models prior to this study, but there was general agreement that they were effective and useful aids for communicating new process patterns and showing the implementation of concepts that would improve the quality of care from a patient perspective. In some cases, the simulations raised new considerations, such as the importance of scheduling for both efficient staff use and minimization of waiting times.

Most surprising for the health care consultants was the extent to which discussion of the models increased participation, particularly among the nursing staff. Physicians were interested and took an active part in these discussions, but nurses essentially took over the meeting as they used the models to point out their concerns and ask questions. One possible explanation for this phenomenon is that the nurses were more inclined than other participants to view the proposals from a process perspective. Another possibility is that their interest was highest because planned changes would have the most significant impact on their role.

Increased participation led in turn to more input in decision making in some circumstances, but it did not necessarily restrict the ability of senior managers to limit the range of discussion through decisions to consider some issues internally without the consultants' involvement.

Finally, the consultants demonstrated that models can be used to extract background information rooted in local practice and values. It should be emphasized, however, that the individual who took the lead in these discussions was very sensitive to cultural cues and actively used the models as tools to facilitate the articulation of local practices.

TRADEOFFS AND LIMITATIONS

Information on existing health care practices in China was quite limited at the start of the project, but useful data and process definitions were incorporated in the models as they became available. Facility and process proposals were necessarily fluid until shortly before each meeting began. Once the consultants were in Shanghai, travel schedules and availability of the translator limited their interaction time with the Chinese participants to three days. When taken together, these factors placed some limitations on the models, which often relied on rough estimates of process times, resource availability and other parameters.

Data requirements also presented challenges in other ways. At one point, the Chinese administrators recognized the potential value in showing revenue projections from the radiology model to potential investors, but the list of detailed data needed for generation of accurate financial forecasts discouraged further interest. Requests for more process data were, on some occasions, an annoyance for the consultants as well. These professionals were more comfortable dealing with issues of treatment, facility design and technology than with activity sequences, time distributions and alternative paths through the system. However, they acknowledged that the need to focus on process helped to improve their recommendations, as when the models highlighted the importance of streamlining patient registration.

Visual animation was essential in helping the Chinese participants understand new processes and concepts. The MedModel® environment in which the models were constructed allowed quick changes to the logic and two-dimensional graphic elements. Some of the participants suggested later that they would have preferred animation in three dimensions, but it is not clear that the additional time required in model construction would have added significantly to their understanding. Although animation in three dimensions was introduced for MedModel after this project was completed, the need to create and change models quickly would likely have prevented its use in Shanghai.

CONCLUDING OBSERVATIONS

The use of dynamic models in health care applications is widely accepted, but the emphasis in most projects is on experimentation and quantitative analysis, as when simulation is used in production industries. A well-constructed model using realistic assumptions can offer a degree of precision that facilitates reasonably accurate predictions of system performance or at least establishes a range of expectations when changes are anticipated. These estimates often play an important role in planning or investment decisions, so they are widely documented.

In contrast, the ability of dynamic models to improve communication between individuals has received less formal study. Although many project participants can probably point to situations in which a simulation led them to some new insight or facilitated understanding between individuals, these events are seldom noted in project reports.

An advantage of health care studies is that they often bring together professionals from a variety of disciplines. As in the case described here, a project may involve doctors, nurses, technicians, administrators, architects and other groups, each with their own goals, viewpoints and distinct ways of understanding a system or process. The opportunity to discuss tangible models may give these different perspectives both a chance to make themselves understood and an opportunity to learn from others.

If dynamic models can facilitate participation, they may begin to see more use in public settings. Other forms of simulation with less process focus are beginning to make inroads in this area. Preliminary work by O'Looney (2001), Waddell (2002) and Burby (2003) suggests that time-phased land use simulations can help members of the public visualize the impact of policy decisions, leading to increased citizen input. Some health care organizations have already used dynamic models to show members of the community how a new clinic will work. Others are beginning to consider the use of models to gather input from potential patients on the types of services offered and the processes through which they are provided.

With changes in participation may also come shifts in authority relationships. Although the nurses in Shanghai were generally quiet—speaking only when asked a question—the ability to comment on the models apparently removed some of their reservations about taking part in discussions that would have an important impact on their roles and responsibilities. Fleßa (1996), using systems dynamic models to support a teaching game for hospital administrators in Tanzania, noted that strictly hierarchical patterns of authority often shifted to a more team-oriented and participatory approach, a pattern clearly evident in this case.

Use of models outside of their traditional role in analytical decision support promises to open new opportunities for communication and involvement by individuals with different perspectives, including those rooted in diverse national or cultural backgrounds. The project in Shanghai was exploratory in nature, so these findings will require verification in other settings and applications. Results from a subsequent project at a medical school in the Philippines were generally consistent with those noted here, with the models facilitating both participation and conflict resolution.

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BIOGRAPHY

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Rob holds B.S. and MBA degrees from Brigham Young University and American University in Washington, D.C., respectively. He recently completed a Ph.D. with an emphasis in Public Administration at the University of Utah. From August, he will be teaching at the American University of Sharjah in the United Arab Emirates, where he can be contacted at rbateman@ausharjah.edu.

PRESTA-COACH IN PERFORMANCE MANAGEMENT AND A BALANCED SCORE CARD SYSTEM PRESTA

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KEYWORDS

Performance Management, CSF, Critical Success Factors, PI, Performance Indicators, BSC, Balanced Score Card

ABSTRACT

A methodology has been developed, that guides the enterprise through the use of 5 basic steps, to guide the company in the implementation of performance management.
An intake contact is the first step, followed by a scan of the company, concerning some aspects on global organizational level and some aspects on operational management level. Afterwards and being in line with the mission, the objectives and the strategies of the company, the CSF's (Critical Success Factors) are identified. The PI's (performance indicators) linked with them, are modeled using PI variables, are measured and compared with their determined norm values. Both, the measurements and the norm values are presented in a BSC (balanced scorecard) report. BSC is an essential instrument in performance management.
Knowing the BSC measurements and the evolution of them, management can focus on critical processes and, and will induce organisational and process changes to create the opportunity of evolving to a successful and competitive company.

1. BUSINESS PERFORMANCE MANAGEMENT

Performance management should be a main concern of every company. Organizations are seeking new, integrated systems that enable rapid changes through early identification of opportunities and problems, tracking of progress against plans, flexible allocation of resources to achieve goals, and consistent operations. Traditional systems, including ERP and business intelligence software, are not sufficient by themselves to meet this demand. Out of these requirements has emerged a new category of enterprise automation technology: Performance Management.
The term Business Performance Management (BPM) is used to represent a new category of systems and processes and it pinpoints the need to integrate strategy and key indicators of performance into management processes, and to exploit technology to improve monitoring, management reporting, and decision making.

Additionally, they all rest on the suppositions that organizations must focus on critical success factors and ensure that the business processes of planning, budgeting, forecasting, and reporting are aligned to achieve strategic goals. This involves integrating all organizational activities "from top to bottom" around their strategy.
The best-known reporting model based on the basic idea of performance management, is the Balanced Scorecard of Kaplan and Norton.
Performance Management is aimed to collect and process on a consistent way the large amount of data of a company into management information.

In line with the mission, the objectives and the strategies of the company, the CSF (Critical Success Factors) can be identified. The linked PI's (performance indicators) are modeled using PI variables and can be measured. Both, the measurements and the norm values are presented in a BSC (balanced scorecard) report. BSC is an essential instrument in performance management.

2. PRESTA-COACH

PRESTA-COACH is a solution developed for SME's, within the framework of an ERFRO-project (European Funding for Regional Development). The PRESTA-COACH methodology and the PRESTA system resulted from the teamwork of some local business consultants specialized in different business domains in cooperation with some Professors of the local university in Limburg.

The methodology is guiding the company in implementing of performance management. It passes through five basic steps: an intake contact, a scan of the company, the identification of the critical success factors and the performance indicators and the modelling of the performance indicators, the BSC reporting and in some cases the coaching of the company to improve the critical business processes as identified. In this paper we go into more detail into step 2 and 3 of the methodology. The case study "Furniture-land" illustrates the methodology.

3. SCAN OF THE COMPANY

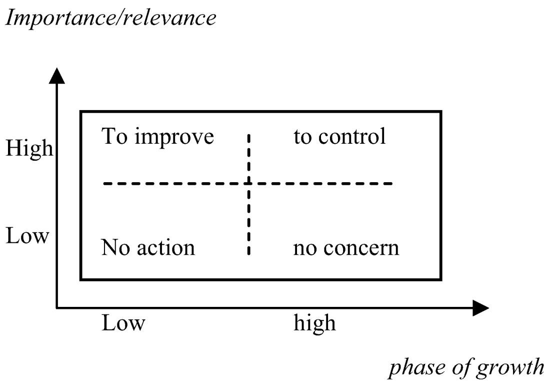
The scan consists of 2 parts:

1.The positioning of the company concerning strategic management characteristics.

2.The positioning of the company on point of the operational management aspects, structured in 6 organizational domains being: human resources, procurement-suppliers, market-customers, finance, environment and process-product/service

The management team positions the company for all aspects in one of four consecutive fazes of growth and at the same time evaluates the importance or relevance of all aspects on a one to four scale.

The system SCANA creates a graphical output of the correlation diagram between these two variables measured for all aspects.



The critical aspects are those marked as being in a low phase and being important at the same time. Those have to be improved.

The conclusions of this analysis form one of the main inputs in the CSF identification step of the methodology.

4. IDENTIFICATION OF THE CRITICAL SUCCESS FACTORS (CSF) AND THE RELATED PERFORMANCE INDICATORS (PI)

4.1. **Critical Success Factors (CSF)**

What is a CSF?
CSF's are for any business, the limited number of area's in which results, if they are satisfactory, will ensure successful competitive performance for the organization. They are the few key areas where "things" must go right" for the business to flourish. If results in these areas are not adequate, the organization's efforts for the period will be less than desired.
As a result, the critical success factors are areas of activity that should receive constant and careful attention from management. The current status of performance in each area should be continually measured, and that information should be made available.

Goals and CSFs:
CSf's support the attainment of organisational goals. Goals represent the endpoints that an organisation hopes to reach. CSF's , however, are the areas in which good performance is necessary to ensure attainment of those goals.

	Goals	CSF's
Automotive industry	Earnings per share Return on investment Market share New product success	-Focus must be on styling -The introduction of a quality dealer system -cost control -meeting energy standards
Supermarket industry		-a good product mix -inventory management -attention to sales promotion -careful price setting

Examples of general CSFs

1. we need to increase our external visibility
2. we must establish an interactive planning process
3. we must understand the basis on which users judge our performance
4. we must have an effective project management
5. we need to ensure that our IS charge-out system is seen by users as being equitable
6. we must have an intensive communication between management and employees
7. we must promote understanding of the value of the IS function

Examples of CSF's of a furnishing manufacturer:

1. expand foreign sales for product lines B and C
2. improve market understanding of product line A
3. redesign sales compensation structure in three product lines
4. improve production scheduling
5. mechanize production facilities
6. strengthen management team

4.2. **Mission, objectives and CSF's**

MISSION ↓	Reason of existence	Ex. Play tennis
OBJECTIVES ↓ ↓ ↓	General directives	-winning the game -improve physical condition -business networking
CSF's ↓ ↓	What should be done	-Take care of quality of game -training in advance
INDICATORS	How to control, to measure	-number of winning games -number of aces -number of unforced errors

4.3. CSF and measurement: the performance Indicators (PI)

Management has to discuss about the way how to measure each of the CSF's. Where hard data were perceived to be available, the discussion can be short. Where softer measures were necessary, lengthy discussions of the type of information needed and the difficulty and/or cost of acquiring it often ensued.

Example: Microwave Associates

CSF	Measuring model
1.Image in financial markets	1.Price/ earnings
2.Technological reputation with customers	2.Orders / bid
3.Market success	3.Change in market share
4.Company morale	4.Turnover, absenteeism
5.Performance to budget on major jobs	5.Job cost budgeted/ actual

The identified performance indicators have to be useful and reliable and the company must be able to deliver measure values, to extract them from existing systems and processes. One can state that performance indicators should be 'SMART', specific, measurable, acceptable, realistic and time-related and they should ally with the postulated strategy. Performance indicators should also be adjustable by management otherwise measurements are useless. Suggestions to adjust processes or registrations can come to the fore in this phase. When these changes aren't possible, another indicator should be searched for. The final result is the determination of a set of good and usable performance indicators.

4.4. CSF session

Anyone who has run a business or has already organised a project, has discovered how hard it can be to get the whole team on board to ensure that everyone knows where the enterprise is heading and agrees on what it will take to succeed.
We need a method that helps managers do just this.

- We identify goals
- We identify the activities critical to their attainment
- We provide a way to measure success

In an intensive session at which all the key managers concerned, agree on what must be done and accept specific responsibility.
The method requires a buy-in from everyone not only to identify what is needed but also to commit to the process.
The management team can be a formal group of managers, a board of directors, responsible for various sectors of the company.

The CSF (critical success factor) method mainly consists of the following steps:

1. The team reflects on their corporate and their actual operational management processes
2. The mission statement or their strategic goals have to be made explicit, and fixed to the wall during the session. (some managers learn their unit's true mission for the first time)
3. During a brainstorming session the team will formulate everything they believe could have an impact on achieving their mission. The team answers on some questions.
4. The team identifies a limited number of CSFs
5. The team identifies and lists what has to be done so that a company can meet its CSFs. Performance indicators will be identified and measuring models will be set up.

We set forward the *following brainstorming rules:*

1.Everyone should contribute
2.Everything is fair game, no matter how crazy or outrageous
3.Nobody is permitted to challenge any suggestion
4.The facilitator should write everything down so the team can see the whole list.

5. MEASUREMENT AND FOLLOW-UP OF THE PI'S AND THE COACHING OF THE ORGANIZATION

To measure the performance indicators, a PI-measure and two ore more PI-measure variables should be defined. The measure values for the PI-measurement should be collected in the organization and are compared with the posed norm values. The analysis is reported in a balanced scorecard (BSC).

The consultant and a team of experts will draw conclusions out of the results and will formulate some advice how the management can adjust and if further coaching is necessary.

The set up of a performance measurement tool that considers the strategic objectives of the organization, the focusing on achieving long-term objectives, the creation of an intern communication medium and the controlling of crucial processes in the organization, are the most important results of the PRESTA-COACH-approach

6. BSC SYSTEM PRESTA

The PRESTA system is planned to be a generic DWH based on a management performance system. Based on the input of specific CSF's and PI's of an enterprise, it generates a DWH dimensional data structure. The input of the data is done automatically from the operational databases.
A specific BSC report is being created

The overall architecture of the PRESTA IS is designed to be adaptable to the needs on point of access availability of consultants and enterprises, being located spread over our geographical region of the Province of Limburg.

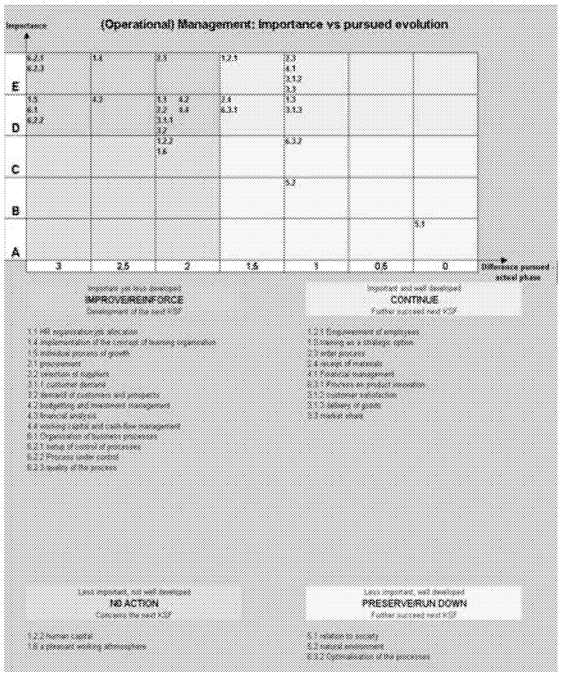
The system and the data warehouse are installed and will be hosted on a central LUC-LEARNING server. The consultants and the enterprises have the possibility of remote access internet browser access).

Technically this infrastructure includes a web-server, a database server as application services facilities for the PRESTA system. The web-based PRESTA system is developed in ASP. The decision on which web development tool to use has been taken, taking into account the in house available knowledge of the ASP language. Another decision element was the wide spread use of windows server in case a change of server will be needed.

We have chosen for the database system MySQL. The advantages of using an open source solution are well known. As a consequence the implementation of front-end data access tools and of commercial management reporting and analysis tools is guaranteed. Based on data from our data warehouse, our PRESTA system is generating the BSC management report, But the DWH can also be used for other management reporting, resulting from other DSS tools.

7. CASE: "FURNITURE-LAND"

7.1.SCAN analysis



7.2.CSF session

1. Discussion about the strategic goals

The management agrees on the following set of strategic goals:
-to increase sales in the 4 collections (product lines)
-to profile each collection as appropriate for the market segment
-to be a low cost producer in parallel with a high quality and a customer focused service

2. Discussion on the competitive strategy and the critical business processes

For production line 1 is cost leadership the strategy, and main attention is on: procurement, sales volume, personnel cost and production process optimization. The second product line opts for the differentiation strategy and puts emphasis on raw materials, innovative techniques, quality in the performance and marketing. Product line 3 follows a focus strategy and priority goes to marketing and realisation of the overall concept with special attention to procurement and design. Also the cooperation with external partners, especially the designers, is of importance.

3. Brainstorming session over three questions

a) What shall be the characteristics of your company in the near future taking into account the tendencies of your sector and your environment? Characteristics can be the product line, the market, the sales and distribution channels, the production techniques, the concepts and technologies, finance, the organisation, the relations with personnel, customers and suppliers.

1. Globalisation 2. Sales volume 3. Changes in consumer and purchasing behaviour 4. Lack of company ethics 5. Unstable Economic situation 6. Inventive production facilities 7. Co-operation 8. Involvement of our personnel

b) Which are our strong points and which are the strong points of the competitor?

WE are STRONGER	COMPETITORS are STRONGER
1. Our product! 2. A good financial situation 3. good geographic location: access for a big part of the world 4. Customer approach 5. relation with supplier 6. the will to improve	1. Bigger volume and as a consequence more impact on supplier 2. Bigger volume and as a consequence purchase power 3. Bigger volume and as a consequence ambitious investment program 4. marketing en sales organisation 5. Budget 6. organisation of production process

c) What are potential risks and in the coming 3 years?

1. Globalisation of the market 2. Bad functioning of sales function 3. Good marketing instrument of competition 4.Controlling and optimisation of production process 5. The disfunctioning of machines and infrastructure 6. Vagueness of product definition 7. Delivery to the customer 8. Decreasing sales volume 9. turnover in personnel

4. Identification of the CSF's

The management team of Furniture-land agrees on the following set of CSF's

1. Controlling of sales prices 2. Realisation of sales on West-European market 3.Force up of the production/sales volume 4. Equip the production process to produce according to the demands of the customer 5. Transfer the demand of the different markets onto the collection 6. Transfer the different needs concerning product development of the different markets onto the collection 7. Tools and methods support of the customer to increase his sales 8. Evolve to control of production concerning process control 9. Evolve to control of production concerning the impeccable functioning of the machines 10. Controlling the purchases 11. Controlling the costs

5. Controlling the CSF's

Each of the CFS' is appointed to a manager, who is responsible for the succession.
The identification of the PI's is ongoing.
The Performance indicators are measured and reported in a BSC.

8. CONCLUSIONS

Performance management is based on the measurement of performance in an organization. It is an opportunity for management to control the company (better) on these performances. Performance management should be on the agenda of every company. A methodology has been built that leads the company through five steps to the implementation of performance management.
The PRESTA system is used for the creation of the specific KSF-PI model of the enterprise, for the generation of a specific data warehouse, for the input of company data and norm values and last but not least for the generation of the BSC en its evolution scheme.

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E-BUSINESS

CUSTOMISING SYSTEMS ENGINNERING CONCEPTS : CASE STUDY ON CONCURRENT ENGINEERING CONTEXT

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KEYWORDS: requirements engineering, systems engineering, requirements change, safety requirements.

ABSTRACT: The paper on systems engineering concepts and their deployment. We consider the concurrent engineering approach can be modelled by systems engineering processes at least for the on development phases of the product. The paper is very technology oriented and wholly based on EIA-632 standards; the paper is extended with requirement evolution issues and a methodological approach is proposed.

INTRODUCTION

The actual systems are more and more complex, because they integrate a variety of technologies. The system need often long period of development. When we take a change on requirements the objectives are to improve the functionality, the cost or the delay of systems; but unfortunately, this modification can be affect a problem with others requirements those involved with the safety of the system.

The requirements change occurs in two main cases. The first concerns revising/updating existing requirements that led to an actual version of the systems to adapt to new environment (Larsen and Buede, 2002). The second is when new technology is being developed and new requirements are implemented consequently for reasons of cost or feasibility.

When we consider the change of requirements, we focus mainly in this paper to study the effect of the change on the security of the system; we try to see if any change cannot harm the system and the risk to affect the systems security. You have two type of change for requirements. The first such as the requirement change (Zowghi et al. 2002) and the system is in the phase of development, the second when we take a modification for a realise requirements

The main idea in this part is to present the effect of change on the system if one or many requirements change, and to present what are the considerations we must make, and to know the importance of safety requirements.

A recent survey produced Customer Focus group (CFG) of an aircraft manufacturer indicated how airliners keen on the integration of new technologies as requirement change for more functionalities rather integrating new technologies that may not be appropriate for safety issues and show that new technologies that succeeded in some application may not do for other application as there was no assessment of side affects on performance and safety for the whole system.

Another key aspect is that we often find out the domain has change and no requirements have been set so that the system detect such change. Some time the system is made to adapt to the change but only at the implementation and not at the requirement levels so that we can see the impact of such change on other requirements.

Our goals in this paper are to study:

- The problematic if we take a modification (on one or many) requirements, how can be sure that we have not any problem on safety of the system?
- The problematic of How can we take a study of the effect on safety when we have a modification?
- The problematic that how can we know the requirements have link with safety, and how can we know the safety requirements?
- What type of change (functional requirements, non-functional requirements, physical requirements, operational requirements…) make a problem of security of the system?

REQUIREMENTS ENGINEERING

Requirements Engineering covers all activities related to the elicitation, modelling, analysis (Nurmiliani et al. 2004), specification and management of requirements throughout the systems development life cycle. RE is a multi-disciplinary and communication rich part of software development that utilises a variety of techniques and tools at different stages of development and for different kinds of application domains.

The processes are applicable for the engineering or reengineering of the end products that make up a system, as well as the development of enabling products required to provide life-cycle support to system end products. The graphic to the right shows the relationships between the processes.

Our context study will, through the system engineering (Sheard 2003) framework, give importance to end products but also enabling products; there are many experiences in the literature about failed projects where requirements for enabling products were neglected as most focus only on requirements of end products.

The system to which the processes are applied consists of both the end products to be used by an acquirer for an intended purpose and the set of enabling products that enable the creation, realization, and use of an end product, or an

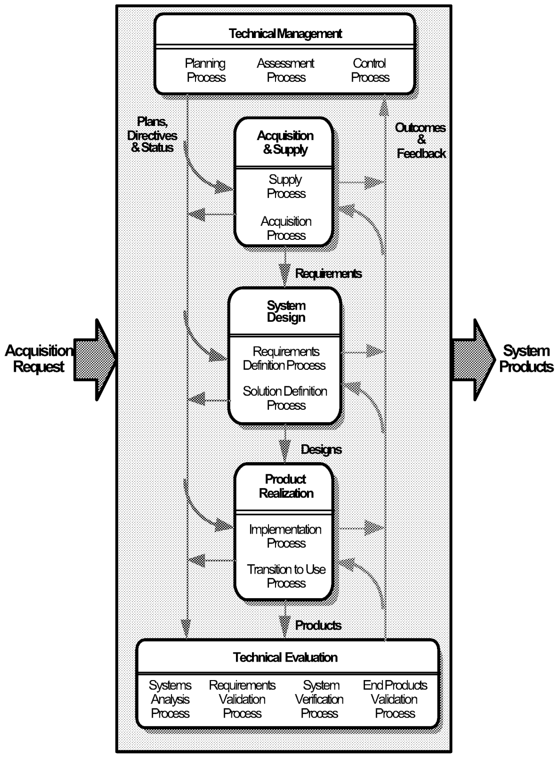

Figure 1: Requirements for engineering a system

aggregation of end products . Enabling products are used to perform the associated process functions of the system develop, produce, test, deploy, and support the end products; train the operators and maintenance staff of the end products; and retire or dispose of end products that are no longer viable for use. Both the end products and the enabling products are either developed or reused, as appropriate. The relationship of these system elements is shown in Figure 2.

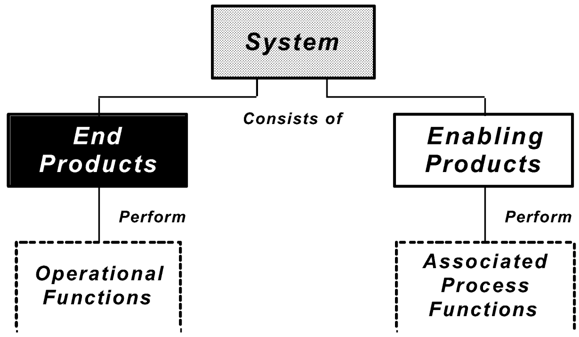

Figure 2: System concept

The system forms the basis for a larger structure, called the *building block,* shown in Figure 3. The building block. Effectively, it can be seen the end product is separated from other enabling product issues; this framework will help companies to enhance their RE process development when considering critical issues that often get mixed up with final product; the infrastructure for agile development relies highly on what is often called logistics but in fact they are the enabling product in systems engineering view: training, deployment products, test, development, product etc as shown in figure 3.

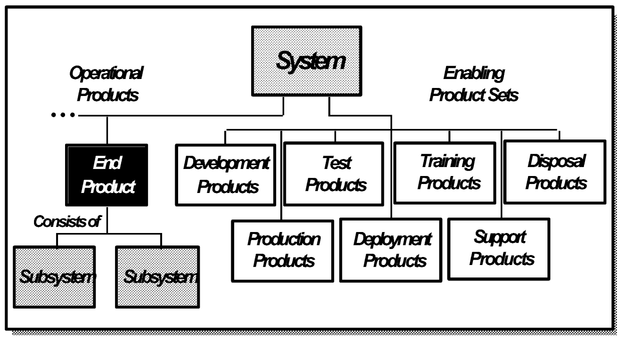

Figure 3: Building block

For such objective, standard EIA-632 will be considered as the mostly popular and effective standard being used ; such standard has been deployed in major space, manufacturing, military and aeronautic industries;

Errors in requirements specifications (Traoré et al. 2004) (Traoré et al. 1997) can have a major impact on software costs and project duration. It is evident that early detection and correction of potential problems during requirement analysis may alleviate many much larger problems later on during testing and maintenance.

Requirements engineering is a process from system engineering(Stevens et al. 1998), only active in an upstream phase, the objectives of this process is to identify the stakeholders, to capture, to explain, to formalise, to analyse, to validate, to allocate requirements. One specification for any system contains a highly number of requirements. The specification is necessary to make requirements very coherent, and to control, to change, to manage requirements.

Many studies in Requirements Engineering(Buren et al. 1998) show that 90% of costs are engage in the first phase of development of System Engineering, and that is better to change(Nurmiliani et al. 2004) one or many requirements in the first phase of development of the system. But when we apply a modification on our specification we have an impact not only in cost but also in safety. In Concurrent Engineering (CE) there should be a virtual data bus communicating between every process so to enable to activate parallel processes when a change is being made during systems development

MAPPING SE TO CE

The mapping we prone is how to customise the SE processes to CE. Such mapping is not systematic as it depend how CE is deployed in every enterprise.

As stated in European research for the integration in manufacturing: Information technologies already have a pervasive influence on modern manufacturing and engineering . This ranges from supporting the design and engineering process, through production planning and control, and on the toe control of manufacturing equipment and distribution systems. However, there remains enormous scope for IT growth in the manufacturing sector.

The main topics covered within the Integration in manufacturing research area include:

- Product data exchange and modeling which deals largely with the internal representation of all product-related design and manufacturing data.
- Factory automation, which includes the development of software tools to support human-centered production concepts; advanced work in robotics; and software developments in the field of simulating products, the manufacturing process, and the design and layout of manufacturing cells, assembly work-stations and entire plants.
- Communications and logistics, to improve the integration of distributed manufacturing applications, both within a plant and between enterprises collaborating in a supply chain.

Unifying processes for the needs until the disposal cannot be attained sequentially in any product or service development.

The systems development is based on unified process. These processes make abstraction of the systems nature. In (Sahraoui et al 2004) we proned numerous research issues related to the subject.

A DECISION FOCUSED FRAMEWORK FOR LIFE-CYCLE BASED ARCHITECTING AND DESIGN IN SE

Definition of the Problem

Systems engineering is a multi-disciplinary problem definition and problem solving process that is implemented by people. There are as many definitions of this process as there are systems engineers with no real agreement on an underlying theory that unifies the process. Most systems engineers will agree to the following characterization of systems engineering:

1. *Focus*: a process and systems management focus that will result in the engineering of a trustworthy product or operational system that will satisfy user and customer requirements and for which these stakeholders will pay
2. *Scope*: entire life cycle of the system, including the definition of user and customer requirements, development of the system products and enabling products, and deploying them in an operational environment. These enabling product systems include test system, deployment system, training system, operational support (logistics, maintenance, etc.), refinement system, and retirement system
3. *Products*: Systems Engineering Management Plan, Operational Concept for the product, hierarchy of requirements documents for each key system (starting with the system-level requirements document and following the physical decomposition of the system), architectures and hierarchy of interface control documents that define the interfaces at each level of the physical decomposition
4. *Characteristics of SE Process*: Combination of qualitative, quantitative, and executable models to examine the behavioral (functional) and system-wide (non-functional) characteristics of alternate designs and architectures.

Research Approach

A design process is characterized by a collection of decisions. In this, we use the fundamentals of decision analysis in which a decision is characterized by alternatives (what you can do – designs), values (objectives hierarchy with a quantitative value model to describe the trade-offs of the stakeholders across the key measures of effectiveness), and facts about what is known and not known. Within this context view systems engineering as a risk mitigation strategy that includes architecture, design, and testing. We must recognize that the entire process must adhere to the following principles:

1. Coherent value structure across all decisions
2. Top-down, decentralized (distributed, asynchronous) decision making

3. Managed by an adaptive, feedback-control process for decision making
4. Focused, cost-effective, risk management of both the (life cycle) design and design process

Expected Results

- Integration of values across all decisions for the system's life cycle
- Architecture and design framework for an integrated and coordinated decision-making framework with a schedule that identifies serial and concurrent decision-making activities
- Structure for reviews of key products that is based on the principles of feedback-control systems as well as the coordinated decision framework and is sensitive to the uncertainties
- Framework for risk management that is sensitive to the integrated values across the system's life cycle and the decision framework.

Process that can be generalized to other problem solving situations

REFINING THE APPROACH: EIA STANDARD APPLICATION TO CE

The EIA 632 as briefly presented in part 1 is common standard adopted in aeronautic and space industry and still to be deployed in other sector with other standard as IEEE –P1220 and ISO-15288.

Our work in such limited only to the design and verification processes (8 processes from the total 13 processes); the left out processes concern the management, supply and acquisition processes.

We are concerned also by the products and enabling products, that is really implicit in concurrent engineering and recommended in EIA 632

MIL-STD-499B was intended to be the first military standard to address systems engineering as a whole. MIL-STD-499A addressed the management of systems engineering and, thus, had a different focus, although MIL-STD-499B was intended to supersede it. MIL-STD-499B uses a lengthy definition for systems engineering which concentrates on integration of disciplines, full life-cycle coverage, assurance of interface integrity, management of technical risks, and validation that the system meets the needs and requirements. The actual work of systems engineering is clarified only by reading the full standard. This work tends to lean heavily toward the Technical Management definition of systems engineering.

The standard begins with five pages of definitions and follows that with one chapter on General Requirements and one on Detailed Requirements. The General Requirements chapter is ordered by life-cycle phase, while the Detailed Requirements call out individual systems engineering work products. These work products clearly imply a large military contract environment, calling out numerous customer reviews, for example, and including things like Survivability tasks and Integrated Logistics support.

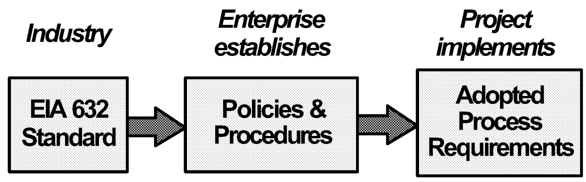

Figure 4: Application of the standard

While this standard was never released, the May 1992 copy in particular has enjoyed a long applicable life in that it served as the basis for both the IEEE 1220 standard and the EIA IS 632 standard, both of which were fairly minor modifications

- Main Product development: Why "Product Development" and not "Engineering?" Because the management science shows that to achieve the best results not only must the several engineering disciplines work concurrently but the key cross-functional stakeholders from marketing, product management, purchasing, manufacturing engineering, production, quality, and other functions must be concurrent as well. Perhaps more importantly, many companies and industries that develop products have no engineers. Biologists, nutritionists, chemists, physicists, and other technical disciplines perform the technical roles in cross-functional product development teams. Product Development better captures the reality of the management science and the disciplines of the companies that develop products

- Enabling Product: Enabling effective concurrent engineering raises another issue 'How can we best capture and communicate information and knowledge in a concurrent engineering environment?"

- Deploying the 8 processes: all SE process covers the CE requirements. Concurrent engineering can be seen a final product and enabling technology are the product that enable it. Hence the classical SE process presented in figure "processes for engineering a system " can be applied to such product development : the CE implementation. Ranging from logistics and supply to more technical processes as requirement process, design process, implementation process

REQUIREMENT EVOLUTION IN CE CONTEXT

Our approach and contribution will focus mainly on impact of requirement change and development a methodology for requirements change (El jamal and Sahraoui 2005) (El jamal 2004). This will be carried on the basis of:

- traceability model
- The concurrent processes
- A formal framework for the requirement change

General approach

We are investigating many approaches to such issue. However the global approach is thought as an operational view as illustrated by the following figure. The formal basis for such approach is not tackled yet but some items are thought to be useful and to be discussed in latter section.

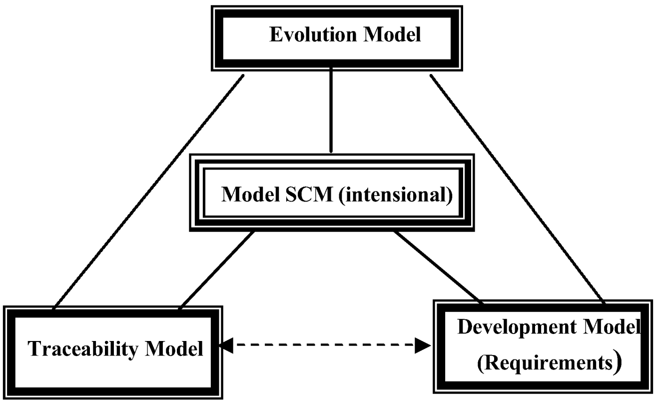

Figure 5: Approach

This preliminary approach is systems engineering context characterised by the interaction by four models; these involve respective processes. Our concern is the development of the change (Malayia and Denton 1998) model and its interaction with all other models. We will present the traceability model dynamics that have been used in earlier work (Hellouin et al. 2001) (Hellouin 2002) and make abstraction of the development and system configuration management models as their basic characteristics are known for long time. We know that any requirement change will concern and trigger all four models. In our first approach we will be concerned the change, traceability(Hughes et al. 1998) and development models. However, some principles will guide towards the deepening of the approach as future work will focus mainly on refining the approach:

- Any change request either at any step of development model suppose the availability of a traceability model.
- A change request for an operation module will necessarily require tracing back the original requirement
- Make distinction between functional and non function requirements
- Identify security/safety requirements.
- Create link between associated function and safety requirement.

Traceability model

As discussed earlier, providing traceability of requirements to their sources and the outputs of the system development process can be along several dimensions. Different stakeholders contribute to the capture and use of traceability information, often with different perspectives. A user has a different vision from an audit specialist, a system designer or a validation engineer. Some typical questions are often asked:

What are the systems components that are affected by a specific requirement?

Why are the components affected by such requirements?

How are the components affected by such requirement?

What are the sources of a low level requirement?

Why and how two requirements are related?

And so on …

An object can belong to one of the following classes: requirement, design, components, system/subsystem, etc. Attributes and operations (activities) are associated with each class, subclass.

Sources are all available information as documents, phone call, E-mail about the object lifecycle. Traceability concerning specific decision made can be found through the relation documents.

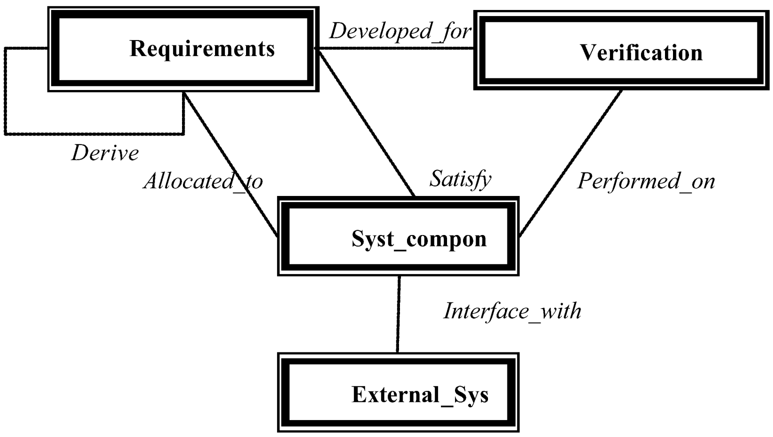

Figure 6: Traceability at low level

We can use this traceability model to identify any link that may be subject and constrained by a requirements change.

CONCLUSION

A mapping of SE processes deployment in a concurrent engineering approach has been presented

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BIOGRAPHY

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IT-SECURITY IN E-ENGINEERING – CHALLENGES AND SOLUTIONS

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KEYWORDS

Virtual Engineering, Security, Watermarking, Encryption, Policy

ABSTRACT

Organizational innovations like Global Engineering and the growing importance of the Internet as a communication backbone for distributed processes induce a risk for the integrity as well as the confidentiality of digital product data. This paper gives an overview of the challenges and technical solutions in the area of IT security for E-Engineering. Basic technologies and specific solutions for CAD and product data in general are presented and an outlook towards further research in this field is given.

INTRODUCTION

The virtual product bundles together all available information for a product, including shape and function as well as the internal structure, details on the manufacturing processes and potential suppliers. Thus it represents an extremely valuable intellectual property for all companies and is worthy of protection. With the progressive development of product models as knowledge sources for technology, materials and processes, these models are a critical target for espionage and sabotage.
Rigid protection measures however, stand in contradiction to the necessity for close co-operation with innumerable partners in the product development process. The solution of this conflict is a major challenge today. Without suitable security concepts, the virtual product and the idea of collaborative product commerce will not be able to develop their potential.

The topic of IT security for E-Engineering has been gaining more and more visibility in the last few years. With the German research project Integrated Virtual Product Creation (iViP) [LUK01], with important partners from the automotive industry, we have one starting point for a structured approach to ensure IT security [LUK00].

In the remainder of this paper we will mainly focus on the technical aspects of security. Although other viewpoints such as organizational changes, psychological questions or legal matters are not covered here, this does not mean that they are any less important.

CHALLENGES

The dramatic progress in information and communication technology has had a strong impact on the processes of virtual product creation [CHA02]. Virtual conferencing, digital engineering and internet market places are just three of the buzzwords in this context. The industry makes use of these innovative capabilities in order to create their products faster, increase the quality and minimize production costs. However, by shifting more and more steps from the physical world to the virtual world, we do not only gain speed and flexibility, we also increase the risk of losing knowledge and of cyber crime in a fragile virtual engineering supply chain.
The following list highlights some concrete aspects that obviously influence this area – resulting in major challenges for IT security:

Mobility: Accessing the company email server and other information sources when travelling, retrieving up-to-date information from the PDM system while presenting a product at a customer's site, using wireless networks on the shop floor during the ramp-up and maintenance periods - all these are examples of mobility – in one form or another. In terms of security we have to deal with insecure networks, with appliances that can easily be stolen and with the blurring of borders of the traditional company.

Extended enterprise: The engineering process is not limited to a single company. Today we always find digital engineering supply chains, where the OEM collaborates strongly with a huge number of suppliers at different levels. Suppliers and engineering service providers typically work for various competing OEMs at the same time. It is absolutely crucial that there are reliable "Virtual Walls" between the different project teams. Deriving from this organizational issue we have to deal with complex questions of Digital Rights Management in a highly distributed environment.

Data sharing: The traditional approach to work jointly on product structures and CAD files is spreading out replicates via FTP or similar tools. These replicates are difficult to control and often partners work on outdated data. To avoid this we can share the data e.g. by opening up the PDM systems to the development partners. Using federation [NOW03] it is also possible to keep all the product model parts in the place where they have been created and offer a unified view and a central point of access. Obviously this approach must be built in a secure fashion in order to be accepted by the users.

Complex infrastructure: IT infrastructure is becoming more and more complex: It is not only internal services that are connected in order to establish continuous data flow along the process chain.- by relying on offers of external services providers (collaboration spaces, market places, etc.), by integrating partners along the supply chain and by combining and sharing resources in the spirit of GRID computing, we have to deal with an infrastructure that is difficult to monitor, to manage and, last but not least, to protect against internal and external attacks.

HTTP tunnelling: The conflict between the need for communication and the rigid protection of the internal network by means of firewalls is often solved by HTTP tunnelling. This protocol typically is not blocked by the firewall, which makes it the protocol of choice for cross-enterprise collaboration tools. However, "smuggling" all communication traffic through this channel, which is intended for web surfing, makes it quite hard or even impossible to control the traffic and detect abuses such as hacker attacks.

Lack of awareness by users: Information security is important but not really attractive to engineers. To increase the awareness of the risks and the available security tools among their staff members is an important challenge for any company. Following a recent study [ERN04] this issue is even more challenging than budget constraints or lack of availability of skilled security staff.

BASIC TECHNOLOGIES

This section introduces basic measures to ensure the integrity of the data, to protect intellectual property stored in digital files and to increase the security level in a company in general. These are only a small selection of security measures. Standard procedures to increase the security level of a PDM server by configuring the operating system and standard services are e.g. explained in detail in [UGS04].

Encryption

Encryption of data is the basis for authentication and confidentiality of information. We must differ between symmetric and asymmetric encryption methods. Symmetric encryption uses the same key for de- and encryption. Thus the key must be kept secret. With asymmetric encryption we have a pair of keys: One key for encryption and the other one for decryption. Only one key must be secret (called private key). The other key is published (public key). If one sends data to a receiver he has to use his public key to encrypt the data. Only with the receiver's private key can the data be deciphered.

Certificates

The authenticity of public keys is proven by a trust centre or certification authority (CA) by the use of certificates. This means, a trust centre authenticates the coherence between a public key and a person or institute with a digital sign. For a receiver it is now possible to verify a public key from a sender. A certificate includes the name of the person, the public key, period of validity and a digital sign from the CA.

Digital Signature

Digital signatures permit the verification of the authenticity of data. Thus, the use of digital signatures usually involves two processes, one performed by the signer and the other by the receiver of the digital signature. Digital signature creation uses a hash result derived from and unique to both the signed message and a given private key.

IT security policy

An IT Security policy comprises all rules, instruction and practices which define the processing of sensitive information and resources of the IT system. IT security policy does not cover rules and measures for handling information outside IT systems. Usually an IT security policy has a distinct area of validity. A crucial aspect is the documentation of the security policy. Usually a security policy is documented in book form or in "verbal" form. A formal representation of a policy will not be available in most cases.

Digital Watermark

A Digital Watermark is a signal or pattern inserted into a digital file. While the addition of this message to the signal does not restrict that signal's use, it provides a mechanism to track the signal back to the original owner. There are visible and invisible watermarks. To make the hidden watermark more robust against attacks to destroy it, the data is spread (in copies) over many areas in the digital file.

Combination of Security Measures

Keeping in mind the seven layers of the OSI Reference Model, we can identify different levels where we can hook in with security measures. To really increase the security level, we typically have to combine solutions at various levels. The following Figure 1 illustrates a simplified model developed in the iViP project. Depending on the requirements of the users, the confidentiality of the data and the available resources, we can define different profiles. Each profile combines a set of security measures in a concrete collaboration context.

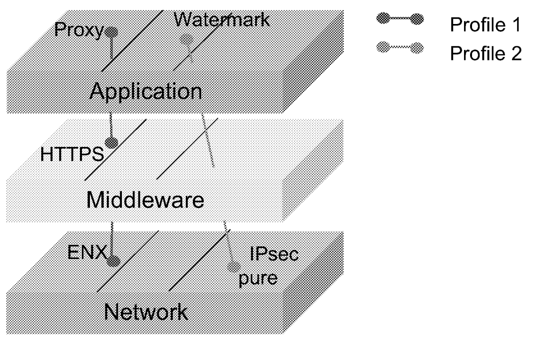


Figure 1: iViP Security approach [LUK00]

APPLICATION SPECIFIC MEASURES

Based on the general technologies introduced in the last section, we now concentrate on the application field of E-Engineering. Specific measures for product data and the systems used for modeling and storing virtual products are introduced. This gives an overview of innovative applications and current research in this domain.

Digital Signatures for CAD Data

The commercially available solution *CADsign* [DOC04] enables users to sign their AutoCAD drawings electronically either by means of a hand-written signature image or a bitmap image. If there are any unauthorised changes after approval, the signatures are instantly removed, thus alerting the user not to work on the drawing until it has been rechecked. Users can apply their signature either by conventional passwords, or a finger scanning device.
The signed drawing files can be loaded into other programs, but to see the signature, recipients have to install the viewer (ref. Figure 2).

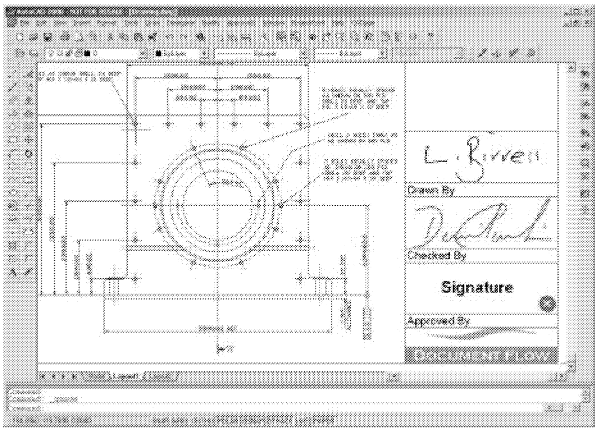
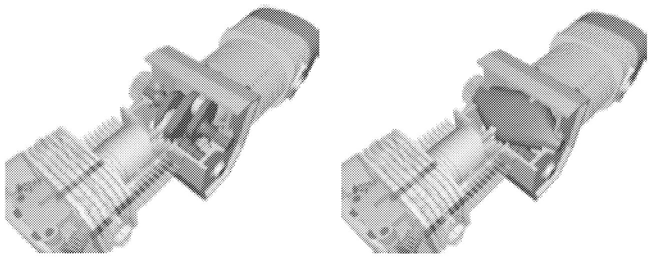


Figure 2: CADSign using signatures [DOC04]

Role-based Presentation of 3D data

Role-based presentation [CER03] protects sensitive engineering information like model geometry, topology or behaviour by using sophisticated limits for visualisation, printing, measuring, markup etc. It enables controlled collaborative supply chains for mixed teams of designers, subcontractors and suppliers. Also, designers of different disciplines working on common design models don't have to suffer from cognitive distraction when they must interact with unnecessary design details that they do not understand and cannot change.
This can be achieved through integration of multi-resolution geometry and security models. In this way, 3D models are geometrically partitioned, and the partitioning is used to create multi-resolution mesh hierarchies that obscure, obfuscate, or remove sensitive material from the view of users who don't have appropriate permissions. Figure 3 shows an example where the convex hull is used to hide some internal details of a crankshaft.



(a) Original model (b) Simplified view with convex hull for crankshaft

Figure 3: Example of role-based presentation using convex hulls [CER03]

Watermarking of 3D-Data

Digital Watermarking [BEN03] is a well-established technology, which can be used to embed information directly in various data formats. This embedded information can be used to control access to the file and detect the originator of a given file. The following flowchart illustrates how data (e.g. a copyright message) is typically embedded, optionally in an encrypted way, and extracted again.

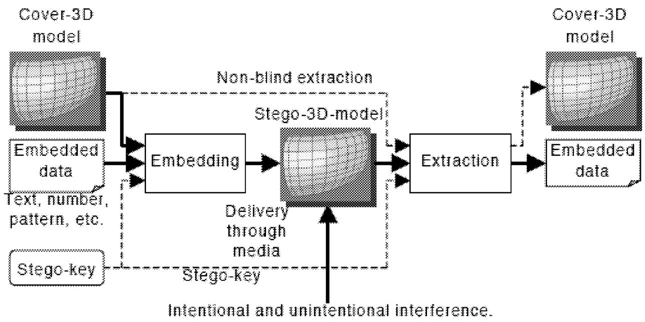
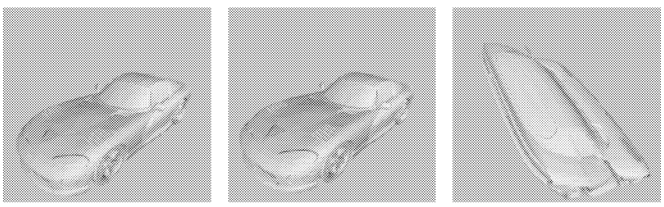


Figure 4: Representative flow of watermarking [OHB00]

Depending on the algorithm, and the size of the watermark to embed, the shape of 3D model is either not changed at all, or is only slightly modified. When using watermark that is not shape-preserving, the watermark can even be extracted after producing a physical object from the digital model, e.g. by STL methods. The following figure compares an original triangulated model, the same model after embedding a 32 byte watermark and an affine transformation that would not destroy the watermark.



(a) Original model (b) Watermarked model (c) Affine transformation

Figure 5: Security awareness demonstrator of MakoSi [BEN00]

Security Awareness for E-Engineering

Security Awareness does not shift the responsibility for meeting the requirements of a security policy to an IT system. Rather, it makes the risks visible for the user and advises him to re-think an action, which might cause some trouble. To maximize the effect of security awareness and avoid confusion for end users, we have to implement a unified approach that observes the activity of the user, the level of confidentiality of the involved data and uses a central "awareness cockpit" to inform the user about risks and concrete alternatives.
Promising research already has been conducted by ZGDV, in context of the MakoSi project [HER04]. Based on collaborative engineering tools developed in the context of the iViP project [LUK01], a set of components was implemented to grab user events, assess their risks and inform the user about potential violations of the security policy by means of a central awareness monitor.

Policy driven system

Security policies are typically specified at a very abstract level. On the one hand this makes the policy flexible enough to adapt to arbitrary technologies. On the other hand it is often difficult to decide (for the IT department and the end users) if a given action would violate the policy or not.
Furthermore, it is almost impossible today to offer a software system that decides or even assists in the enforcement of a policy. Formal verification of security policies (are they complete? are they consistent?) is another task that typically cannot be done with today's policy descriptions.
The MakoSi project [MAK03], [HER04] followed an holistic approach to cover the whole process from policy formulation up to the secure configuration of IT systems and applications. The concept of a policy driven system was developed and its feasibility was demonstrated in a first prototype.
Based on this approach Vettermann [VET04] introduces the idea of an IT security control loop (ref. Figure 6). Relevant events in the context of IT security are traced, evaluated against a set of conditions and if one of the conditions is affected, an appropriate action is initiated. The control loop is an innovative approach to couple security domains across company boundaries and offer end-to-end security of collaborative product data management. The work is based on the PDTnet schema [PDT04] and offers a systematic approach to introduce IT security on collaborative engineering scenarios.

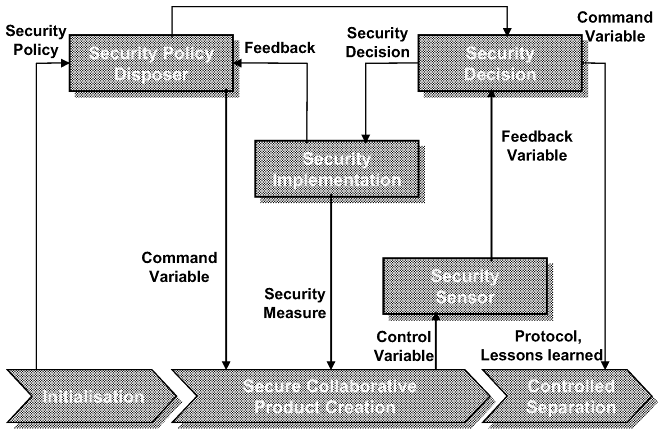


Figure 6: IT security control loop [VET04]

SUMMARY AND OUTLOOK

This paper started with a list of aspects in E-Engineering that have an important influence on IT security. Organisational changes as well as technical solutions for communication and collaboration lead to challenges that must be faced by companies in order to protect their infrastructure, data and knowledge. Based on this motivation an overview was given on general security technologies and specific solutions for the engineering domain.
However, security measures in general and all the technologies presented in this paper are not for free. Increasing the security level always results in costs. These costs can be classified in monetary terms (buying hardware and software), implementation effort (selecting and implementing public domain solutions) and decreasing productivity (the overhead for manual interaction with tools - e.g. deriving role based views from a given model). To make the process even more complex we have to think about the fact that an increased security level typically will have an impact on the communication possibilities. Everyone who has implemented perimeter security by setting up a firewall solution to shield against attacks from the internet will have had this experience: various communication and collaboration tools will not work any longer.
To find the balance between security, access for collaboration and costs will remain an important challenge for all the players in E-Engineering (ref. Figure 7).

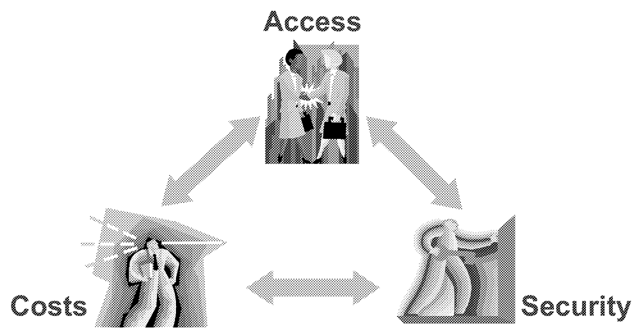


Figure 7: Balancing interest in the context of IT security.

A current paradigm shift in the question of where to locate access control and similar technology will help to solve the conflict between access and security: The typical concept of perimeter security, where security measures are taken with a minimum of knowledge about the semantics and context of the communication is more and more being replaced by intelligent concepts, implemented inside the application. Here we have much more information about the relationship between the communication partner and can react more flexibly than by just blocking the connection or granting access.

This paradigm shift will lead to even more application-specific solutions – similar to those already presented in this paper. This new generation of security tools for E-Engineering will protect the infrastructure and intellectual property of the owners without neglecting the requirements of the engineers.

ACKNOWLEDGEMENTS

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BIOGRAPHY

UWE VON LUKAS graduated in computer science from Darmstadt University of Technology. He joined the Fraunhofer Institute for Computer Graphics as a research assistant in 1994 and, subsequently, as a member of the scientific staff of the Computer Graphics Center (ZGDV) in Rostock. Since April 1999, he has been head of the CAD & Teleservices research department. In 2002 he received a PhD from the University of Rostock for his thesis entitled "Integration-based tele-cooperation". Since October 2002, he is the Associate Director of ZGDV Rostock. His current research interests are in the area of distributed applications, collaboration, and Virtual Reality as well as Augmented Reality technologies for virtual products.

Limits of Build-to-Order Processes in the light of changing Business Framework in the Automotive Industry

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KEYWORDS

Build-To-Order – Business Model – IT Strategy – Process Stability – Process Optimization – Supply Chain Management – Lean Production Strategy

ABSTRACT

As a general rule, all companies aim to satisfy customer demand. However, only few companies accomplish that goal at low cost and with customized products. Build-to-order is an approach to understand customer demand and to adjust internal processes so that customer's expectations are met at low costs (reduction in inventory; higher average margin per vehicle).

Many companies do not accept this challenge and manufacture standard products in large quantities, guided by long-term forecast. If the long-term forecast, however, proves to be wrong, companies either suffer from costs caused by excess production (lower demand than expected) or by missing potential sales (higher demand than expected).

It is also not sufficient to locally optimize processes (so-called "island solutions"). Research has shown that those "island solutions" sometimes backfire as they may badly influence other processes of the value chain. Only a sustainable approach guarantees a customer-centered solution that will meet customer demands in the most efficient way.

Today, there are some case studies available of companies that successfully implemented the build-to-order approach in their processes. Some describe newly founded companies that considered build-to-order from the beginning, whereas some focus on existing companies that performed a full transition to build-to-order. However, one question which has not been thoroughly analyzed yet is how to manage the build-to-order approach, once implemented, in times of radical changes (e.g. changing business model)? The objective of this article is to discuss how a company can handle this challenge without downgrading efficient processes. A case study from the automotive industry is used to describe key success factors in fulfilling build-to-order in times of a changing framework.

The authors recommend following the same steps as if build-to-order was to be implemented "from scratch" in a company. Moreover, it is critical that modified processes are stabilized and consolidated. Otherwise, the transition may fail. From lessons learned, the authors recommend not to solely concentrate on build-to-order as this makes a company more vulnerable to demand fluctuations.

I. INTRODUCTION

Today, most manufacturers are being forced to offer products with a higher degree of customization to satisfy customer demand and compete in niche markets. However, if products are not designed in a way that allows manufacturing them flexibly, companies cannot react quickly to changing market demands or offer more product variety. Additionally, costs will be much higher when following the traditional build-to-forecast process as the required customization level increases.

Throughout all industries customers are increasingly demanding products that are tailor-made to their specifications. According to a study in the automotive industry, conducted by Accenture, two-thirds of industry experts surveyed expect a continued increase of model variants and options [EHR02]. Figure 1 shows the trends influencing the automotive market that require a change in the current OEM business model.

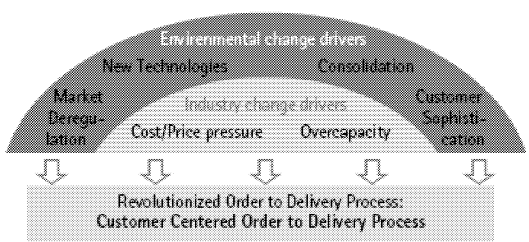

Figure 1: Trends influencing the automotive market require a change in the current OEM business model [EHR02]

But how to fulfill customer demand without exploding costs? Build-to-order is a popular alternative solution that is used to streamline a company's order-to-delivery processes. Anderson defines build-to-order as "the capability to quickly build standard or mass-customized products upon receipt of spontaneous orders **without forecasts**, **inventory**, or **purchasing delays** [AND04]."

He differentiates among four different ways of creating products [AND04]:

- *mass production*
- *virtual build-to-order*
- *assemble-to-order*
- *spontaneous build-to-order*

Mass production means that products are built in batches based on forecasts. Typically, the standard products are inventoried hoping that the customer demand can be met. This approach is also called build-to-forecast.

The second approach, *virtual build-to-order* describes a process, where a company waits for an order. Upon receiving the order all the materials required are ordered or searched for in the internet and delivered at the right time (e.g. aircraft production).

The third approach, *assemble-to-order,* assembles products from forecasted parts inventory (e.g. Dell Computer).

The fourth approach is *spontaneous build-to-order* that creates mass-customized or standard products on-demand without forecasts or inventory.

The original approach, *mass production*, has been successful in a time of stable demand and little product variety. A very popular example is the "any-color-as-long-as it's-black" T-Model by Ford that had a market share of 57% in 1923 [LAC86]. However, it was pulled off soon by General Motors that offered variety such as color paint and other options. At this time Ford could not quickly respond to changing customer demand because of mass production characteristics as hard tooling, labor specialization, economies of scale preventing it from adapting to emerging trends.

Companies still following the mass production approach use very complex material requirements planning software to order all required parts in time. After setting up the equipment, products are built to satisfy the forecast. Despite the fact that it is more difficult to satisfy customer demand from inventory, it is also very expensive. The average inventory carrying cost has been calculated as over 25% of inventory value per year [AND04], i.e. € 4m in inventory will cost the company € 1m per year to pay for the interest, space, insurance, and administration. This price will add to the selling price regardless of whether the inventory is at the factory, distributors, or stores. Thus, when a company succeeds in eliminating inventory costs, it can realize higher profits or gaining market share by lowering the selling price. Build-to-order helps to reduce or even eliminate inventory [SCH03]

The next chapter describes a general approach for implementing spontaneous build-to-order.

II. GENERAL APPROACH FOR IMPLEMENTING BUILD-TO-ORDER

The most important basic strategies for implementing build-to-order are [AND04]:

- supply chain simplification (e.g. part standardization, material variety reduction, automatic re-supply techniques etc.)
- the development of a spontaneous supply chain that is able to pull in materials and parts on-demand

In general, there are three steps to follow:

1. Identification of Goals and Drivers

First, it is necessary to identify the goals that can be improved by build-to-order such as profit, growth, market share etc. Then, one identifies the drivers for those goals, i.e. all activities that will help to achieve the goals.

2. Analyze Customer Demand

Knowing the customer's preferences and competitive rankings will help the design team to develop products that are designed for build-to-order and that fulfill customer demand (see also [PIL03] for details).

3. Define Scope and Implement Build-to-Order

Rationalization of product lines will help to eliminate those products that are not designed for build-to-order. Other activities within scope are standardization, supply chain simplification (e.g. conversion to automatic re-supply thru extended partnership as done by Wal-Mart), lean production and total cost measurement to identify low-profit products.

Instead of relying on material requirements planning software and purchasing functions, information technology will support the business departments in implementing comprehensive processes designed for build-to-order (e.g. state-of-the-art order entry system that enables pulling of parts and materials into production without forecasts or material requirements planning).

III. CHANGING BUSINESS FRAMEWORK

Most companies continue analyzing customer demand in order to quickly adapt to changing trends, thereby assuring that the current build-to-order solution is optimized. The overall effort for doing this is limited, since the analysis can be done regularly using standard tools. The chapter "Changing Business Framework" does not refer to evolutionary changes as described above. Instead, it refers to radical, often unplanned changes for a company.

Increasing globalization, new technological challenges (particularly in the area of information technology) and deregulation of markets are trends that have favored mergers & acquisitions in the marketplace.

The most important forms of mergers & acquisitions include:

- Corporate merger
- Friendly and unfriendly company and corporate take-over
- Alliance, co-operation and joint-venture
- IPO
- Restructuring
- Management buy-out and buy-in

Besides mergers & acquisitions, companies may also internally provoke a changing framework (e.g. changing business model as new business strategy). How to manage the build-to-order approach in times of radical changes as described above?

The build-to-order approach concentrates on supply management and lean production strategy enabling the company to produce on-demand without forecasts and inventory. Changes to the framework may identify the current build-to-order solution as not appropriate anymore.

In order to verify that the existing build-to-order solution does not require any modification, the company has to go through the general steps for implementing build-to-order again. Are there any changes to previous goals and drivers? What are the implications to customer demand? Are there any changes to rationalization of product lines, standardization, supply chain simplification, lean production and total cost management?

Although, it is very difficult to anticipate radical changes such as a changing business model or company take-over in advance a company should be prepared to re-think its build-to-order strategy at short notice. Since the company may have gained a competitive advantage or higher profits from following a build-to-order strategy, it may lose its position if it cannot quickly adapt to the changing business framework. In the next chapter the critical success factors for fulfilling build-to-order in front of radical changes will be discussed.

IV. CRITICAL SUCCESS FACTORS

As stated earlier a company has to make sure that it is able to adapt to radical and non-radical changes. While non-radical changes are adapted through an organizational solution, there is no fixed, organizational solution that would be sufficient to handle radical changes.

Here, it is critical to have a virtual, organizational solution that can be quickly established in case of radical changes. Companies will alert the key players (process owners, product experts etc.) to guarantee a successful migration into a new build-to-order solution. The earlier the new solution is implemented the lower is the danger that the company's position will be weakened or lost in the competitive marketplace.

Implementing a new build-to-order solution, however, will only be successful if processes are stabilized and consolidated quickly following the change. Furthermore, it is recommended to establish a cross-functional initiative for process optimization in order to establish an overall optimum instead of "island solutions" that may backfire. Such an initiative that consists of representatives from all departments guarantees that topics are regarded from the point of view of the company, i.e. it is assured that solutions bring sustained value to the firm. The levers to achieve this are (see Figure 2):

1. Process optimization and settlement of sata
2. Clarification of tasks, competencies and responsibilities (TCR Regulations)
3. Modification of IT systems

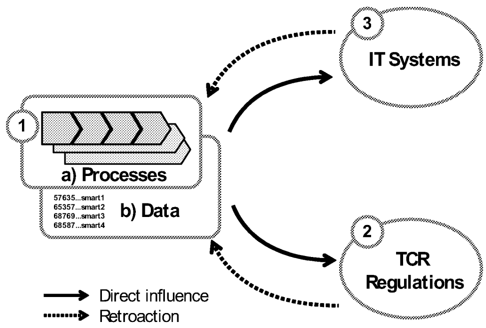

Figure 2: Most Efficient Approach to Process Optimization

Process optimization is a prerequisite for a lean and efficient organization, smooth functioning processes and stabilized and consolidated systems and data.

Business Case

Cost advantages of build-to-order mainly result from reduced or eliminated inventory, lower effort for forecasting, and abdication of supplementary customization efforts.

Customer satisfaction is much higher since build-to-order allows for a best match of customer needs, i.e. the customer receives a customized product at the right time.

Build-to-order as business model helps the company to gain a competitive advantage from faster delivery, better prices, and high customization.

V. CASE STUDY

This chapter provides an example of

- the implementation of build-to-order from scratch
- a radical change to business strategy and its effects on build-to-order
- the migration into a new build-to-order solution

- a cross-functional initiative to stabilize processes, data, and systems

at an automotive manufacturer. The newly founded automotive manufacturer had the initial vision to "change the way the automobile industry operates".

This included the creation of

- a new brand
- a new market segment
- a new retail concept and network (two-tier business model)
- an entirely new, highly-integrated supply chain (build-to-order)

The Implementation of BTO from Scratch

The newly founded company could rely on a clear, static framework (one model, system partner concept, green field approach and a market focus limited to Europe) when defining its business processes and setting up its IT systems.

Obviously, it is easier to implement the build-to-order approach from the scratch than upgrading an existing company. Upgrading an existing company "*will involve enormously complex changes to already-complex IT systems that support all facets of the business, spanning design, supply chain planning and logistics, manufacturing, sales and distribution* [HAL01]."

After having defined clear goals and drivers, the company did extensive market research to analyze customer preferences. The effort for such an analysis is much higher at the beginning; however, successful build-to-order processes and initial capacity planning require a precise analysis.

Then, the company defined all business processes making sure that those fulfill the build-to-order requirements. Later, it built a highly integrated IT system using state-of-the-art technology.

For instance, the supply chain had been designed to be very simple and efficiently. The company could dramatically reduce inventory and facility costs vis-à-vis its competitors as an immediate effect. Materials are pulled in on-line and invoiced after being assembled (payment after consumption). This process could be successfully set up because it was implemented in conjunction with a new system partner concept. *Figure 3* shows the advantages of the efficient supply chain in comparison to a classic procurement chain.

Another characteristic of this implementation was the world benchmark order-to-delivery chain (see *Figure 4*). A highly integrated system supports the whole order-to-delivery process starting from Sales Planning, Pipeline Check, New Order Entry, Order Change, Vehicle Assembly up to Vehicle Distribution. For example, the value chain link "New Order Entry" describes the on-line communication of the production and delivery date to the dealer upon order entry.

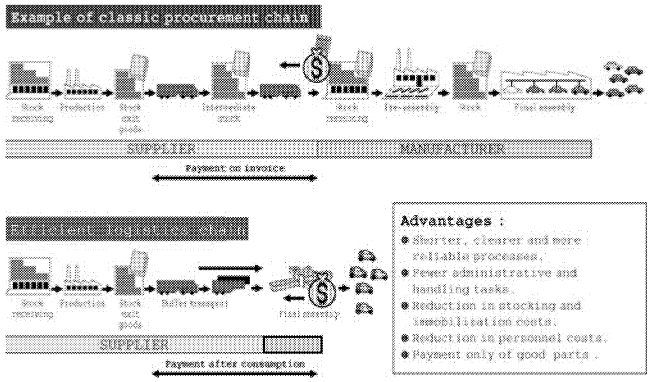

Figure 3: Comparison between a classic procurement chain and an efficient supply chain

Usually the dealer configured the vehicle together with the customer and created an offer. If the customer decided that he or she wanted to order the vehicle and the dealer clicked on the "order button", the delivery date was communicated on-line to the dealer. How exact was that information? Delivery date deviation was very narrow (+/- 2 days). No other automotive manufacturer could offer that information to the customer at that time. Overall delivery lead time was only three weeks.

The customer could change the order up to 4 days before production (e.g. choosing seat heating and a different color).

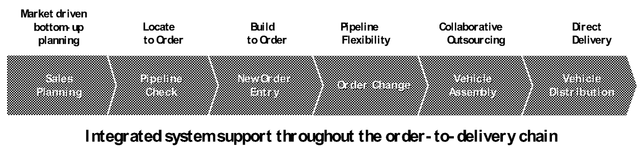

Figure 4: Integrated system support throughout the order-to-delivery chain

Changing Framework

Originally founded as a joint-venture, the automotive company today is a 100% subsidiary of a large automotive corporation. The change in ownership led to some radical changes of the business model:

- changing from two-tier to three-tier business model (the new tier being market performance centers on the country level)
- launching more models (instead of the one-model concept)
- entering new markets outside Europe

Additionally, the question arose whether to keep up with pace of new markets and market development by

- independently pursuing growth or
- integrating the subsidiary into the mother's corporation.

Migration into a new build-to-order solution

It was decided to integrate the subsidiary into the mother's corporation. In order to allow for a successful migration, the integration project SHAPE (Systematic harmonization of all processes and IT systems) was started.

Since the mother corporation had its own build-to-order processes in place, the subsidiary could keep its competitive advantage. Nevertheless, the general steps of implementing build-to-order had to be re-done including the modification of goals and drivers, re-analysis of customer demand and analysis of the mother corporation's build-to-order processes. As a result, some concepts were newly introduced into the mother corporation's IT systems, while others were adopted from the mother. Why was it required to re-do the general steps of implementing build-to-order? Through the integration into the mother's corporation there have been fundamental changes to the earlier business framework. The original build-to-order solution no longer fit into the new business framework.

Setting up a cross-functional initiative

The company introduced new models (e.g. 4-door passenger car) that were built on different production sites and entered new markets (e.g. Australia). Earlier, the company's business model had been limited to the headquarters and European dealers (two-tier business model). This was extended to the headquarters, market performance centers on country level and many more dealers. Consequently, overall complexity was significantly increased.

Top management, therefore, chose to implement a cross-functional initiative to stabilize and consolidate all processes, data and systems. Additionally, responsibilities, tasks and competencies had dramatically changed and needed to be re-defined. Since this initiative consists of representatives from all departments, it is assured that sustainable solutions are found.

VII. LESSONS LEARNED

Implementation efforts are lower if build-to-order can be considered from the scratch (green field approach). However, if there are radical changes build-to-order may have to be re-implemented that may result in high modification efforts. Nevertheless, inventory and stock management costs are considerably lower for a company that follows the build-to-order approach. In addition to that, the likelihood to meet customer demand is much higher.

Build-to-order is not enough!

Following a pure build-to-order approach is not feasible in most situations due to supply chain constraints and high implementation efforts. Hence, having no inventory at all is an ideal state that can generally only be reached in theory and within a static framework.

One should consider that a company that strongly follows the build-to-order approach is more vulnerable to demand fluctuations [EHR02]. For instance, in case of slumping demand that may be caused by an economic downturn plant utilization is much lower while the company cannot quickly reduce fixed costs. This will lead to decreasing profits that cannot be avoided within the short-term. From a financial point of view it might be more economic to produce vehicles on stock that are sold at a later stage while maintaining better plant utilization.

Be flexible!

Experiences suggest that the order-to-delivery process can be optimized if two competing approaches are followed: build-to-order and locate-to-order. Locate-to-order describes the "*selection of existing (standard) products according to customer requirements* [REI02]."

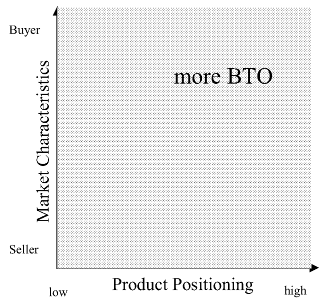

Figure 5: Optimal Mix of build-to-order (BTO) and locate-to-order (LTO)

Depending on the positioning of a product and the characteristics of a given market a company will use either more build-to-order (BTO) or locate-to-order (LTO) while maintaining the same plant utilization rate (see *Figure 5*). An automotive manufacturer of luxury cars whose customers are willing to pay a premium should stress the build-to-order approach to fulfill customer demand of tailor-made products. Instead, low and middle segment manufacturers will require more locate-to-order to achieve a faster financial turnover and a better delivery lead time. Empirical research has shown that customers of luxury cars are more willing to wait for their vehicles than customers of volume brands [EHR02].

Only companies that follow both approaches are capable of maximizing plant utilization. For example, a company may start with an 80:20 relation (80% BTO and 20% LTO). Changing market characteristics or product positioning, however, may urge the company to actively change the relation to 50:50 or suffer from a lower plant utilization rate that may fall below the critical mass. In times of high market demand build-to-order will be stressed as it allows for higher profit margins. Consequently, it is a competitive advantage to have flexible processes and systems enabling shifting proportions of build-to-order and locate-to-order.

Demand fluctuations can be better managed through using innovative stock management techniques (e.g. digital sales channel).

Following the two competing approaches build-to-order and locate-to-order offer the following advantages:

- Realization of higher profits through reduction of stock (BTO)
- Reduction of losses from unused capacity during times of low demand by pre-building stock vehicles (LTO)
- Realization of synergies from closer connection with suppliers through system partnership (BTO)
- Realization of synergies from closer connection with dealers through integrated sales channels that offer instantly available stock vehicles (LTO)
- Higher customer satisfaction by offering tailor-made vehicles that can be amended shortly before production (BTO)
- Higher customer satisfaction by offering instantly available stock vehicles (LTO)

VIII. SUMMARY AND OUTLOOK

Companies that follow the build-to-order approach can achieve a competitive advantage and higher profits due to reduced inventory. However, it is not a good strategy to solely concentrate on the build-to-order approach as it makes the company more vulnerable to changes in market demand. Instead it is suggested to follow an optimal mix of the build-to-order and locate-to-order approaches. Implementing build-to-order requires excellent process know-how. Having this competence in-house or sourcing it externally is a prerequisite.

In case of radical changes to the underlying business framework, it is critical to quickly follow the same steps as if build-to-order was first being implemented. A virtual organization consisting of key players (e.g. process owners, product experts etc.) can help to successfully migrate to a new build-to-order solution. Having people with deep process knowledge is a prerequisite for, but no guarantee of a successful migration.

It is important that all modified processes are stabilized and consolidated. This can be achieved by implementing a cross-functional initiative that brings in the company-wide view: instead of encouraging "island solutions" within single departments, the company develops sustainable and optimal solutions from the point of view of the company as a whole. Those value-oriented solutions will help the company to gain a competitive advantage (Detailed information on the cross-functional initiative to follow in a subsequent article).

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SUPPORTING TECHNOLOGIES

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Simulation-Based Value Stream Mapping: The Formal Modeling Procedure

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KEYWORDS
Value stream mapping, Simulation modeling, Database, Model generator

ABSTRACT

Value Stream Mapping (VSM) has become a popular lean implementation method in recent years. However, its drawbacks such as being time-consuming and its inability to detail the dynamic behaviour of production processes have stimulated some researchers to look for tools to enhance VSM. Simulation, which creates consensus by its model-building interface, visualization of dynamic views and output analyzing abilities has been proposed as such a tool. In this paper, we focus on explaining the simulation modeling procedure, using a company case, which leads to a meta-model that then automatically generates a simulation model. The latter is a discrete-event simulation method, which does what VSM can do, compensates for the shortcomings of the traditional static VSM, and generates the model automatically without constraints such as single unit load, capacity limitations, non-stochastic times, specific to push environment that have been addressed in the literature. Correct raw inputs, raw data processing and algorithms of converting the raw data and information of a VSM map into generator tables of the structured database are main points to be described. Further, we demonstrate the model generation and model execution. The simulation results of main measurements are summarized. This paper explores a real case by our simulation-based VSM formal method, clarifies its modeling procedure and gives a general view of the company's current system.

I. Introduction

Lean transformation, such as physical factory layout redesigns or changes of the supply chain infrastructure, involve high costs. In recent years, VSM has emerged as the preferred way to implement lean. VSM is a mapping tool used to describe supply chain networks. It maps not only material flows but also information flows that signal and control the material flows (Rother and Shook 1999). However, since VSM is a paper and pencil tool of lean manufacturing, it is time-consuming. Furthermore, VSM is a static tool, which has limitations for detailing dynamic behaviors, disability to handle the complexity and uncertainty, and causes barriers to effectively apply the improved situations. Some researchers have proposed simulation as a tool to enhance value stream mapping for lean manufacturing (McDonald, Van Aken and Butler, 2000; Lian and Van Landeghem 2002, 2003, 2004).

Owing to supply chain integration, the task of manufacturing systems modeling is becoming more complex. Alfieri and Brandimarte (1997) indicate that the variety of tasks involved calls for a modular approach, which is characterized by reusable modules, and stable interfaces to connect them and enables the designer to experiment with different alternatives by simply assembling a set of predefined building blocks. Several other researchers (Thomson, 1994; Drake et al., 1995; Valentin and Verbraeck 2001, 2002, Son et al., 2003) also point out the importance of reusability of building blocks for simulation modeling. Objected-oriented simulation languages are well suited to the purposes of the approach. Based on these arguments, we have chosen an objected-oriented simulation language, Taylor Enterprise Dynamics® (Taylor ED) as our modeling language. Building blocks are called "atoms" in the simulation language of ED.

The idea of a simulation-based VSM formal method is that the functions of the VSM icons in a Value Stream Map can be obtained by composing a similar "map" of VSM atoms (building blocks) that we designed, together with some ED standard atoms. The VSM Atoms in a simulation model can be interpreted as VSM icons in a value stream map. They are object-oriented, self-contained, reusable modules of a simulation model and describe the behaviour of entities (e.g. machine, product, buffer, storage, etc.) within a manufacturing system. Modeling the material and information flow in such a system is achieved by connecting the input and outputs (channels) of the VSM atoms through the model generator.

In our formal VSM Modeling method, a model generator written in Enterprise Dynamics' programming language 4DScript reads this data from a database with several tables (a Microsoft Access database in our application), takes the required atoms, connects them and generates the simulation models through a wholly automated process. It reads the entity types/names, layout/location of the entities, the relationships between the entities, and transforms all these messages into a simulation model. This database describes the resources/entities, their layout and relationships within a manufacturing system and contains all the information which normally occurs in a VSM.

In this paper, we describe the modeling procedure of the formal method through a real company case. The company, located in Belgium, is a major manufacturer of poultry and pig raising equipment, including feeding, drinking, storage and feed transportation systems. The current manufacturing system of their division "Components Production" encounters a capacity problem on a machine (HYDRAP). The detailed input information including a VSM of current state will be provided in Section III of the paper.

II. The formal VSM Modeling and Simulation Procedure

There are 5 steps in the modeling procedure as Figure 1 shows. We describe the steps as follows.

1. **Determine the required Raw Input Data through a VSM Map**
   The aim of our VSM formal method is to enhance traditional VSM and compensate the drawbacks of it. Therefore, first of all raw input is to draw a VSM map of the system that the manager would like to investigate. This static VSM provides some basic information that we need for the model generator tables such as numbers of entities (atoms) in the system, locations of the entities (x, y, z coordinates), simplified flows, setup times and cycle times. To generate the links between atoms, we will need detailed flow descriptions. It is important that a "routing table" which describes the paths of all the simulated products is supplied in this step. While the VSM map provides the "table of contents" of the model, and the basic topology of information and material flows, most detailed data can be obtained directly from the company's ERP database, possibly after some reformatting and filtering.

2. **Data Processing of the Raw Input Data**
   Data processing is a step that transforms the raw input into the data format that can be used by the model generator. After the processing, 4 generator database tables ("Atoms", "AtomConnections", "AtomChannels" and "ParameterValues") are produced. A detailed conversion algorithm of the "Connections" table will be illustrated in Section IV.

3. **Model Generation**
   In this step, the model generator selects the atoms (model building blocks) from the model library according to the data in the "Atoms" table, connects the atoms (relationships) as stated in the "AtomConnections" and "AtomChannels" tables. The behaviour of the atoms in the model follows the data in the "ParameterValues" table when executing the model.

4. **Model Execution**
   During model execution, the production control atom (VSMCUST02) will read in the order data provided by a table atom (T098-Table). With these two atoms, the release of orders can be simulated in two ways, push (MRP) or pull (Kanban). By ticking the "Product" box to "on" or "off" (Figure 2), the production control atom will release "products" or "containers". In the first case, the released products will push to downstream. In the second case, the containers request (pull) the order quantities from upstream and flow them through the system.

5. **Simulation Results**
   Operational output measurements such as lead-time, value-added time, value-added ratio, machine utilization and queuing time are available after model execution.

III. Illustrating the Modelling steps using the case study

The current VSM of the company is shown in Figure 3. This manufacturing system consists of 31 main atoms (entities). Over the reference period to be simulated, the production control center (atom ID 18) releases 975 production orders of 382 different components to work stations. There are a total of 8 entities of workstations in the simulated system: (1) HYDRAP, (2) metal shear, (3) laser-punching machine, (4) MULLER, (5) bending<2m, (6) bending<4m, (7) Outsourcing, and (8) Others. Work station 1, 2, 4 are single-server workstations. Workstation 3, 5 and 6 are stations with parallel machines (capacity 3, 2, 2). Workstation 7 is an outsourcing process whose cycle time is not considered in the simulation and workstation 8 is a general workstation representing all other machines in the system. Before each workstation, there is an entity of staging inventory (ID 10-17) presenting the work-in-process. Some other entities are: order staging (20), warehouse (9), measurements (21), Order / flow type / cycle time / setup time data tables (19, 24, 25-31). The 975 production orders are also represented through atoms in the system, but they are only produced during model execution, not in the stage of model generation. Therefore, we don't need to consider them here. The released orders are only influenced by the data in the order data table (ID 19).

In the production process, each component has a routing (flow type). In the routings table (Figure 4), the first column indicates the flow type and following columns the sequential steps. For example, when production control releases the production order of a component with flow type **1**, this component will be manufactured through the system with the following sequence: 1) going to WIP inventory **16** and wait for the process of workstation 8, 2) processed by workstation **8**, 3) going to WIP inventory **15** and wait for the process of workstation 1 of HYDRAP, 4) processed by workstation **1**, HYDRAP, 5) going to WIP inventory **17** and wait for outsourcing process, 6) outsourcing process **7**, 7) going to the warehouse (magazijn, atom ID **9**). Thus, it reads "**1-16-8-15-1-17-7-9"** in the first row of the routing table. Most information at this stage can be entered manually, or be generated automatically from an ERP database (as was done in this case).

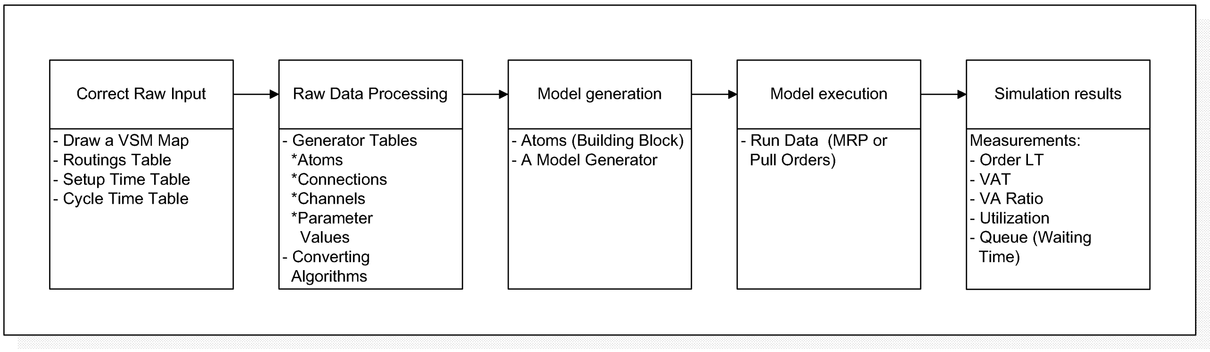


Figure 1. Modeling Procedure of the Simulation-Based VSM Formal Method

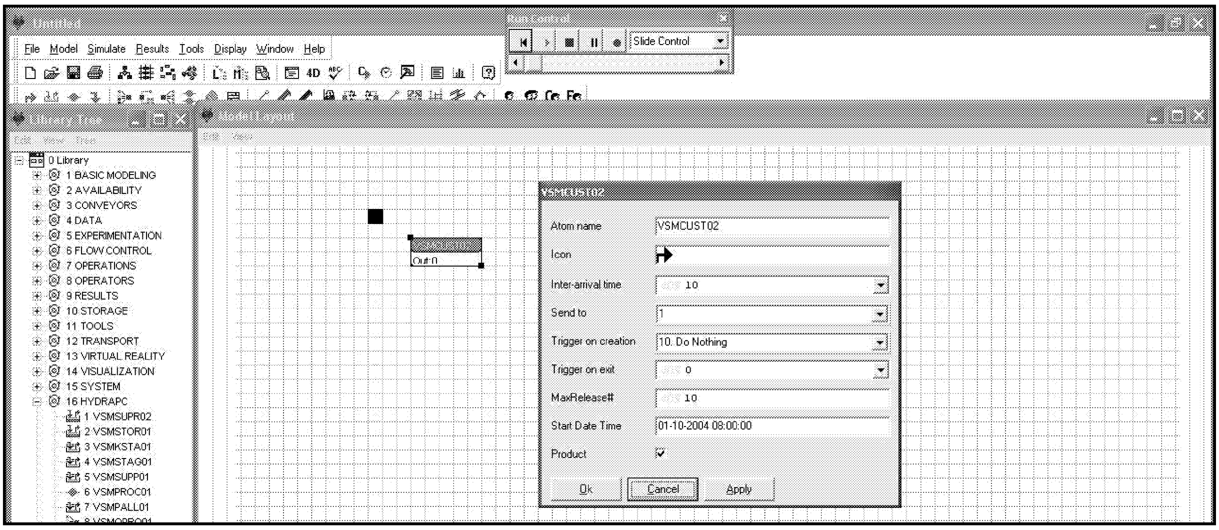


Figure 2. Production Control Atom (VSMCUST02)

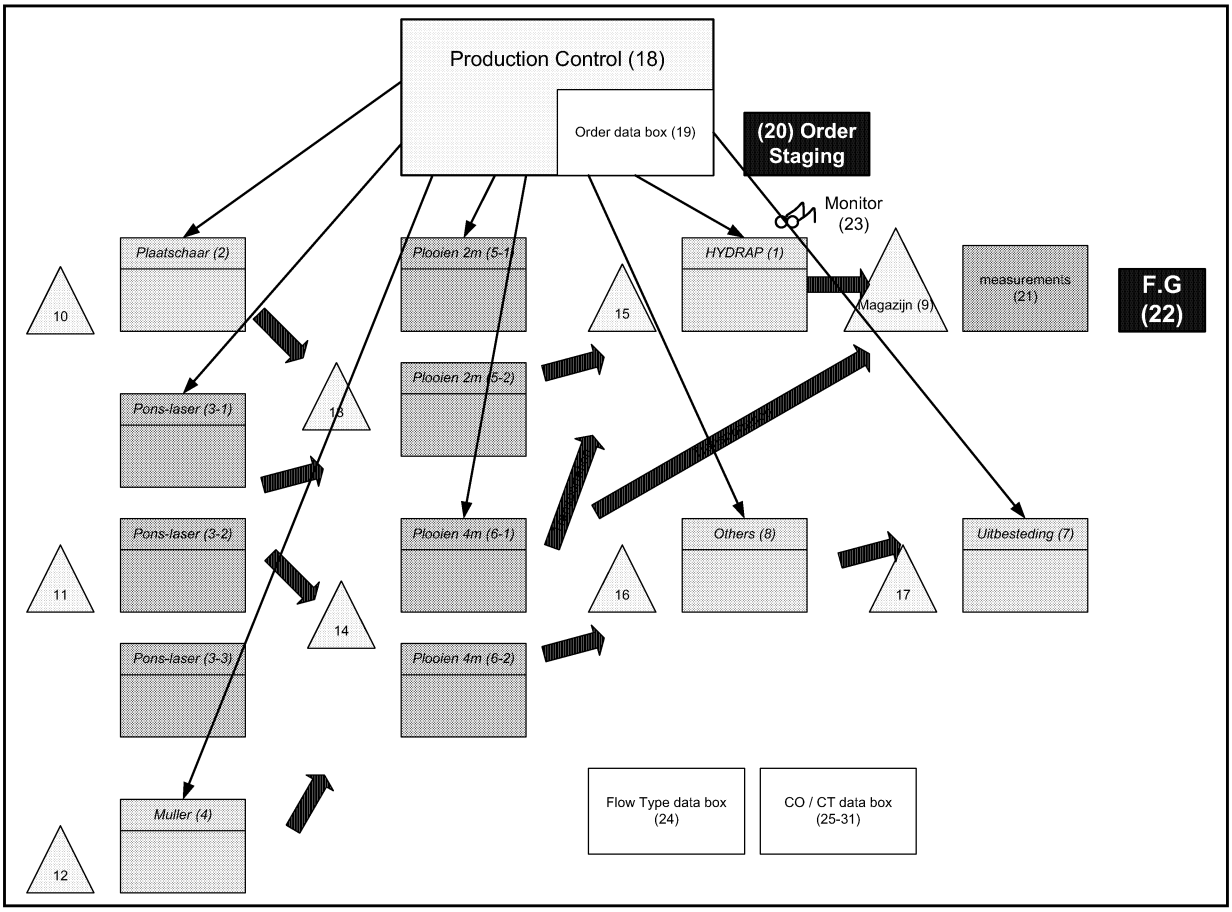
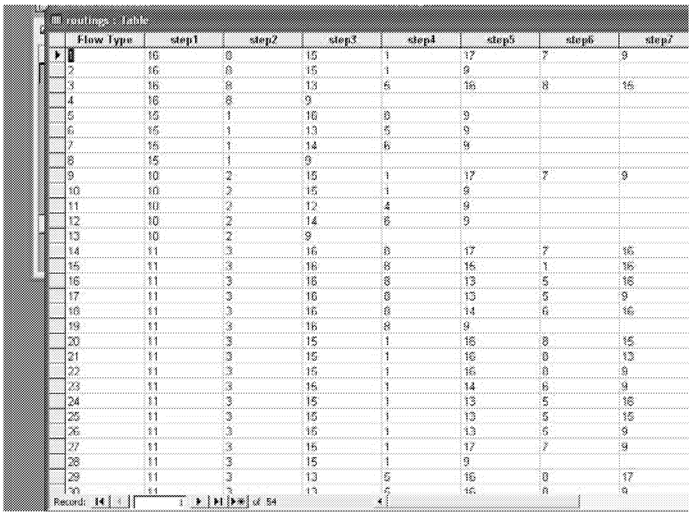


Figure 3. Current State of the Value Stream Map of the Case Study



routings : Table

Flow Type	step1	step2	step3	step4	step5	step6	step7
1	16	8	15	1	17	7	9
2	16	8	15	1	9		
3	16	8	13	6	16	8	16
4	16	8	9				
5	15	1	16	8	9		
6	15	1	13	5	9		
7	15	1	14	6	9		
8	15	1	9				
9	10	2	15	1	17	7	9
10	10	2	15	1	9		
11	10	2	12	4	9		
12	10	2	14	6	9		
13	10	2	9				
14	11	3	16	8	17	7	16
15	11	3	16	8	15	1	16
16	11	3	16	8	13	5	16
17	11	3	16	8	13	5	9
18	11	3	16	8	14	6	16
19	11	3	16	8	9		
20	11	3	15	1	16	8	15
21	11	3	15	1	16	8	13
22	11	3	15	1	16	8	9
23	11	3	15	1	14	6	9
24	11	3	15	1	13	5	16
25	11	3	15	1	13	5	15
26	11	3	15	1	13	5	9
27	11	3	15	1	17	7	9
28	11	3	15	1	9		
29	11	3	13	5	16	8	17
30	11	3	13	5	16	8	9

Record: 1 of 54

Figure 4. Routing Table of company case

IV. Data Processing – Conversion Algorithm

The data processing procedure transforms the raw input into the data format required by the generator tables. In our previous work (Lian and Van Landeghem 2004), we have explained the more straightforward rules for filling the tables. In this paper, we further develop the algorithms that convert raw data into generator data automatically. An example of "AtomConnections" table generation is illustrated in this section.

As shown in Figure 5, a programmed conversion algorithm of "AtomConnections" table reads raw data from the routing table (Figure 4), converting the linear sequence of process steps into pairs of cells, for every 2 consecutive cells. This information is stored as a FROM-TO matrix. For example, the values of first 2 consecutive cells of flow type 11 are 10 and 2. The programmed algorithm will locate the matrix cell, identified by the row id 10 (FROM cell) and the column id 2 (TO cell). Then, cell (10,2) will be set to value 1. After all combinations of 2 consecutive cells are read, the remaining cells are set to 0.

We can see in Figure 6 the Routing Matrix for the Case study. Its cell (10,2) is equal to 1 (record 3, field 11), which means that an output channel of atom 10 is connected to that of atom2. All other cells from column 10 are equal to 0, indicating that the output of atom 10 has only a relationship with the input of atom 2. If we want to see the input relationships of atom 10, we need to refer to the row of atom 10. In this way the routing matrix displays input and output relationships (connections) of all the atoms in the system. The algorithm further counts the number of input/output connections and generates input/output channels (ic/oc) for each atom. These are written into the "AtomConnections" table automatically (Figure 7). We can see that atom 10 (record 37) has only 1 output channel, which is linked to the first input channel of atom 2.

The programmed algorithms of generator tables are written in 4Dscript in a *.fnc file which is a function file of ED. Our model generator is also a 4Dscript file. In order to execute the algorithms easily, we added them as menu selections in ED. We added the menu "Model / Import Database Table / (Atoms Table, AtomConnections Table or ParameterValues Table)" and these tables will be filled automatically by selecting the menu or by shortcut key such as "Shift+Ctrl+D" (used to run the algorithm of generating "AtomConnections" table, See Figure 8).

V. Model Generation and Execution

The model generator reads the processed data from generator tables, takes the required atoms (entity types/names), locates the position (layout/location of the entities), connects them (the relationships between the entities) and transforms all the messages from the database into a simulation model automatically. The model generator is data-driven so that different data source under the same database structure will produce various simulation models using only the generator. This is an important point, since the VSM method always required modifying the current state map into one or more future state maps. Hence, the generation will allow to quickly achieve new future models, using the same raw data as input. In this way, the simulation runs will automatically be comparable, since they are based on the same set of orders, machines, etc.

After running the model generator, a simulation model is generated automatically in terms of the data set from the 4 generator database tables. Figure 9 is a screen shot of the generated company model (current state).

VI. Summary of Simulation Results

We summarize the simulation output in Table 1 and 2. As we can see in the histogram "Utilization" within the model of Figure 9, the utilization of HYDRAP is high. Its average utilization is 55.3 % and average waiting time of each order is 347.22 minutes before it can be processed by HYDRAP. The average order lead-time is 0.236 days and the value-added time is 0.036 days. There are 300 orders that cannot be fulfilled before their due date. This is 31% of the 975 production orders that were released during 3 months.

VII. Conclusions

In this paper, the detailed simulation modeling procedure of our simulation-based VSM formal method is demonstrated by a real company case. It illustrates a fully automated cycle, starting with corrected raw input data from the company's ERP database, and ending with a fully funtional simulation model and its results. The different data processing algorithms that convert raw data and information of a VSM map into the generator tables in a structured database are explored. The generation of the current state model also provides us a general view of its current system. Further research will focus on more elaborate examples, in order to explore the best rules to aggregate the extensive ERP data into representative simulation models of limited complexity.

By using a rather simple and intuitive paradigm such as VSM Maps, combined with a simulation model generator, very large and complex models can be generated without much effort. We consider this to be a genuine breakthrough, and hope it will overcome the aversion that many companies (especially small ones) have regarding the use of simulation models to support their tactical decisions. Of course, to achieve this we will have to keep a balance between the realism of models (i.e. very complex ones) and the insight they can offer (i.e. simple models). We are convinced the VSM paradigm, combined with our generator, can provide this balance.

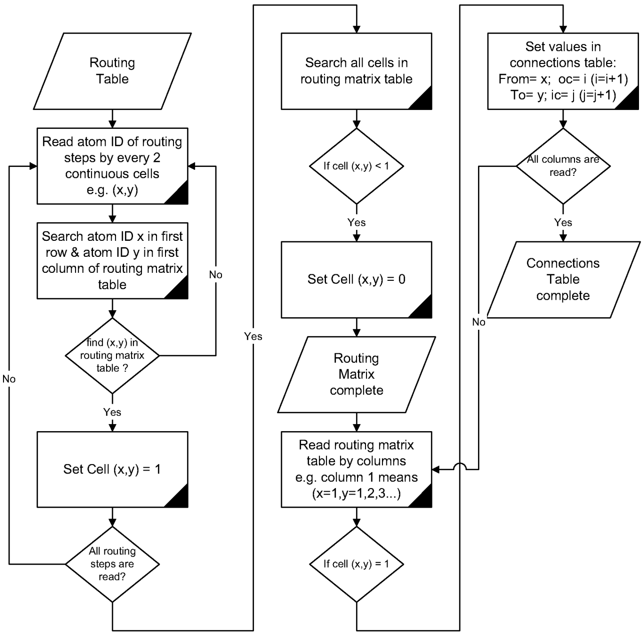
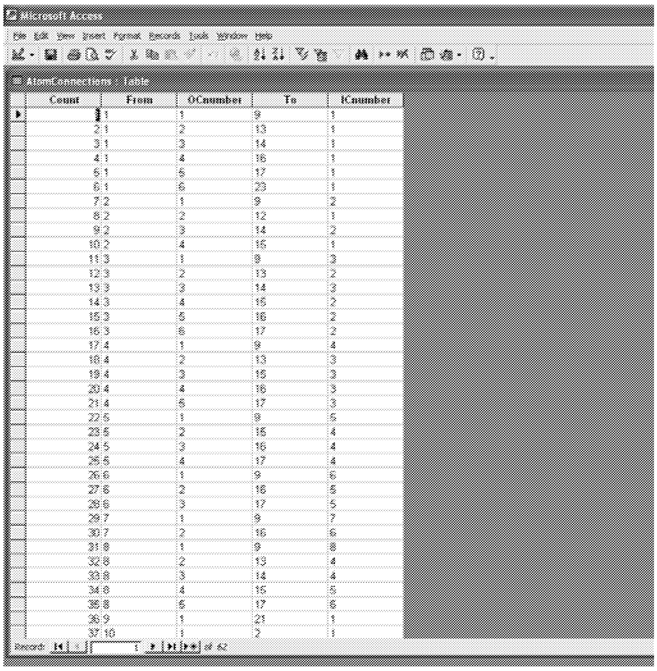
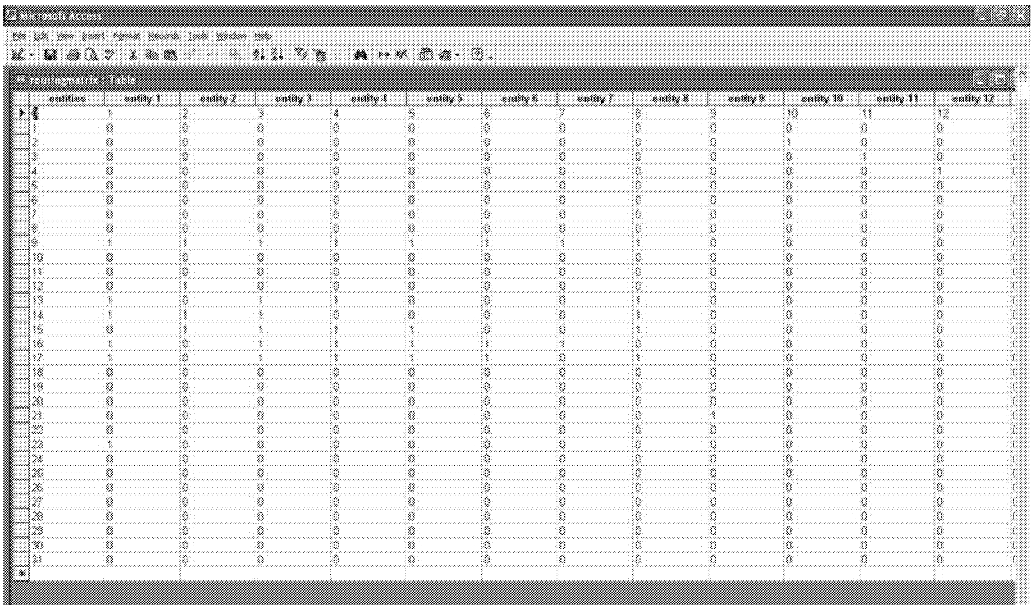


Figure 5. Conversion Algorithm of "AtomConnections" Table



Count	From	OCnumber	To	ICnumber
1	1	1	9	1
2	1	2	13	1
3	1	3	14	1
4	1	4	16	1
5	1	5	17	1
6	1	6	23	1
7	2	1	9	2
8	2	2	12	1
9	2	3	14	2
10	2	4	15	1
11	3	1	9	3
12	3	2	13	2
13	3	3	14	3
14	3	4	15	2
15	3	5	16	2
16	3	6	17	2
17	4	1	9	4
18	4	2	13	3
19	4	3	15	3
20	4	4	16	3
21	4	5	17	3
22	5	1	9	5
23	5	2	15	4
24	5	3	16	4
25	5	4	17	4
26	6	1	9	6
27	6	2	16	5
28	6	3	17	5
29	7	1	9	7
30	7	2	16	6
31	8	1	9	8
32	8	2	13	4
33	8	3	14	4
34	8	4	15	5
35	8	5	17	6
36	9	1	21	1
37	10	1	2	1

Figure 7 "AtomConnection" Table



entities	entity 1	entity 2	entity 3	entity 4	entity 5	entity 6	entity 7	entity 8	entity 9	entity 10	entity 11	entity 12
	1	2	3	4	5	6	7	8	9	10	11	12
1	0	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	1	0	0
3	0	0	0	0	0	0	0	0	0	0	1	0
4	0	0	0	0	0	0	0	0	0	0	0	1
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	1	1	1	1	1	1	1	1	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0	0
12	0	1	0	0	0	0	0	0	0	0	0	0
13	1	0	1	1	0	0	0	1	0	0	0	0
14	1	1	1	0	0	0	0	1	0	0	0	0
15	0	1	1	1	1	0	0	1	0	0	0	0
16	1	0	1	1	1	1	1	0	0	0	0	0
17	1	0	1	1	1	1	0	1	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	1	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	1	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	0	0	0	0	0	0	0	0	0
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0
28	0	0	0	0	0	0	0	0	0	0	0	0
29	0	0	0	0	0	0	0	0	0	0	0	0
30	0	0	0	0	0	0	0	0	0	0	0	0
31	0	0	0	0	0	0	0	0	0	0	0	0

Figure 6. Routing Matrix Table

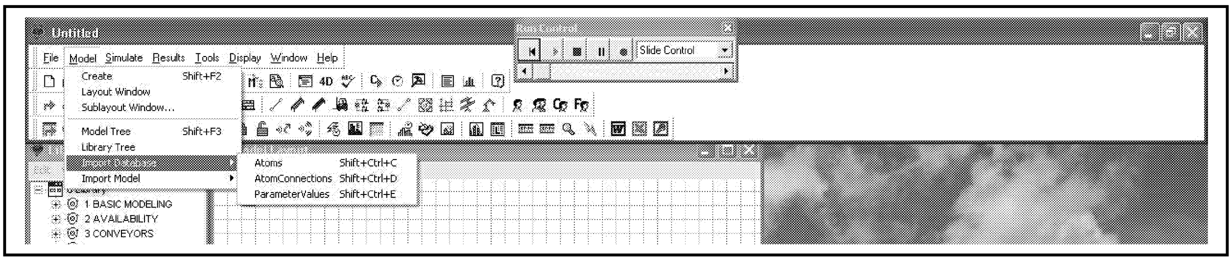


Figure 8. ED Screen Menu for Database Generation

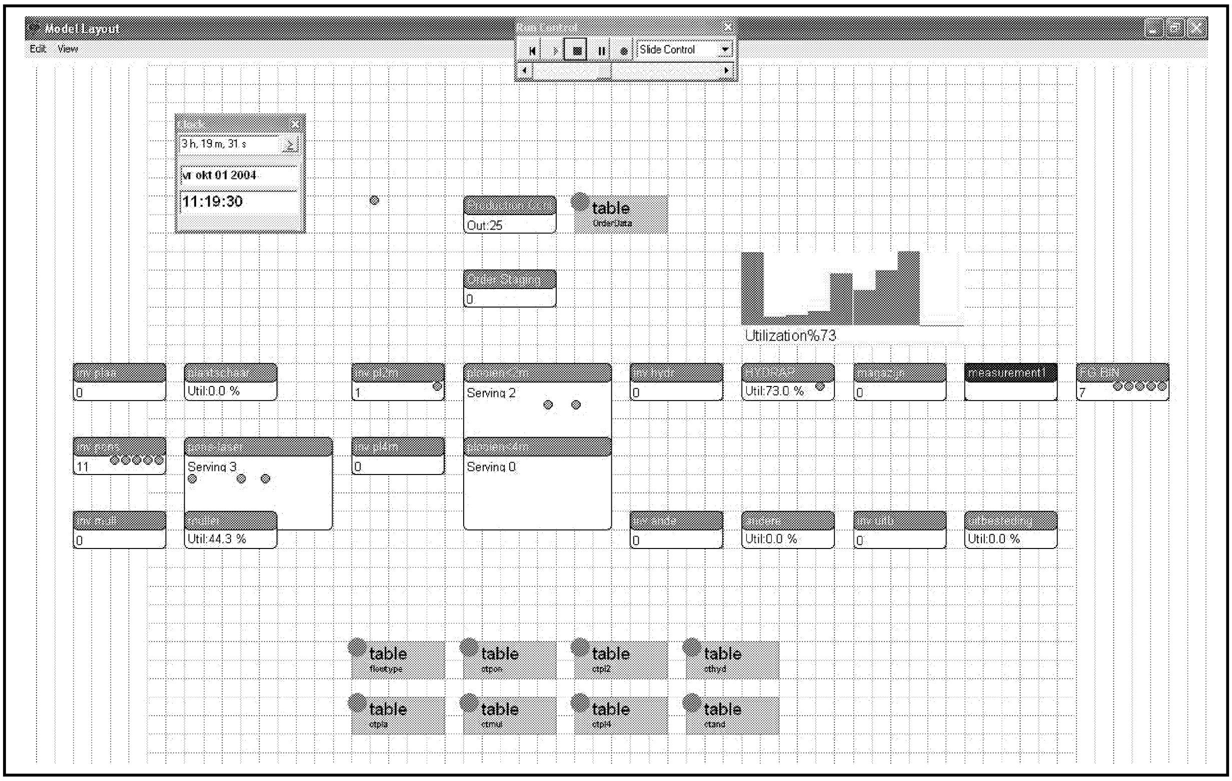


Figure 9. Generated Current State Model of the Company Case

Table 1. Machine utilization: Simulation results (1) *

Work Station	Shear	Laser-Punch	MULLER	Bending<2m	Bending<4m	HYDRAP
Utilization (%)	2.1	53.2	19.1	55.3	10.6	55.3
Waiting Time (min)	8.41	265.25	159.04	122.85	8.77	347.22

* Based on 2 shifts

Table 2. Lean Indicators: Simulation Results (2)

(In Days)	Lead-Time	Value-Added Time
Average	0.2360	0.0360
Max	2.1713	0.4413
Min	0.0012	0.0003

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A COMPONENT BASED APPROACH FOR SYSTEM DESIGN AND VIRTUAL PROTOTYPING

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KEYWORDS

Systems engineering, system design, component based approach, Petri nets, UML, virtual prototyping, VHDL/AMS.

ABSTRACT

This paper is primarily concerned with system design. The considered systems are heterogeneous, such as those that include both hardware and software parts. The complexity of such systems is taken into account by a rigorous method for analysis of the requirements in order to progress to system design and virtual prototyping. Presented is a component based methodology, using UML formalism and Petri nets. The virtual prototyping is performed using the high-level design tool "Hiles Designer". "Hiles Designer" is a graphical tool that allows the description of components and their relationships by means of Petri nets. A simulation in order to verify the virtual prototype of the designed system is possible via a translation into VHDL-AMS. The example of a fuel injection pump is used to illustrate the presented approach.

I. INTRODUCTION

The design process of heterogeneous systems based on several domains (software, electronics, mechanics, etc.) cannot be developed in the same way as single domain system design. It is therefore necessary to adopt a rigorous design approach.

The Systems Engineering process recommended by INCOSE (International Council on Systems Engineering) describes the required phases for optimal system development. The EIA 632 standard (EIA 632; Martin 2000) defines the necessary technical processes for system design from the product specification to the utilisation phase. This standard puts the design process as the central part of development, between the acquisition and supply process and the product realisation process.

The step concerning component realisation is developed taking into account the initial requirements, without predefining an architecture for the solution that would satisfy the specifications. For this we can use a top-down approach to obtain one or more architectures from the requirements defining the system.

The technical evaluation process and the technical management process are driven for and from the acquisition, design, and realisation processes. The objective of the former is among others, to insure the verification of the requirements, and the validation of the system. This can only be done if the architecture of the system, or at least a part of it, is completely defined. Thus a validation by simulation of the solution can be considered.

In this paper we present a component based approach for system design. This component approach has multiple benefits, including:

- Isolation of the constituting elements of the system. This can be attributed to the separation of the domains responsible for the heterogeneity of the system. In this way the complexity of the system can be reduced, because it is shared across several parts that are considered separately;
- Increasing the know-how and reuse during the process based on previous design efforts. In fact once the design has been achieved, the component is also a solution for the technical requirements (Hall et al. 2001);
- As a result of the top-down approach, components are described with different levels of abstraction, resulting in a composite structure from the approach development. Components are themselves described as a coherent assembly of components from lower abstraction levels.
- Finally, the components of the lowest abstraction level are described using behavioural models. Their description in a common language (such as VHDL/AMS) provides a solution to validate by simulation the entire designed system.

Our component based approach is a globally top-down and iterative approach. The first step is to consider the technical requirements that the designed system must satisfy. Using UML formalisms and Petri nets models, the result is one or more solutions organised as a hierarchical structure of components.

Petri nets are useful in modelling parallelism and time constraints. There are numerous examples of work based on the common use of UML with Petri nets (Bondavalli et al. 2001; Bouabana-Tebibel and Belmesk 2004; Pettit and Gomaa 2000).

The validation of the obtained solution is performed using the "Hiles Designer" tool by virtual prototyping in VHDL/AMS.

This introduction has described the problem and provided a general idea about the proposed approach. Section II of this paper shows how our approach uses the specifications of the system, and Section III demonstrates how to determine the basic elements for one or more solutions. Section IV is concerned with the designer viewpoint, and explains briefly the principles of the validation for the designed system. Finally, Section 5 summarises the paper.

II. REQUIREMENTS ANALYSIS

In this first design step, the analysis is carried out from a user viewpoint of the system, and not from the viewpoint of the designer. The goal is to translate the requirements specification by means of a component based approach.

II.1 Requirements Specification

The requirements specification is the output from the preliminary studies performed by the project manager. This document is produced through many dialogues with the different stakeholders, as the contained list of user needs must be as exhaustive as possible in order to enable the stakeholders to develop solution (Meinadier 1998). Such a list is therefore the starting point of our approach. The example of a fuel injection pump is used to illustrate the implementation of this approach.

The system is responsible for adjusting the gas mixture (fuel / air / exhaust fumes) for a four-stroke engine (Figure 1). The real time control system will need to generate two types of information:

1. Discrete information based on time considerations such as activation date and duration, to control the injection time (variable according to the operating mode of the engine).
2. Continuous information to control the position of the recirculation valve, for the circulation of part of the exhaust fumes (to limit pollution).

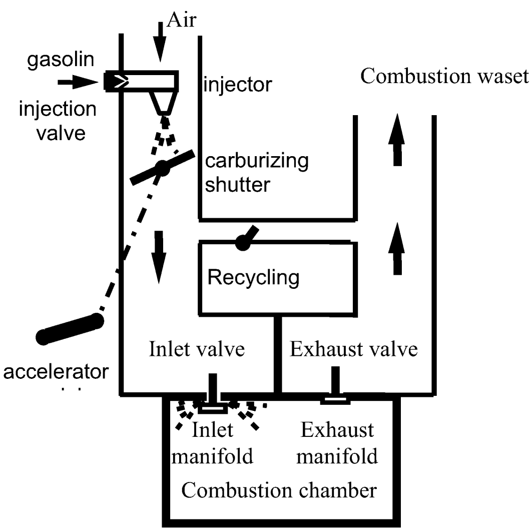

Figure 1: Fuel Injection Pump

II.2. Environment Description

The purpose of this step is to consider the number of elements with respect to the system. A preliminary list of elements is established (Table 1).

Table 1: Elements of the Environment

Elements of the Environment
Exhaust Gas Recirculation
EOS (Exhaust manifold Oxygen Sensor)
Water T°
RS (Rotation Speed RPM)
OOS switch (Off/On/Start)
Throttle Position
Injector
IGP (Inlet manifold Gas Pressure)

When the definition of the elements of the environment is completed, we can schematize the interaction within the "system-environment" through a context diagram. Figure 2 shows a summary of the relationships and the exchanged signals between the system and the environment.

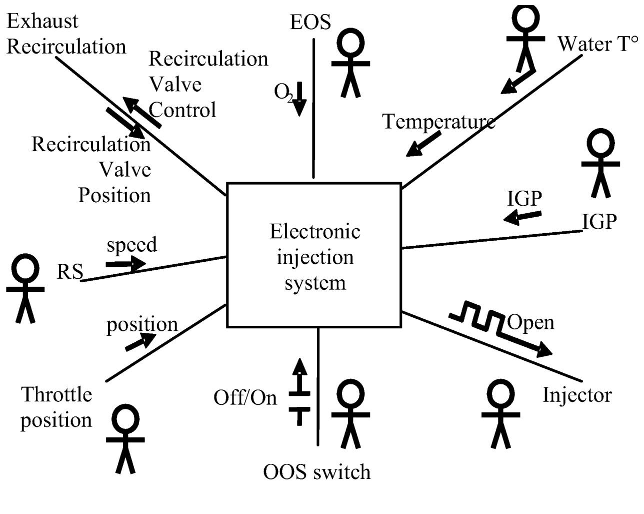

Figure 2: "System - Environment" Interaction

It is now necessary to work with abstraction elements in order to apply a component approach. The concept of actor defined in UML (Booch et al. 1999; Muller and Gaertner 2000) is used define the abstraction elements. The determination of these actors can be based on the following criteria:

- Role of the element
- Interaction between the elements
- Active or passive nature of the element
- Etc.

By applying the proposed criteria, elements of the environment can be organised and grouped. New elements are defined with a higher level of abstraction than the first. For the case of the fuel injection pump, 3 new elements exist as shown in Table 2.

Table 2: Abstraction Elements

Elements of the Environment	Abstraction Elements	Signals
Exhaust Recirculation	Exhaust	valve control
EOS		exhaust O_2
Recirculation Valve Position		continuous
Water T°	Engine	continuous
RS (engine)		cont. speed
OOS Switch		discrete actions
Throttle position	Inlet	cont. position
Injector		discrete control
IGP		cont. signal

II.3. Time Requirements Analysis

The time analysis of the requirements enables us to define possible actors. For this example, we focus on the "injector control". We do not consider here other temporal requirements such as "power on", "engine starting", "gasoline flow computation", or "exhaust gas recirculation computation", etc.

Constraint:

It is necessary to determine the correct instant for the injection control relatively to the motor strokes.

Analysis:

According to the firing order, a cylinder is in the power stroke and another in the intake stroke. The injection order can thus be synchronized on the firing signal, with a variable delay determined according to the rotation speed.

Conclusion:

The role of the firing order is very important because it is used as a reference for the injection control. It is therefore necessary to consider it as an element of the system, and will be taken into account by the engine actor.

This analysis step is reiterated for the other temporal requirements. All the deduced actors are potential elements of the overall system.

II.4. Selected Context Diagram

The context diagram shown here (Figure 3) is based on the abstraction elements of the environment, and the temporal requirements. Each one is linked to the others by the flow of exchanged information.

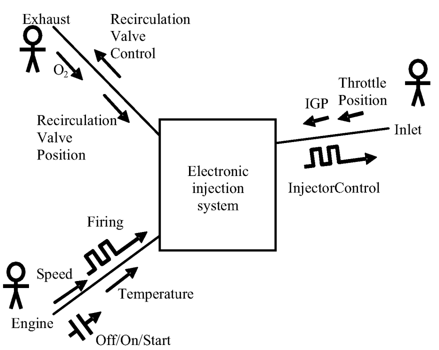

Figure 3: Selected Context Diagram

III. FUNCTIONAL ANALYSIS

III.1. Operating Scenarios

According to the specification, this step of the approach leads us to obtain different operating scenarios based on the different operating modes of the system. The scenarios are first considered from an abstract aspect.

The operating modes are:

1. Starting and Heating
2. Constant speed
3. Acceleration
4. Deceleration
5. Stopping

We now take the operating modes: **Starting and Heating**

- Start by the Off/On/Start switch
- Beginning of starting (threshold given by the AGR_starting_threshold table, an Air-Gasoline-Rate table)
- Computation of AGR adjust
  - Open loop control of the gasoline flow based on AGR_starting table
- Heating (heating time from AGR_starting table)
- Achieve operating temperature.

The operating scenario based on this operating mode can be expressed with a UML Use Case (UC). UCs group like scenarios and concerned actors in a single diagram. Scenarios are then linked using elementary relations such as Include and Extend.

III.2. Use Case

According to the different operating modes listed, we can draw the UCs for the different operating scenarios (Figure 4): - Starting and Stoking

This operating scenario is a specific UC. The control is based on a pre-determined value (AGR_starting) without exhaust gas recirculation.

- Gasoline Flow Computation

The computation of the gasoline flow at the operating temperature is another specific UC for the engine. This UC includes several sub-UCs.

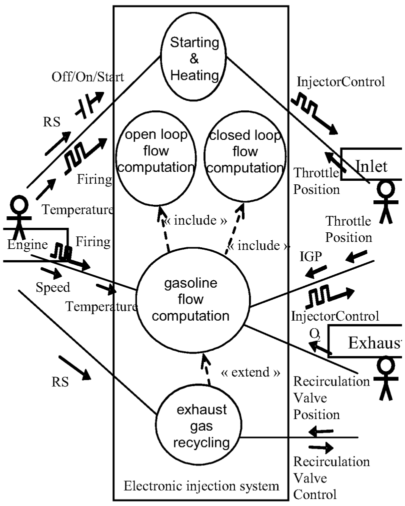

Figure 4: Use Case Diagram

III.3. Elements Relation Diagram

The objective of the Elements Relation Diagram (Figure 5) is to give an idea of the composition of the physical elements of the environment, and their relationships. It is possible to use the UML Class Diagram formalism, but this does not prejudge the constitutive objects of the system, as their definition will be performed in the design phase.

III.4. Sequence and Collaboration Diagrams

A detailed description of the scenarios can be based on Sequence Diagrams of UML. Here we express the interactions between the potential components of the system in the design. Initially these components can be deduced from the actors of the system. To more clearly express the scenarios, the sub-components can be used instead of the components themselves (Figure 6).

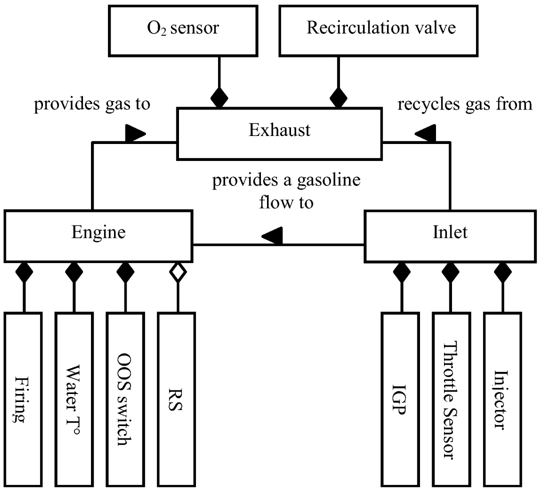

Figure 5: Elements Relation Diagram

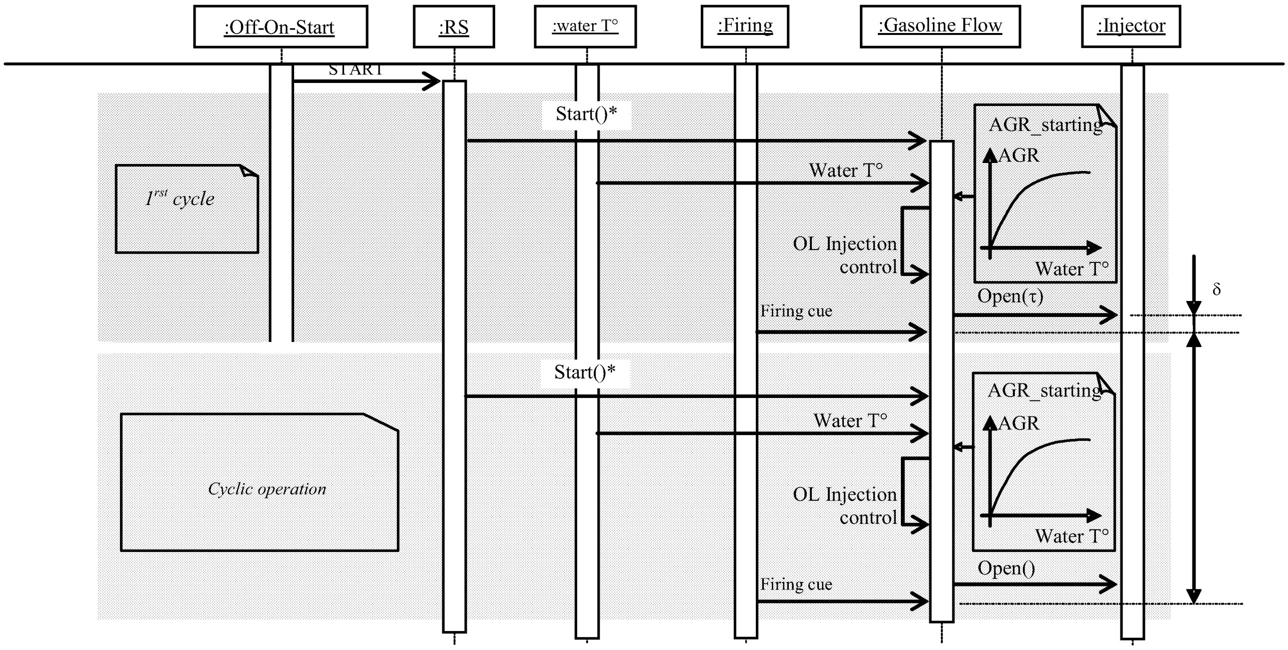

Figure 6: "Open loop gasoline flow computation" Sequence Diagram

Another type of diagram that can be used to express all the exchanges between the components is a Collaboration Diagram. This presents all the roles played by the objects in a particular context, as well as the interaction between these objects. Figure 7 is the Collaboration Diagram associated to the Sequence Diagram in Figure 6.

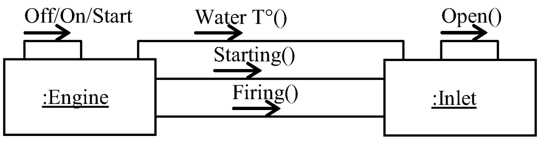

Figure 7: "OL gasoline flow comp." Collaboration Diagram

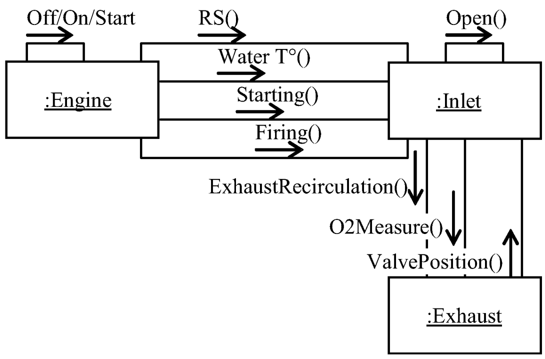

Figure 8: Final Collaboration Diagram

Additional sequence diagrams are necessary to obtain a complete picture of the system. Figure 8 shows the Collaboration Diagram obtained as a final view of the different scenarios and their associated Sequence Diagrams.

The Collaboration Diagram shows the interactions between the components from the user viewpoint. The design phase will be used definite the effective objects of the system as the third step of the proposed approach.

IV. DESIGN PHASE - VIRTUAL PROTYPING

IV.1. Design Phase

This step is the first one to introduce the designer viewpoint. The goal here is to obtain a solution based on components of the system. This is appropriate given that the components have been obtained during the preceding steps. But, “Are they all necessary?”, Must they be grouped together?”, and “Is there enough components?”. The following guide can provide some answers to these questions:

- Retain the active objects, i.e. those that include data, treatments, and a behavioural description
- Consider the actors of the Use Case diagrams. They are generally good candidates, but sometimes logical objects (such as speed, trajectory, etc.) also have to be considered.

For the fuel injection pump example, "Engine" is an appropriate candidate because it exists in several Sequence Diagrams. Furthermore it provides some working conditions of the system. "Inlet" and "Exhaust" are also candidates for the same reasons. The analysis step showed the role of each of them therefore we are satisfied that there are enough components.

To keep the system independent from the technology, it is necessary to define an object for the environment interface. Two components are added, one for the sensors, and one for an actuator (the Recirculation Valve).
The last considerations are timing constraints. They require the definition of an entirely new component, called "Timer".

Finally, the components list is as follows:
- "Engine" (active component)
- "Inlet" (active component)
- "Exhaust" (active component)
- "Sensor" (passive component)
- "Actuator" (passive component)
- "Timer" (hardware component, necessary for the calibration of the injector control impulse)

In accordance with the object concept, it is appropriate to use Classes for the description of the components. The classes are described with the following structure:
- Non-functional needs
- Functional needs
  - Public data
  - Private data
- Behaviour
  - External behaviour (relationships with the same level components)
  - Internal behaviour (described at the lower level)
- Methods
  - Processing provided by the class to other classes.

For such a class, the behaviour can be expressed by way of Petri nets with some information deduced from the Collaboration Diagram. Ordinary Petri nets are used for the description level shown in the example, however, enhanced Petri nets are available for particular descriptions. For instance, the internal behaviour could be modelled by differential predicate-transition Petri nets when discrete and continuous data are linked together (Nketsa et al. 2004).

Based on ordinary Petri nets, Figure 9 shows the external behaviour of the "Engine" object. This object is related to the "Inlet" component by way of three method calls: Reg_Starting(), OL_Reg() and CL_Reg() (for Regulation Starting, Open Loop Regulation, Closed Loop Regulation respectively).

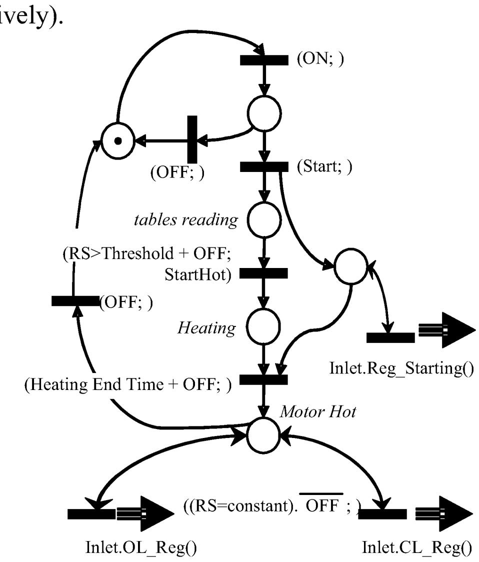

Figure 9: External Behaviour of "Engine"

Once all the components have been defined, an architecture diagram can then be drawn. Because of the timing constraints, some objects of the system are necessarily hardware components, such as a programmable timer, useful for the synchronisation impulse and for its length, and a firing sensor, that provides the required information for timing considerations. Figure 10 shows a possible architecture. It is to be noted that the firing sensor component is an instance of the sensor component.

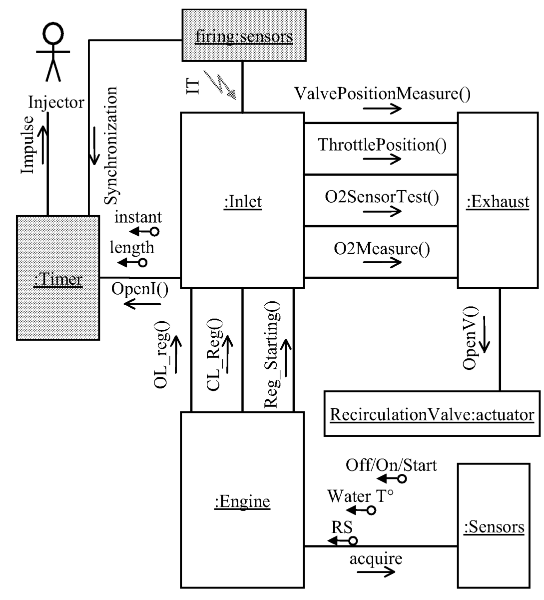

Figure 10: Architecture Diagram

Adding an instance associated to each of the sensors leads to a more complete representation. Depending on the complexity of the description, these instances are either at the same level of the active objects or included in them.

IV.2. Virtual Prototyping

All the components of the system can be described with the "Hiles Designer" tool (Hamon et al. 2004). This tool is used to obtain a virtual prototype of the system. Each component is associated to a HiLeS block, those behaviour is described by the Petri net of the modelled object.

The blocks are linked together by the methods of the classes they depend on. When all the elements are translated into VHDL/AMS (Nketsa et al. 2004), the validation by simulation of the virtual prototyping is possible.
The "Hiles Designer" tool allows the designer to input system specification by way of a graphical format (with related information) using a top-down design technique.
Figure 11 is a representation of the "Engine" component.

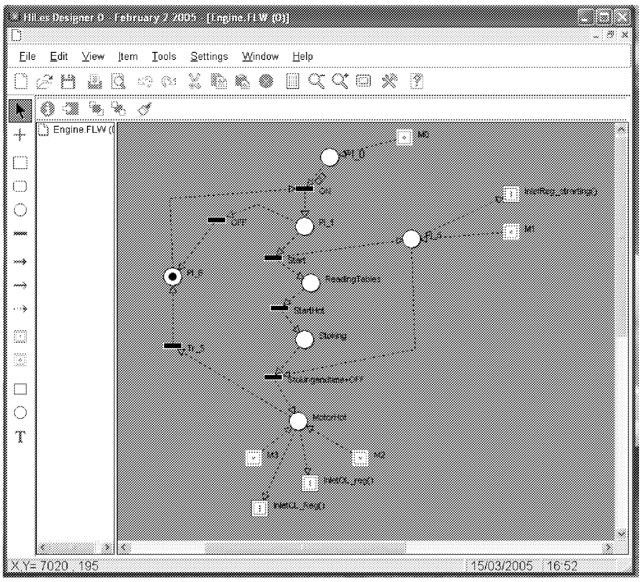

Figure 11: "Engine": “Hiles Designer” Screen Dump

The steps described lead to a first level of the virtual system prototype. The design phase must be repeated for those components that need to be detailed. The obtained architecture is then a hierarchical structure based on structural blocks. The modelled behaviour of the final blocks (called "functional blocks" in Hiles Designer) is translated into VHDL-AMS for a complete virtual prototype.

V. CONCLUSION

This paper shows how a component based approach is used for system design. The input of the approach is based on the requirements specification of the system. The output is a possible solution architecture of the system. A virtual prototyping is built using the "Hiles Designer" tool. The translation into VHDL-AMS allows the validation by simulation of the solution.
The fuel injection pump example was used to highlight the main steps of the approach and its practical application.

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ENGINEERING DATA MANAGEMENT AND INFORMATION MODELLING

CAPITALIZATION APPROACH OF THE DESIGN SITUATION BASED ON THE INTERACTION CONCEPT AND THE COGNITIVE ORGANISATION VIEW

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KEYWORDS

Design process, traceability, work - situation, interaction, cognitive organization

ABSTRACT

The aim of this paper is to propose a new modelling approach to improve situation traceability in design activities. Our assumption is that the product is the result of various interactions, implying different actors. In every interaction, a particular actor may contribute with a specific role. Our models describe an organization of the entities contained in the design situation and a classification of the different interactions among these entities. They take into account the cognitive organization of the activities according to their goal, defined in the corresponding task. We will also discuss the formalization of our concepts and their exploitation with a view to design traceability tools.

INTRODUCTION

During the past ten years, the development of new methods and techniques has lead to an improvement of the results of the engineering activities. Design process management takes an increasingly high place to reduce time to market. Nowadays, each complex artefact, such as car, is defined with the interactions of many actors (sometimes more than several hundreds), working on different elements of the design (Hatchuel, 1996), (De Terssac, 1996).

Due to these reasons, keeping the history of the design activity presents a great interest for all competitive enterprise, the aim is to capitalize the best practices and contribute to their development.

However, the knowledge actually used and produced by the designer during his activity is at most difficult to be explicit because knowledge is often mobilized during an unforeseen interaction (for example: help actions, improvised meetings to solve a particular problem, …)

Generally, every activity achievement is related to the dynamics of the context. When a new task appears, the actor recognizes similarity between the current situation and past situations that he has already faced. These similarities direct the plan to be followed to perform his activity. The result of this activity will be observed by changes on elements of this situation. In this situation, the actor identifies some partners' requirements and their actions effects. According to this situation identification, he decides about his interactions with the others.

The design capitalization process must take into account the context evolution (Kwan et al., 2003)

In design activities, the result is in general different from the initial goals of the mission because of the cognitive character of this kind of activities and the specific character of this domain.

The purpose of this paper is to present a new approach of traceability in order to keep the history of the work situation. This approach is based on the concept of interaction between a set of interrelated entities, it includes also a representation of the cognitive organization of the action plan before and during the activity. First, we present an overview about the design activity and our distinction between the concept of task and activity. Then, we present a model to make links between these concepts and finally the meta-model of the situation.

CHARACTERICS OF DESIGN ACTIVITY

Simon (Simon, 1991) defines design as a succession of problems solving. Each actor makes his own representation of the problem to be solved and deals with others according to this representation in order to get coherence.

The design characteristics were discussed by several authors (Darses, 2001), (Perrin, 1999), (Micaëlli et al., 2003), (Lhote et al., 1999)... For example, three points can be distinguished.

- The task goals are not completely defined at the beginning, there is **not an** only "good solution", but the actors establish several consensuses to get the most satisfying one. Also, there is neither a unique nor a predetermined way to obtain this "best solution". (Brown *et al*. 85)
- The design is a distributed process during which there is a permanently production of intermediate objects until obtaining the final solution (Blanco 1998).
- Consequently, the final solution of a design process is the result of several interactions coming in a dynamic and constraining context.

According to these points, the design process could be compared as an automatic system tending towards a moving target defined by the objectives. The goals and the results will be built simultaneously and progressively during the project. At the end, the results value tends to the goals value with a signifying distance. This distance informs about the actor's performance.

Then, we suggest describing the design progress with two concepts: “task” and “activity”. In this way, it is possible to represent both the evolution of the design goals (requirements) and the evolution of the corresponding activities results.

COGNITIVE ACTIVATION

According to the internal view of the competency model (Bonjour et al, 2002), (Dulmet & al, 2003), the cognitive activation of competency during the actor's activity could be split up into the three following steps:

Situation identification

We assume that, during a mission, the first mental task is the identification of the actual situation. The actor has to take in charge the actual mission. To do this, he has to perceive, translate and understand the preliminary information on the mission (i.e., task to perform and action framework). From some recognized elements, he has to identify a known class of situation, referred to a specific scheme. So, an acquired scheme is activated. The scheme gives the generic frame to the action.

Anticipation and inferences

The scheme is able to adapt itself to the actual variables of the situation thanks to inferences. These mental processes are calling various cognitive resources (concepts, declarative and procedural knowledge) that are specific to the action. They produce an action plan and action rules (linkages conditions). This action plan is an instanciation of the scheme according to the situation particularities.

Decision and control

The last cognitive processes are decision making and action control. Decision-making generates the real action. Control assumes that first, there is an evaluation of the actual situation related to the foreseen events, and second, there are corrective actions to compensate possible gaps and to reach the action plan (planned sub-goals). These processes are calling two kinds of specific resources:

- Behaviour rules, which are given in an explicit, or not manner by the management and the Organization,
- Mobilization factors which are coming from last experiences, from the actor's interest for his mission.

This model is based on the Piaget theory. A scheme is an entity that integrates heterogeneous cognitive components into a structure, specifically related to the aims and to the action context.
These concepts are a base of our model and we suggest integrating it in our representation using three descriptors:
The situation is represented as a system of inter-related entities.

- The perception stage is represented by a “useful situation” class, which contains all-important elements for the actor regarding to his activity.
- The cognitive organization of the activity is represented by an «action plan» class, which contains all planned actions. The structure of this plan can be modified during the activity.

THE CONCEPT OF TASK

Our definition of the task concept results from the ergonomics and the "skill management" fields (De Montollin, 1994) … Some authors of industrial engineering will approve it (Hernandez, 1995), (Lhote *et al.*, 1999), …
“***Task corresponds to the description of the goal (expected results or requirements) as well as the associated conditions (constraints and*** evaluation criteria***) to reach these goals***”. Task is “ **what is to do in the system**”, it is a set of processing: physical transformation and/or information processing and/or problem solving. It concerns a set of given planned objects (material or immaterial inputs). The objective of the given task is to produce a set of expected outcomes (resulting objects or outputs). The success of the task goal is judged according to a set of evaluation criteria.
Achieving a task implies a transformation on the state of the principal object and possibly, some of secondary objects. Before performing, the cognitive actor will make an interpretation of all assigned objectives, and also of all elements that form his action framework. (Bonjour &al, 2001).
Formally, task T = {Goal ; Object ; Manager ; Recipient; Constraint ; Support } (fig. 1)
Action framework contains all complementary information about the general context.
Task version is used to record all task progressions, (redefinition of goals, state modifications…) Task is considered completely achieved if all goals are satisfied according to all the evaluation criteria.

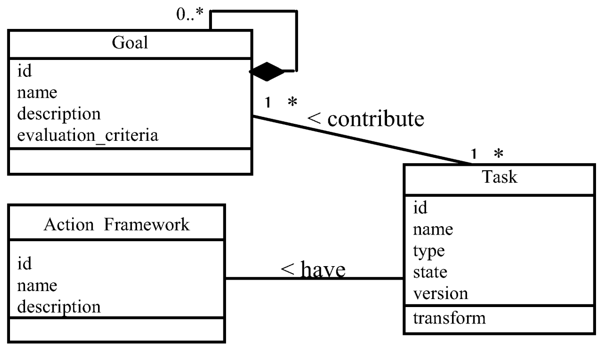

Figure1. The concept of task

CONCEPT OF ACTIVITY

Activity is described in an environment known as "the achievement environment", it is of an operational nature and it is defined as a set of physical and mental actions, by which the actor implements all material and informational resources he has to dealt with, in the actual situation he has to face, as well as possible, to achieve the mission which is entrusted to him. (Hernandez, 1995).
We represent activity through the following elements:

- The task to perform and constraints,
- The direct object treated by the activity (+ possibly of the intermediate objects),
- The cognitive actor (and participants),
- Material or informational resources,
- Various context elements.

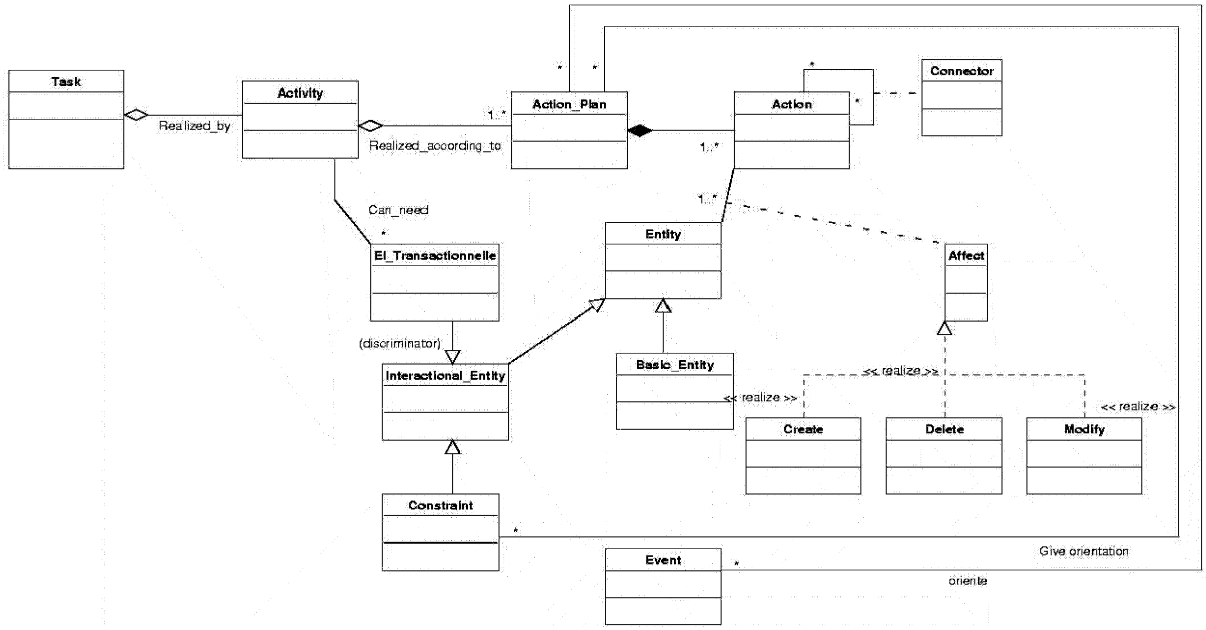

figure 2. The model of activity achievement

The activity results are given by the following elements:

- The new object (or new state of object)
- Action plan (which describes the activity organization)
- New constraints
- Informational exchanges between cognitive actors.
- States changes of the participating resources.

As it is shown in the following figure (figure2), every task is carried out by an activity according to an action plan. At the beginning, the cognitive actor defines his action plan (recorded in release 0), completely or partially. The action plan contains a set of structured actions (or semi structured actions), the result of each one will be the creation, the deletion or the modification of one or more entities of the situation.

During the activity, several modifications can be observed on the action plan (every modification is recorded in a new release). These modifications are the results of either new events not envisaged at the beginning, or the presence of new constraints, generated by the concerned activity or by activities of other cognitive actors.

The action plan (planned sub-goals) give an appreciative representation of the cognitive organization of the activity; it is a description of the manner with which the actor intends to reach the task goals.

ACTIVITY RESULT

As it is shown in the diagram of activity achievement (figure2), the result of any activity can be the creation, the deletion of an entity or the modification of his state. Activity results can be obtained by listing the different states of concerned entities before achievement and these states of the same entities after achievement (figure 3).

The result is presented in three lists:

- The list of the result “creation” includes all concerned entities which have the state before achievement = empty 0
- The list of the result “delete” includes all concerned entities which have the state after achievement = empty (0),
- The list of the result “modify” includes all concerned entities for which the (state before) ≠ (state after) ≠ empty.

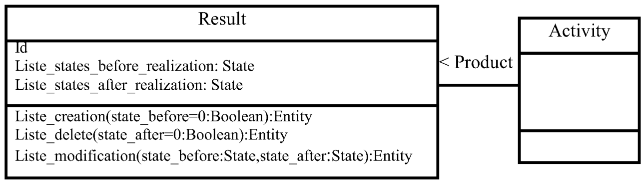

figure 3. Activity result

ACTION VIEW

Every modification on the plan structure imply a new cognitive action on the internal dimension, it can be a creation of a new external action (analysis, design…), the deleting of some actions or some order changes. In fact, this modification is the result of the presence of new constraints or new events.

In order to approximate the cognitive functioning of the design actor, two main kinds of action will be distinguished:

- External action: includes all actions which have an effect on at least one object of the external situation (regarding to the actor) .
- Internal action: concerns the actions that imply a modification of the action plan (new action, deletion of an other action...).

We distinguish five kinds of external actions covering all aspects of the design situation and can indicate about the main nature of the activity (figure4). The internal action has as object one or more external actions.

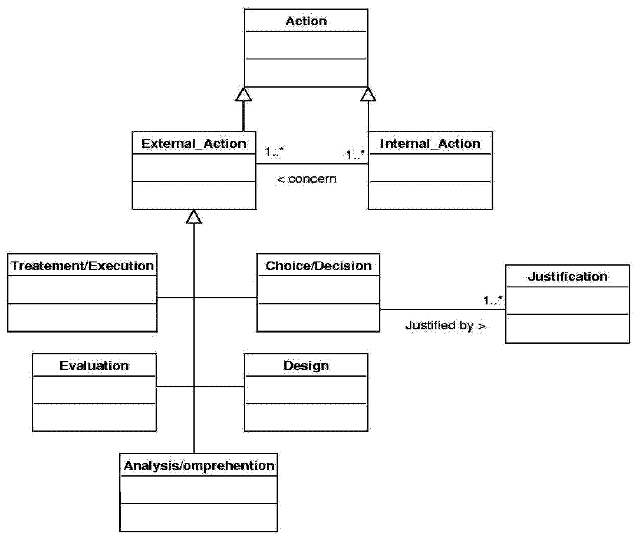

Figure 4. Action view

- Analysis/Understanding: The aim of an analysis action is to extract new knowledge from the studied situation (or the studied problem). The result of this kind does not affect the state of the studied entities.
- Research/Design: It is the action of imagination and proposition of solutions to the target problem (technical, managerial or other problems). This kind of action can affect the situation by the creation of some hypothesis, new definitions… But it does not modify the states of studied entities.
- Evaluation: An action of evaluation gives information about properties of an entity or sub-entity regarding to some criteria. This kind of action can help to classify solutions and it has no important effect on the entities state.
- Choice/Decision: The action of decision has a direct or indirect effect on at least the state of one entity. The decider chooses the best solution (technical or managerial) between some alternatives regarding to his goal and related constraints.
- Execution / treatment: This category concerns all the actions that will produce physical or informative transformations on the object. It have a direct effect on at least the state of one entity. For example: the determination of a parameter value, the resolution of equation, simulations, …

CONCEPT OF SITUATION

Definition of situation concept

We put the concepts of situation and interaction at the centre of our approach and we study the contribution part of each actor in any interaction. We discussed the concept of the work situation in preceding papers (Belkadi *et al.* , 2004), we defined it as: " **the situation is a set of various entities and of various interactions describing globally the external environment in which an actor mobilizes his competencies".**
Three representation levels of the situation are distinguished according to the actor perception:
- The Concrete situation S_C: Includes the set of all existing elements in the situation.
- The Observable situation S_{obi}: Presents a set of entities and relations, which can be observed by an actor in his situation
- Useful situation S_u: Concerns all entities and relations observed by an actor and judged as relevant by this actor in the achievement of his task.

We associate a special form of situation to those levels, called **modelling situation Sm**. This form includes all the entities and relations observed by an external modeller. The model of this situation includes all entities and relations that can be observed by all the actors. So we assume that an external modeller can perceive the situation in a more complete manner.

Definition of the entities

We distinguish two kinds of entities:

- *Basic entities (BE) or concrete entities:*

They gather all the human actors (called individual entity) and the material resources (called physical entity) like product components, work tools, communication tools, …

- *Interactional entities (IE) or abstract entities:*

They describe links between the entities. Three forms of interactional entities are distinguish:

- Operational interactional entities witch describe the various tasks an actor has to perform.
- Community interactional entities establish a membership link between functioning rules.
- Transactional interactional entity that describes the various mechanisms of information exchange between actors during the realization of their collective tasks. Specially the cooperation and coordination mechanisms

Definition of the roles

The contribution nature of any entity in an interaction is supported by a set of specific relation Rij that we name "Role". Each entity among interactional entities is able to have a role. In fact, the role is a representation of the interpretation that an actor makes of his environment. Roles can have different significance according to the entities, which they refer to.
We distinguish five kinds of roles in accordance with the organization theory (Uschold *and al.*, 1998) (table 1):

Question	Role	Description
Who?	Actor	Entity which directly participates to the interaction
For whom?	Customer	Customer order is always downstream, and the entity describes the need
About what?	Object	Entity on whom the interaction acts…
With what?	Support	Entity that indirectly participates to the interaction.
How?	Manager	Entity that controls the interaction.

Table 1. The roles classification

THE SITUATION META-MODEL

According to the upper definition), the meta-model of the situation is described in the UML class diagram (figure 4) by a set of entities and roles. Any object of the entity class can be related to an other object of the interactional entity class according to a specific role, which is described as an instance object of the class role. The class "weighting" contains information about the importance degree given by an actor to any component of the situation.

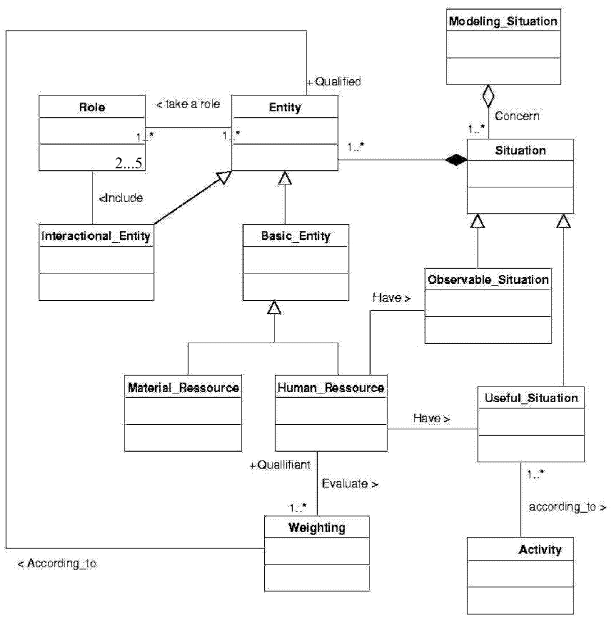

Figure 4. The Situation Meta model

The class role is a generic class that have five specific classes (Actor, Manager, Support, Client, Object). This formulation can make easier the browsing among different aspects of the situation model and be used to generate useful view.

CONCLUSION

In this paper, we have presented a new traceability approach of the design activities based on the concepts of situation and interaction. This approach includes an approximation of the internal organization of the designer's activity. It intends to help users to analyse the cognitive activation during design process.

We make two strong assumptions: The first is that the analysis of any design activity (or project) requires a multidimensional representation: it can include the task goals, the activity resources, its achievement and its results. The understanding of the achievement process must integrate an analysis of all the interactions (various) produced during the process.

The second hypothesis assumes that it is possible to apprehend the contribution of each actor in a project, starting from the analysis of his various elementary contributions. For this, we have established a systemic adaptation of the role concept (borrowed from the organizations theory).

The concept of internal action can be useful to describe how the cognitive actor organizes his actions before and during the achievement of his task. If we compare the evolution of the action plan and simultaneously the constraints evolution, the events occurring and the transactional interaction, we can get some ideas about the cognitive functioning of the designer and possibly find some reasons of project failure.

The prospects of this work are to contribute to improve the understanding of collective work and to favour the knowledge capitalization in design. It can be used to help managers to get a diagnostic of the project.

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META DATA AS A BASIS FOR THE CONTEXT SENSITIVE PROVISION OF INFORMATION

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ABSTRACT

Saturated markets with increasingly customer specified products, services and problem solutions require an increasingly customer focused performance. The trend to concentrate on core processes wherein companies are able to realize advantages compared to competitors due to know how and a head start of information and resources is the expression of a global change in gaining added value. New variations of cooperation are created by combining different Business Capabilities in value added networks.

The increasing competition requires the companies to rethink their previous strategies and to implement partly radical changes. Agility flexibility as well as the associates' integration in (partly) automated business processes constitute the real challenge. No longer does the simple invested capital compose the companies' success and value. In the first instance there are rising invisible values mainly of the requirement oriented provision of information and communication support which are expressed through the organization and the cycle of comprehensive business processes.

INTRODUCTION AND MOTIVATION

Due to the globalization, the increasing pressure of time and cost and the progress in information technology companies of the information age show completely different principles of added value (Grabowski and Klimesch 2003). The increasing competition demands the companies to rethink their hitherto strategies and to partly implement radical changes. Saturated markets require customer oriented products and problem solving (Höbig 2002). This means a highly increasing demand for the requested competences and abilities, which can often no longer be provided within a company economically.

This leads to concentrate on core competences and to perform services in value networks (Wiendahl 2003). The complexity of the entire system increases due to the hereby emerging outsourcing of competences to partners. By this, an increasing meaning is coming up to the complexity management and simultaneously to the control of transaction cost (Intra Enterprise Consulting 2004). Agility and flexibility i. e. adaptability are required more than ever. This is significantly expressed by networking comprehensive business processes (Bley et al. 2003; Heinrich and Betts 2003). The integration and interaction of all incorporated associates in and with these (partly) automated business processes enable the companies to gain advantage in competition.

In the meantime business processes are recognized to be what they really are: chains of activities as a logical consequence of using abilities (business capabilities), which are performed by different organisations. The development of "optimal business processes" with new ways of cooperation requires an ability management (business capabilities) and the herewith linked information of knowledge, structures and experiences (META 2002).

The requirement and business process oriented provision of information and support of communication also beyond the companies' borders presents the challenge for companies (Spath 2001; Spath et al. 1999). Connected information describe a context (Grabowski and Klimesch 2003; Nonaka and Takeuchi 1997; Selinger 2000; Vester 2003). Therefore the task is to provide this context in the individual process steps to all associates of the involved organisations. The complexity of the whole system is increased by outsourcing the competences or abilities (Business Capabilities) to partners. By this, the danger exists to become inflexible, because many partners are quickly involved, coordination can be increased dramatically and transparency is lost.

Future oriented companies therefore mainly need transparency of all business processes, involved applications and systems as well as a context and requirement oriented provision of information and possibilities of interaction with these business processes.

META DATA BASED INFORMATION SYSTEMS AS A BASIS FOR COMPLEXITY MANAGEMENT

The system theory explains the terms of complexity and complex systems. Different components are linked in complex systems. Because of that, a composed complex conglomerate is built up. Complexity therefore characterises the state of organization comprised in a system.

The components are chosen and structured in a way they realize capacious business processes which cannot exist in a non structured bulk of parts ("emergence" in the structured complex unit is generated more than in the sum of parts). The features of a complex system also remain, when individual parts are changed in the meantime. This is a significant aspect for the inspection of information and knowledge provision in value networks (Beer 1959; Zerdick 2001).

Highly developed complex structures keep themselves stabile by organising their internal structure as a whole so that the components among each others and outside structures are interacting (Malik 1989). The interacting business processes keep the entirety stabile. Only if the components differ from each other they have to interchange information (specialization, differentiation), but they also have to be sufficiently similar in order to interact.

In complex systems, business processes interact in a way, that they cannot be broken down to simple linear "if-then-sequences" (Kruse 2004). Consequently complexity means multi causality, multi variability, multi dimension ability and openness. Here appropriate new concepts in complexity management will be playing a decisive role. They have to guarantee the view on the entire system (go to the outside, consider the whole system or a specific part from a bird's point of view and find relevant patterns) and to guarantee a fast and accurate information transfer. The task therefore is to provide all associates of the involved organisations with this needed context sensitive information in individual process steps.

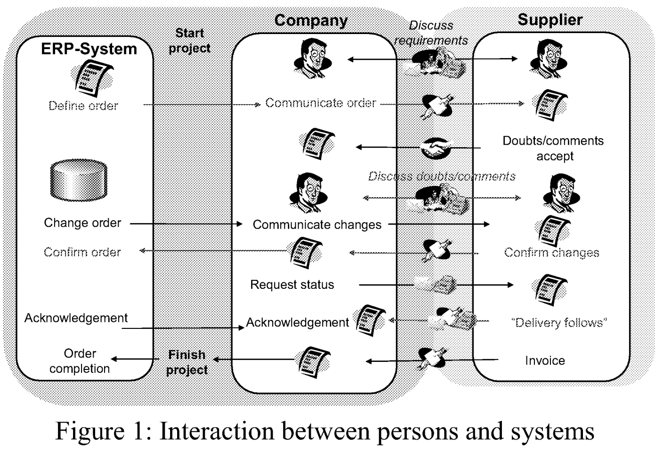

Figure 1: Interaction between persons and systems

INFORMATION PROVISION DEFICITS IN BUSINESS PROCESSES

Companies increasingly face the necessity to exchange data and information between systems and applications internally and externally with their partners (companies, associates). Due to the high dynamic in value networks, the requirement arises to quickly adapt to changes and to flexibly react on unexpected situations (Grabowski and Klimesch 2003; Spath et al. 2001a). This requests decisions through involved associates with the appropriate specific process knowledge which are decisively influencing the business process' operation (Spath et al. 2001b; Sternemann 2000).

The bulk of unstructured data and information arising from documents, emails or memos which are necessary for a founded decision constitutes an outstanding challenge. To find and "process" them in actual process step requests much more time and attention compared to structured data from operational standard software. At the same time, the system change and the complexity of the individual application with optimised interfaces for "power users" is aggravating the necessary speed and performance for "real-time-enterprises". Hereby the big challenge to be worked out by appropriate concepts and tools is getting situational access to the proper information at the right moment.

REQUIREMENTS-COMPATIBLE PROVISION OF INFORMATION IN BUSINESS PROCESSES

In transfer research area 48 G 3 of the german research foundation (DFG), the methods and concepts worked out in the special research area 346 were checked with regard to a requirements-compatible provision of information and conversion relevance in manufacturing companies. The basis are analyses of the industrial partners' determined business processes to elaborate a defined business area considering the required abilities. Necessary competences, requirements of information and communication during the individual process phases were analysed and structured. In Figure 1 manifold interactions between humans are exemplarily shown in automated process flows.

At several involved companies Microsoft Office was presupposed as a basis for the appropriate user interfaces. Systems to be integrated were SAP R/3, Tieto Enator, MBS Navision Attain, Easy Archive and several company specific applications for standard applications. Unstructured information primarily concerned office documents, emails and scanned (paper) documents in different sizes as well as intranet information (internal websites). Thus, the prototypical implementations base among others on available Microsoft products. As a user interface the XML based Microsoft Office 2003 with the actual upgrade Information Bridge Framework (IBF) (IBF 2004) is used among others. IBF uses the following concepts for the provision of information and the consistent return of information objects:

- Enabling the users to detect information objects and to act from and with office applications (for example Microsoft Office Word 2003, Microsoft Office Excel 2003 & Microsoft Office Outlook 2003)
- realisation of XML support for Microsoft Office Systems
- offer for a standardised, meta data driven access to:
  - "official" information objects (entities) of interest
  - relations with entities beyond multiple back end systems
  - context related access and action possibilities with entities by using "smart tags" or "attached scheme office documents"
- interactive web services and meta data for the use of entities (i. e. idocs, RFCs) in standard applications for example SAP R/3

On the basis of thus provided and situational prepared information, associates are also supported through notification of specific knowledge carriers and offered communication possibilities during business process' execution. The relevant information from the existing systems is extracted, aggregated and conditioned.

In collaboration with the incorporated companies production planning processes, service processes, order and inquiry treatment processes were prototypically implemented as an example - each with a high request of structured and unstructured information. The focus here is the associates' oriented and process conducted communication and interaction focussed on the conjunction of enterprise applications in order to provide an unimpeded information flow in and between the companies in an adequate time.

A further challenge has to be seen in the organisation of complex transactions going on between applications having to satisfy the individual business processes. I. e. in an exemplary business process associates are often faced with the problem of quick decision making depending on results of profit margins' analyses compared to material and logistic dependencies. The focus of the examination is the notification of a good's lead time to the customer referring to production bottle necks due to customer specific changes of variations and the resulting machinery occupation. Thus, the employee has to decide within shortest time, which customer receives which order.

This scenario necessitates having access to the customer's data base within shortest time in order to make reliable statements if possible during the phone inquiry on for example the delivery period. Here, priority of customers has to be considered, which is shown by a requirements appropriate customer history from the applied CRM system. This customer history is completed by additional information regarding open invoice items, actual order backlog, executed and overdue orders with relating detail information from ERP Systems (SAP R3, MBS Navision Attain). In addition, the customer's payment history (obligo) as well as its credit limit and information on securities (i. e. Hermes insurance and amount of insurance) influence the decision.

All information can be shown graphically. Memos and telephone notes of the associate, visit and service reports as well as access to existing customer contracts or the claims' data base expand within the Office surrounding.

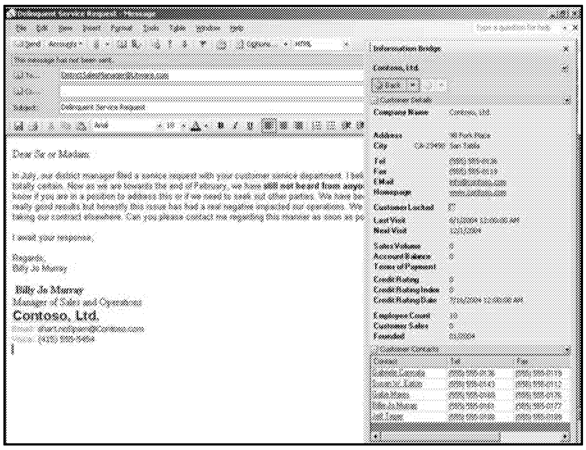

Figure 2: Customer's email and situational provision of information on the basis of XML and meta data

Following, the possibility to provide a context sensitive information is shown by a typical course of a claim:

The first contact person in the company is receiving an email (Figure 2) with a customers claim due to a delayed handling of a service request. In Figure 2 the incoming customer email and on the right side the interactive task pane with the relevant customer data are shown. These data from optional applications or disk spaces are provided on the basis of meta data and interactive web services on the basis of XML and WSDL.

In order to properly classify the priority and relevance of this claim and to initiate appropriate measures the associates need detailed information having a correlative significance in connection with the service request.

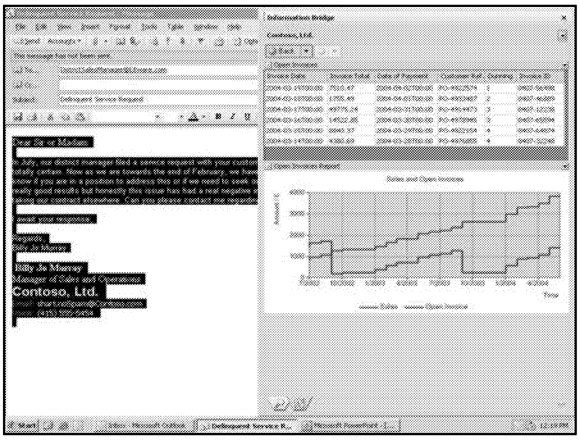

Figure 3: Provision of important information (i. e. sales and open invoices with the course of time) for decision making

In Figure 3 "open invoices" are exemplarily shown as financial information with corresponding diagram, showing courses of sales and open invoices. The access to this information is only possible with an appropriate authorisation. Rolls and authorisations from different applications (i. e. SAP R/3 or MBS Navision Attain) are handled through single-sign-on mechanisms and authenticity checking.

Figure 4: Initiation of a context specific form and automatic integration of customer relevant meta data

Figure 4 displays the form automatically initiated on the basis of meta data for registration of the service request and allocation to problem steps and internal departments. The customer data is extracted on the basis of the provided meta data from different applications with interactive web services and is automatically interposed into the new instance.

Also the relevant email information is transferred by means of the IBF mechanisms into the actual questionnaire instance. Time-consuming and often incorrect copying or recording of relevant information is omitted and accelerates the process course significantly.

First user experiences reveal potentials, which can be realised with this way of context sensitive provision of information and consistent return of human decisions. Even with an already good organisation and electronic storage 15 minutes as an average per day and employee could be saved in a pilot enterprise by finding the right information. This means that with 30 employees the yearly working time of an associate can be used for productive works.

CONCEPT OF INFORMATION OBJECTS, META DATA AND TECHNICAL REALISATION

A situational information provision is guaranteed in the presented scenario by information objects, which are described and defined with meta data. Here, the information objects are requested to be cohesively closed on the one side and on the other side should have a certain context openness. This means that information objects on the one hand build a detached, closed and understandable information unity and on the other hand can be used in further coherence fields, not only in the context of formation.

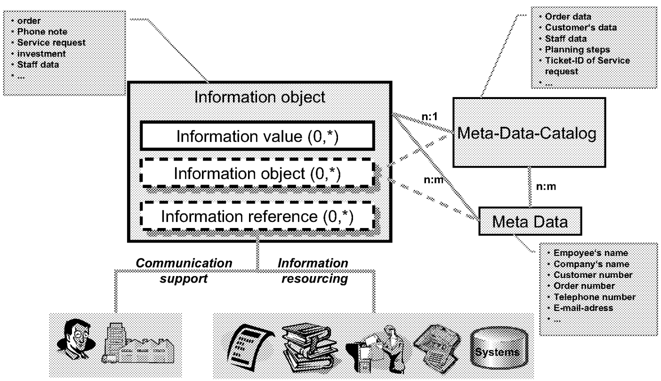

Figure 5: Information objects and meta data

They are labelled by meta data and have to be referable among themselves. Figure 5 shows the relations between information objects and the corresponding meta data.

Information objects can be aggregated to more voluminous objects and cannot only exist of textual contents but also of all kinds of multimedia forms. In addition methods, method calls respectively interactive (web) services are required for the generation of dynamic information parts which also can be as references parts of information objects.

On the user side beside user information and his rolls and authorisations further information on the context and content of the individual situation are available. They are identified through appropriate recognizers (small services analysing the existing XML structures) or through scheme based document drafts. Parallelly the incorporated applications and system accesses are also described by means of meta data. Office compliant interactive services are permitting the access to the associated information objects.

All meta data are stored in a meta data bank and the relevant connections between meta data on the user side and the information objects are provided. In Figure 6 the relations are shown between the required information objects by the individual user, the meta data and the corresponding services (search, provision, conditioning, change and so on of the information objects in the involved applications).

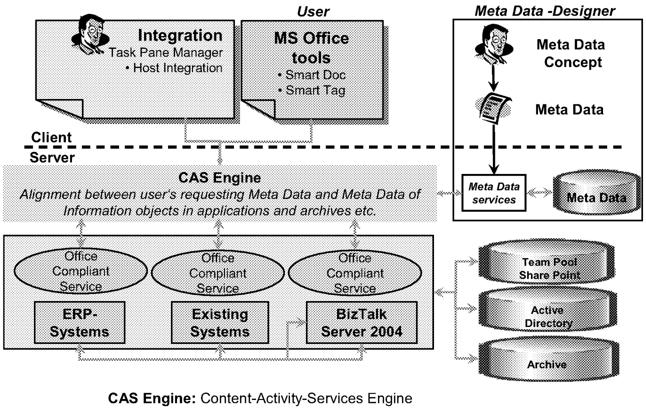

Figure 6: Correlation between the required and provided information objects on the basis of meta data [source: in dependence on Microsoft Corp. IBF Team]

The user is identified by his login, his rolls in the involved application define his rights and access possibilities. They can be transferred and approved by the services to the individual systems. Thus, all rights of the individual applications remain. The systems themselves remain encapsulated.

On the user side meta data are determined by the context and content and transmitted to the content-activity-services-engine (CAS). It compares this meta data with the meta data stored in the meta data bank of information objects, selecting and instantiating the proper services (Office Compliant Services) for interaction with involved applications.

These services are selecting and linking the available information objects. Only the configuration of relations between the information objects to a semantic network as well as the incorporation of their function into the whole context are enabling a context sensitive situational provision of information. This is why the further basis element, the "information correlation" was introduced. With information correlation dynamic links to further objects, information objects respectively physical objects (i. e. paper documents, leaflets) or specific method modules are provided.

LOCALISATION OF INFORMATION OBJECTS

One decisive assumption for the consequent utilisation is a standardized access to the information objects and resources. Only by utilisation of different information objects which "goes without saying" in a familiar user surrounding optimizing potentials in business processes can be used.

The internet localisation technique can be transferred to enterprises' needs. The internet uses Uniform Resource Locators (URLs) for a sure localisation of any resources.

This principle is now extended with methods and the relevant parameters. The defined methods are presenting services in a divided system surrounding. A method type is obligingly determining the signature and semantic for all services which are assigned to the method type. The entire context is not only to be understood as a semantic context but also as the relevance criteria from each individual user's point of view. Instead of a direct file indication a method is called which is accompanied by parameters ensuring the identification. These methods are available in a Middleware-Layer. Based on the parameters they are localising the information objects in the specified information space and are supplying a set of information correlations. The user is now able to choose and process the information objects by means of the retransferred information correlations.

SUMMARY AND PROSPECTS

Integration and collaboration is far more than a product or an integrated product platform. Integration is especially facing the companies with the task to structure, document and analyze their abilities and business processes in order to finally reach a real optimisation of the business processes and not only to adapt them to an already existing information and communication structure.

Especially the direct integration of the associates in automatic and partly automatic business processes should be further on part of the research in order to consider aspects of implicit knowledge transfer by means of direct informal communication as well as the demand of personal decisions within the business processes.

ACKNOWLEDGEMENTS

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A systematic approach to measure efficiency of product data computing processes based on normalised indices

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Keywords: product data, process efficiency, indices

1. Quantifying the benefits of IT – a mission impossible?

Since years IT-software providers promise production industries to solve all diseases of process gaps.
But if asked most industry companies claim, that problems like missing integration of product data and processes are still existing (compare [CADplus5/02])
This happens although it is recognised that information retrieval and information processing are gaining a growing percentage of engineering working time - more then 60%(see fig1.). Industries recognised this need for optimisation at this focal point – therefore IT-consultancy investments are continuously rising since years [CIMdata2004].
But a sustainable improvement and optimisation of the IT-support and the associated product model methods can only be achieved, if the effects of IT-support can not only be identified but also quantified.
Existing approaches start from making general assumption on dependencies of formalisation of product model data and process benefits (see fig.2 and [Abeln95], [SpuKra97], [Mue94]), but they are still rather unproven and also quantifiable results are still missing. Most known analyses approaches are very use case specific so that an comparison of measurement results become impossible. Thereby any evaluation do the present IT-situation compared to other companies or any existing standard becomes impossible too.
Therefore it becomes required to develop an approach to evaluate the IT-support efficiency based on indices, that can be measured precisely and that are normalised from use case specific influences. Only those normalised indices comparable to well known C_A/C_W values in aerodynamics allow to evaluate if the chosen process-/ data and IT-concepts fit together and deliver the desired results, but also where further optimisation potential can be deployed. To develop a measurement approach that can be applied on generic tools and processes to quantify the influence of the IT on the process performance is probably not possible. But by focusing onto the special domain of product data and the related engineering processes this attempt becomes realistic.
The capabilities of the triangle of the IT-toolset, the methods and concepts of product data modelling and the performance of the product data processing process do influence each other tremendously and can't be analysed separately. Consequently in the following for this triangle the term IT-tool-process-product model-system will be used.
To approach this goal this article is structured as follows. In the next paragraph principles of information processing are discussed and applied to domain of product data modelling in order to define first parameters to evaluate the performance of the IT-tool-process-product model-system. Therefore indices first to evaluate the performance of the data processing process (process efficiency indices) and second to evaluate the quality of product modelling as well from a conceptual point of view (product model quality indices) as well as from a functional point of view (IT-function-support indices) are developed. In the following chapter these evaluating parameters introduced before shall be normalised by relating them to attributes describing as well the technical as well as the individual influences of the specific use cases, in order to make the measured evaluating values comparable and by that allowing to built up a data base of experienced analyses. Finally the measurement and analyses approach will be reviewed and a further outlook is given.

2. Developing attributes to evaluate the IT-tool-process-product model-system

To develop the approach required above product developing processes shall be regarded as basic data processing processes and evaluating parameters shall

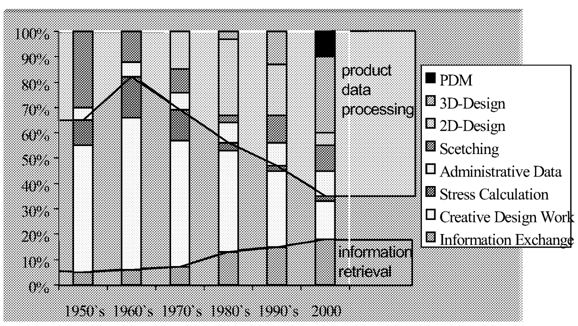

figure 1: work part of product data processing and information retrieval within engineering

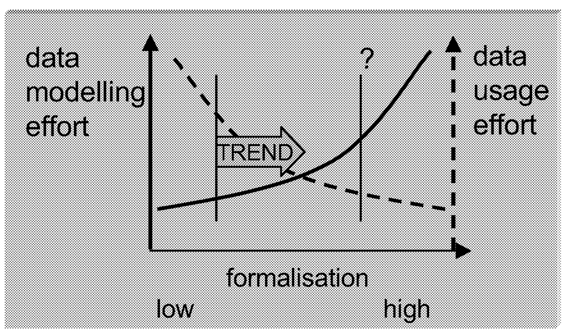

figure 2: trend of higher formalization at product modelling [Abeln95]

be developed by discussing several aspects of these processes.

- **The work aspect of product data processing**

The most important aspect of product data processing can be seen within the working aspect, which covers the working effort to process data.

As a reference any process chain of product data can basically be divided into discrete data processing actions, that each start with an information retrieval for data from the preceding action, interpreting the found data to built up the context and finally formalising the information which are the contribution of this action to whole process chain again into data that can be accessed by the following process action.

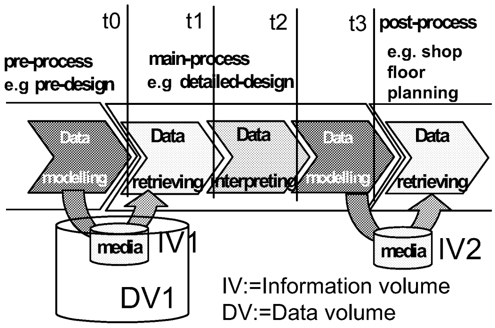

fig3. general data processing process

The relevant attribute to evaluate the performance and efficiency of a product data computing process is given by the process working time which constitute out the required working time of its subprocesses:

Retrieving working time RWT

The retrieving working time *RWT* shall be defined as the time required from start of the query t_0 until all required data or documents to perform the design task are identified and available t_1.

(1) RWT= t1-t0

Interpreting working time: IWT

the evaluating attributes of the interpreting step are the interpreting working time. The interpreting working time *IWT* shall be defined as the time required from moment all required data/documents are available t_1 until the point of time when the person performing the task has acknowledged that the information within document from analysing the data is understood t_2.

(2) IWT= t2-t1

Modelling working time: MWT

The modelling working time shall be defined as time required to formalize a given set of information into a defined product model, measured from point of time a defined set of information is acknowledged to be understood t_2 until the data modelling is finished t_3.

(3) MWT= t3-t2

Consequently the overall processing time PWT of typical data processing task consisting of retrieving, interpreting and modelling data can be derived by adding the working time of its sub-process steps:

(4) PWT=RWT+IWT+MWT

- **The quality aspect of product data processing**

The quality aspect of the overall product documentation is analysed first on a macro-level (is the overall database well organised?) and second on micro-level (is the information within one document or data set well organised?).

Product data organisation quality on macro level:

It is assumed that especially the retrieval working effort is dependant on the quality how the database overall is organised. As a special organisation approach according to the idea of the integrated product model a *product data integration degree* (*pdid)* is introduced. The *pdid* can be analysed per document or model from checking if defined principles of product data integration are applied to the database. Such principles giving a degree of product data integration from the lowest level ascending are:

I that the model/document is managed by general meta data within the database (*pdid=0,25)*

II that the model/document is managed by nodes of the product structure (like parts) (*pdid=0,5)*

III that the semantics of the model and product structure node managing the model are consistent (*pdid=0,75)*

IV and finally that cross relations between these product structure nodes are also modelled within the database to allow the navigation from the known parts of the product data to the unknown parts of the product model but required ones according to principles of a semantic net (*pdid=1)* [wir01].

Product data organisation quality on micro level:

Even more important then finding the right data is to have the right understanding of the data

Generally the understanding of interpreting person is dependant on the precision of the semantic definition of the data and the way the data is presented to the user. Capturing the same information in an unspecific data format like bitmap will cause more ambiguities and thereby time needed to understand the information then if the information was captured within a product specific product data model, defining adequate semantics for each data element containing product information. Consequently the second relevant documentation quality indice is defined as the *product data modelling degree pdmd* which relates the product information that is modelled within a specific product data model to the overall product information volume within the model-file or document to be analysed

(5) *pdmd* = (information volume within a model-file/document modelled as semantic discrete data elements)/(overall information volume represented within the model-file/document).

It is the target of this measurement approach to analyse the effect of an enhanced product data quality (*pdmd* & *pdid*) on the process performance given trough PWT.

- **The functional aspect of product data processing**

First indices to evaluate the functional support of the IT-systems involved within the product data processing process are the Data-coupling-degree *fscd* and the Modelling-support-degree *fsmd.*

The Data coupling-degree *fscd* is based on the assumption, that the appearance of redundant data in product data processing processes is widely spread. Missing data interfaces will cause tremendous manual effort to keep the data consistent. Therefore the *fscd* relates the data volume consistency controlled by data interfaces to the data volume of the overall redundant data of the process to evaluate the IT-function support.
The Modelling-support-degree *fsmd* can be seen as parameter closely related to ergonomics. In an optimised IT-tool-support a minimum of inputs are required to model a given set of information. Therefore the *fsmd* relates the number of Graphical User Interface (GUI) actions to required to model a given Information IV to the Information volume IV.

3. Eliminating use case specific influences from the process working time

Quantifiable parameters were developed within the last paragraph, but still they are of view value for a comparing evaluation due to the fact that several additional parameters do also influence the working time and error rate of information processing processes and therefore make those measurement results use case specific.
In order to relate the results of information processing tests to their special circumstances and to avoid misinterpretation in comparison it is important to define further describing attributes of the information processing process.

- **Identifying describing attributes**

Basically within any working process the working time to complete a task is dependant on the one hand from the workload volume, that has to be accomplished and the other hand the work force/potential which can be used to accomplish the given task. Beyond that also losses in the process have to taken into account.
For the retrieving task the workload can be seen in the size of data volume which has to be analysed whereas within the interpreting and modelling task the information volume to be interpreted or to modelled can be regarded as main driving parameter for the workload volume. The losses in the product data process can be seen in the incompleteness of data processing actions. The elimination of those rather technical influences will be conducted within a first normalisation step (see figure 4).
The driving factor for the potential work force can of course be seen in the intellectual capability of the human being performing the retrieval, interpreting and modelling task. The elimination of those individual properties of the test person conducting the data processing task will be conducted within a second normalisation step.

- **Developing the technical normal form (1nf) of the evaluating attributes**

- retrieving the appropriate data,
It is assumed that retrieving working time RWT mainly decreases the smaller the database is from where the relevant is to be retrieved and the better the database is organised.
Therefore measured retrieving working time is related to data volume of the data base
A good and easy quantifiable parameter to define the database volume DV is the number of documents or model files managed within the database.
Beyond that the retrieval at end of measured RWT may be still incomplete – some required data or documents were not found yet. The relevant parameter is the completeness degree of retrieval *cdr* , which relates the number of found data-files/ documents to number of data-files/documents designated for the task. It is assumed that the working time would increase linear to reach a 100%*cdr*.
Therefore the first normal form of the retrieval working time will be defined as:
(5) $rwt1nf$=RWT/(DV*cdr)
- interpreting data into information
The work load of the interpreting step can be seen in the information volume to be interpreted. Therefore it is assumed the interpreting working time mainly increases the bigger the information volume IV of the document/data pack to be interpreted is. The completeness degree of interpretation *cid* shall be defined as percentage of information correctly acknowledged by the test person in relation to the information volume of the document/model-file. To make IWT-measurement results comparable, they shall always interpolated to theoretical working time for a 100% *cdi*. By assuming a linear growth of information the measured interpreting working time IWT is related

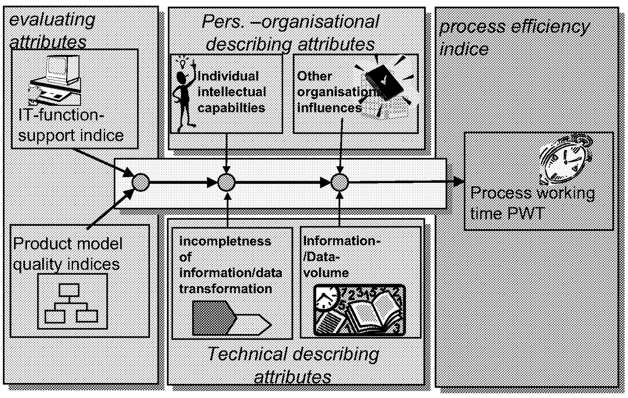

fig4. influence of use case specific attributes on evaluating attributes

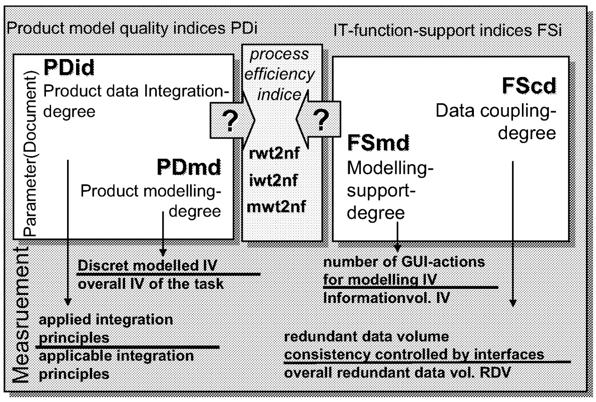

fig.5 overview evaluating indices system

to the information volume IV and the completeness degree of interpretation to retrieve the first normal form the interpreting working time-

(6) *iwt1nf* =IWT/(*cdi**IV)

The information volume IV (which is also required to determine the *dpmd*) of the test is much more difficult to measure objectively. Basically information is something that develops within the human mind whilst interpreting data. But as a simple approach to make documents ore model-files comparable from their information content within the domain of product data and engineering a reference list with engineering entities shall be provided from analysing existing information models like the application protocol AP 214 ARM of ISO10303 (STEP). The approach is to use this reference list to analyse documents or model-files by counting the engineering information entities from the reference list encountered within the document/ model file independent from their data representation or presentation. Those counting results are summarised as the number information units of the *Product Information Volume IV*. At EADS a tool was developed to enhance the objectivity of such information volume (IV) determination by guiding the analyst through a defined procedure to compare the document to be assessed with the product information reference model of AP214(ARM) implemented as the data base of the tool.

- modelling the product

The specific, that make those measurement results of the modelling working time incomparable can be seen in the workload of the information volume IV that has be formalised within the modelling task and the completeness degree of information formalisation *cdf*. Consequently the first normal form of the modelling retrieving working time is derived :

(7) *mwt1nf*=MWT/(IV**cdf*)

- **Developing the individual normal form (2nf) of the evaluating attributes**

In the last paragraphs the measured working time values were related to several attributes describing the specific circumstances of the test, but still these results are only comparable if every test has been conducted by the same test person. Because it is the target of this approach to evaluate the effect of an enhanced product model quality and functional support onto the process performance within second normalisation step, the influence of the individual intellectual capability of interpreting data shall be quantified and eliminated from the process performance measurement. This goal is approached by relating the measurement results of a given product data processing task to analysed to the measurement results of a universal defined reference test. For being universal applicable the reference test scenario was designed to have most trivial documentation form and with a minimum but standardized tool support. The reference test data set as well as the It-toolset is planned to be public accessible via a internet-web server. By relating technical normalised working time Xwt1nf of the use case to be evaluated to technical normalised working time of the reference test data set Xwt1nf' the second normalised form is Xwt2nf is derived that directly indicates benefit of the given data formalisation and IT-Support to worst one defined in the reference test:

(8) rwt2nf=rwt1nf/rwt1nf'

(9) iwt2nf=iwt1nf/iwt1nf'

(10) mwt2nf=mwt1nf/mwt1nf'

5. Summary and outlook

The article presented introduced a measurement system to quantify the influence of product modelling concepts and functional support for the process y IT-systems on the performance of the process. The approach aims to normalise the indices of that measurement system to eliminate use case specific influences in order to make the analyses results of different tests comparable. Of course this measurement system represents only a first and pragmatic approach to quantify the rather abstracts elements of product data of product data processing and it is assumed that first tests will reveal further parameters not yet identified having influence process performance.

The long term objective is to determine those normalised indices and parameters within a standardised test procedure and tool support to generate a data base of analyses experience in order to estimate effects of product modelling concepts and IT-modifications in advance of implementation and by that designing them to an optimum.

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Comprehensive Failure Management in Exceptional Circumstances – a Reference Model

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KEYWORDS
Reference model, failure management, quality management, workflow management.

ABSTRACT

The companies are confronted with a very turbulent and changing environment. To reach a profitable production, they must reduce or avoid scrap and rework. Therefore, one of the most important goals for every company is to realise a zero-defect-production. The goal can be achieved by starting at the processes in the company. On the way to the excellence, a reference process for a systematic thorough accurate failure management, which covers exceptional situations, is indispensable.
Despite the creation of error free working condition and the introduction of procedures to avoid and to correct errors, unplanned process conditions and disturbances still arise. In order to overcome these disadvantages, a handling procedure for every default must be defined to assist the human decision. An adequate system should be developed to reach this goal. There are two principal concepts, which must be considered. The different error handling scenarios must be considered and new scenarios should be developed. On the other hand, In-depth analysis of the company's failure management requirement profiles must be done. An adjustment of the theoretical developed part of the error handling and the requirement of the company delivers a customised solution.

MOTIVATION AND OBJECTIVES

Today, it is essential for a company to have a comprehensive and overall failure management process with appropriate measures in place to deal with the increased requirements made necessary by globalisation, ever shorter development times or statutory changes. It is a fact that failures and call-back actions result not only in enormous costs and a lot of time wasted but can also lead to loss in corporate image. Despite having created the prerequisites for failure-free working, introducing processes to prevent failures occurring and the systematic removal of failures, unplanned and undesirable process conditions and dysfunctions still occur.
Companies today pursue their own methods of finding the cause of unplanned conditions and practical solutions to deal with them (Algedri et al, 2000) (Doege et al, 2000). Reactions to emergencies are, however, often spontaneous and there is no guarantee that they will be complete or correct although any company must be able to deal with an exceptional situation quickly and safely. Immediate recognition of the departures and the use of means to restore trouble-free operations is known as failure management.
Any such solution must, on the one hand, include the definition of a systematic procedure as a method of creating and continually developing the failure management to be achieved. On the other hand, DP support should allow the method to be used more easily as a solution in the day-to-day company operations (Pfeifer, 1996) (Schöttner, 1999).
With these objectives in mind, RIF e.V. has carried out a research project entitled "Instruments for comprehensive failure management to allow rapid and safe reactions to emergency situations in small and medium-sized companies". The instrument allows rapid access to relevant procedures in situations where failures are clearly identifiable and for which tried-and-proven remedies have already been found in the past. Moreover, it provides a safe method of dealing with emergencies which cannot be clearly characterized or for which no suitable remedy has been hitherto defined. The instrument also provides practical support of the idea of having inter-disciplinary control cycles within the company.

OUTLINE FOR CREATING A REFERENCE MODEL

The definition of failure management varies from company to company. In order to guarantee the transferability of compiled results, it is necessary to characterize the various initial positions and, based on these, to define suitable ways of reaching the targeted solution. There first follows a summary and analysis of the various concepts discussed in the literature on the subject of failure management in order to provide a comprehensive analysis of methods already existing, thereby determining their quality characteristics, advantages and disadvantages and describing their fields of application. This first step determines the main processes of the failure management reference model.
In the second step, the sub-steps of each main process are determined. When creating the requirements profile of individual process steps, not only standard requirements but also the corporate point of view are considered. In order to obtain a practice-directed and user-friendly design of the individual sub-steps, emergency situations occurring in those

companies participating in the project are captured and structured and an as-is analysis carried out of the methods of failure management used in those companies.
For this purpose, various types of companies were subjected to a representative survey which, on the one hand, was to record the requirements made by the company regarding a comprehensive system of failure management and, on the other hand, to create a summary of strategies and operational peculiarities in industrial companies.
In the third stage, the failure management reference model was adapted to the needs of the companies – we refer to this as the Customizing Phase.

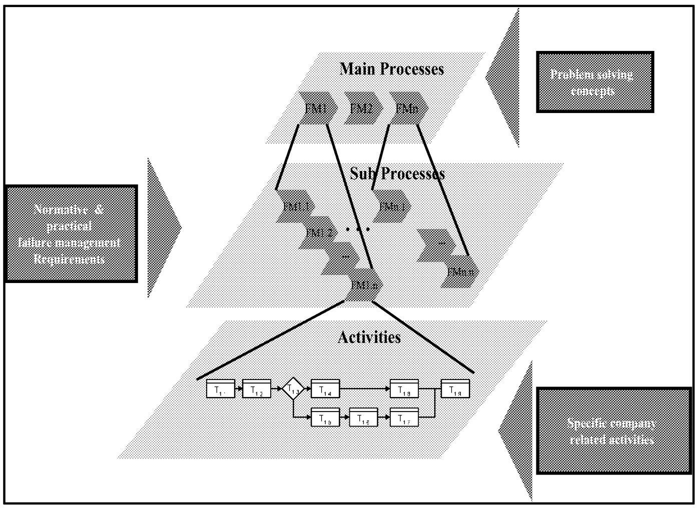

Figure 1: Concept for the creation of a failure management reference model

MAIN PROCESS OF FAILURE MANAGEMENT

There first follows a summary and analysis of the various concepts discussed in the literature on the subject of failure management in order to provide a comprehensive analysis of methods already existing, thereby determining their quality characteristics, advantages and disadvantages and describing their fields of application. The focus lay here on four concepts and procedures (PDCA cycle (Deming Circle), Zero Failure Programme, Six Sigma and the escalation principle), with which faulty processes can be quickly and reliably identified and then remedied.

The development of a failure and its recognition trigger the failure management process. A detailed record of fault data forms the initial point for further stages of the process whereby the focus lies on uniform and continuous recording. The fault data should address the following questions – what, when, where, how, who and why. The second stage serves to classify and assess the fault for later failure tracing, monitoring and analysis. It is sensible to separate the point of origin from the site of discovery and to differentiate between systematic faults and exceptions. Thirdly follows the naming of those accountable for further failure processing as it is essential to determine exactly who is responsible in order to obtain trouble-free and efficient remedying of the failure. The thus ensuing clear organisation allows required information to be directed to where it is needed. The employees responsible are then requested to carry out shut-down measures in order to mitigate or remedy the impact of the failure. The next phase sees the execution of preventive and cautionary measures to avoid a re-occurrence of the failure. This is done by using quality methods to analyse the cause of the failure and to determine solutions to prevent it. Information gained during the shut-down process should be used again in order to support and improve failure analysis and remedies. This results in an evolutionary procedure which in turn leads to more creativity and innovation. Dealing with an emergency should however not only lead to optimisations on the technical side by intervening in a preventive or corrective manner in all phases of the value-added process. It is enormously important that people adapt their behaviour in dealing with failures and acting in the right way in emergencies. People represent a thinking, flexible and active factor which make them the most significant players within the failure management process (Crostack, Ellouze, 2003). The concluding phase of the process must therefore be to express appreciation and highlight the role of the staff. All these factors result in an eight-phase failure management process which covers all these aspects. (refer to Figure 2)

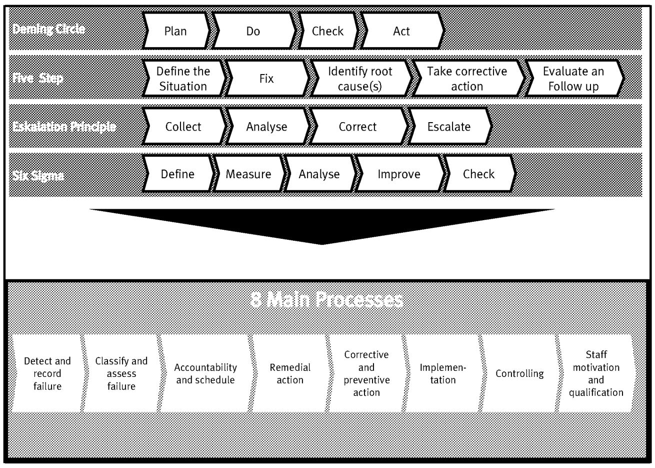

Figure 2: Failure management process

In order to determine the individual sub-processes within the failure management process chain, the standard requirements focussed on DIN ISO 9000:2000 were first considered. This was followed by a survey to achieve, on the one hand, a practice-directed and user-friendly solution targeted at obtaining with the results a summary of strategies and operational peculiarities in the companies and on the other hand, to determine the demands made by the companies on a comprehensive failure management system. Great consideration was given to the companies approached for the survey to allow possible differences between the companies, sectors and regions to be analysed.
The questionnaire was divided up into three sections. The first contained questions regarding employees in failure management particularly concerning accountability and qualifications of those members of staff responsible for failure management. The implementation of the results of this project can thus be adapted to the possibilities and requirements of the staff involved with failure management. In the second section, questions are asked concerning the

targets and design of failure management in each of the respective companies. The third section serves to acquire data on failure management methods and the processing of the acquired failure data in industry. These two sections make up the main focus of the survey.

ASSESSMENT STAGES

The failure management scenarios found in the companies are transferred to the developed reference model. In order to proceed from the respective as-is situation in the company to a comprehensive failure management, instructions for procedure are developed within the framework of the project which are to be used as a self-assessment to determine in-company ability to handle failure management as a degree of performance of the reference model. At the same time, it must also be possible for it to clarify un-used potentials in failure management for Special Areas and Quality Management in general and to support the user in implementing the instructions.
The implementation of individual process stages of the reference model is divided up into several steps. Each step of the eight main processes is broken down into five steps. These five different levels of a process step represent the development stages which have been gone through on the way to introducing the reference model. The fifth step represents a special case as methods and competences have been integrated here which go beyond the necessary level required to meet the reference process, The fifth level therefore comprises those items which represent an extension of the reference model. As a rule, these are strategic instruments which extend purely the ability to meet performance in order to make use of longer-term opportunities.

The check points of the first level take up a special position as they represent the basic skills regarding the respective phase of the failure management. The check list sheets for the first level usually comprise measures which are simple to implement and which represent the basic pre-requisites for later development in this section of the reference process. Companies with deficits in the lowest level of the check list are urgently recommended to remedy the situation.

No inter-phase description can be determined for levels two and three. The allocation of check points to individual check lists is made, on the one hand, with the aim of evenly distributing the development steps and , on the other hand, in such a manner to allow the imaging of a sensible ranking using the level structure. On concluding level four, the user will find himself on the target level of the reference model aimed for; i.e. however not necessarily in every case have all of the concluded individual steps been completely implemented in the company. It is conceivable that in individual cases better solutions are used in a company than the ones described here. Ticking off a development step means that the solution presented is known to the user and that this, or a better solution, has been implemented in the company. The user of these instructions is of course free to leave the path dependent on the check list. In this case, there is still the possibility to make use of the suggestions in the guidelines to develop a failure management system of one's own without having to resort to the proposed structure.

The check lists represent on the one hand details of the reference process which in turn is the core of the reference model and on the other hand, a sum of recommendations for introducing failure management analogue to the reference model. At the same time, they provide the structure of the reference model at a practice-specific level and the connecting points for methods and tools already in use for quality management within a company.

When using the check list, the reference process is thus always the framework upon which the design of individual points should be directed.

EDP SUPPORT

The necessary technical support is based here on the use of the Workflow Management System (WFMS), a software system for modelling, execution and analysing of work processes. In comparison with a pure visualisation of processes which have already been frequently applied in companies, WFMS controls in addition the processing of activities using standardised workflow schemata. Schwab describes the function of WFMS as follows: "*The main task of WFMS in processing definite procedures is active control, coordination of single processing results, integration of automated tasks in processing the activity, extensive fault processing and the documentation of processing results*" (Schwab, 1996). Specified workflows, for example, as a reaction to an identified rare fault can be deposited in the system in such a way that the actual execution of the workflow is supported by WFMS. In this case, integrated communication modules ensure that the members of staff to be informed are actually informed. Functions of document management ensure that the members of staff involved with problem solutions really do have access to the documents required. By means of integrated log functions, the execution of a workflow to implement a measure can be documented and be reproduced at a later time. Each time it is used, a workflow implementing a measure is documented and can be referred to again should the failure re-occur. Analogue to the creation of the reference model, the demands on a software of this nature were structured and determined in cooperation with the chair for Manufacturing Engineering at the University of Dortmund. The reference model was then modelled using a suitable WFMS and implemented as a prototype with the help of two companies from different sectors of business.

SUMMARY

The reference model described here supports companies in implementing a comprehensive failure management system. In particular, small and medium-sized companies who have only limited planning capacities will profit from using the processing instructions and implementing the reference model. The documented and WFMS-assisted procedure in implementing effective measures ensures comprehensive failure management and makes special sense when employing semi-skilled personnel who might not be in possession of detailed and cohesive information. Likewise in companies with high personnel fluctuation i.e. when staff must frequently be trained first before doing a job, support of this nature is just as beneficial as in critical situations which require rapid and fault-free reactions. As the solution path for remedying failures hitherto unknown are documented, the procedure to be developed supports also the up-dating of failure management know-how in companies. In critical exceptional circumstances, employees are able to effectively introduce measures which are known to be efficient where failures have been identified (Crostack et al, 2004). The introduced measures become transparent and reproducible thanks to the workflow support. Systematic procedures and their documentation allow the respective failure remedy strategy to be transferred to other production areas (Jablonski et al, 1997).

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AUTHOR BIOGRAPHY

Wissem Ellouze was born in Sfax, Tunisia and went to the university of Hannover, Germany, where he studied mechanical engineering and obtained his degree in 2002. Concurrently he gained experience through several internships. He worked for a year as a project engineer for the RIF e.V., in Dortmund, before moving to the chair of quality engineering in 2003, where he has been working in quality engineering ever since.

AUTOMOTIVE ENGINEERING COLLABORATION IN JAPAN

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ABSTRACT

Strategic alliances in the automotive industry by cross border mergers and capital tie-ups lead to intensification of global collaboration. Market Oriented Concurrent Engineering faces various obstacles that need to be solved.
This paper describes the automotive industry in Japan followd by the intercultural differences between Japanese and European / German culture and their relevances for conducting business in Japan.
Our practical part is a project description of reorganization the supplier integration within a great Japanese OEM, regarding data exchange and the introduction of international standards.

AUTOMOTIVE INDUSTRY IN JAPAN

Introduction

Starting with a quick overview of the automotive industry in Japan (see: [www03], [YOO04], [BRU04]), intercultural challenges for conducting business with Japanese follow.

Stages of Japanese Auto industry

- *1945 – 1955: Post-war Reconstruction*

After the war the OEM started with truck production. After a major recession 1951 the "Road Vehicle Act" was passed which aimed on promoting automobile safety and played a significant role in improving the quality of domestic manufactured cars. Following 1952 the "Industry Rationalization Promotion Law" with tax advantages and attractive loans, those cost reductions lead to export competitiveness.

- *1955 – 1965: New industrial Policies*

1955 the "Peoples Car Plan" encouraged Japanese OEMs to develop original models of their own compact cars. Lacking international competitiveness, until 1965 car imports were limited to allow the Japanese OEM to make massive investments in plants, equipments and R&D. With the rapid growth of living standards and the strengthening of Japanese position in the world economy, 1965 Japan finally implemented the liberalization of passenger car imports, but the import tariffs were still very high.
Mass production was established with defined production infrastructure (multiple model, small lot production, small factory size).

- *1965 – 1975: The rapid expansion*

1967 JAMA (Japan Automobile Manufacturers Association) was established. The auto production ranked second in the world after the US (in front of West Germany). Along with a steadily increasing GNP (gross national product) 1970 Japan was the world's second largest economic power after the US. By 1972 the auto industry was Japan's leading industry. With the introduction of new production technologies (production line management, high speed automation, robot technology) the entire manufacturing process was computerized including supply of parts and materials.
Liberalization of capital lead to the possibility of mergers and the formation of business groups to secure international competition. As a result, various OEM established alliances (i.e. 1971: Mitsubishi & Chrysler, Isuzu & GM; 1979 Mazda & Ford; 1981: Suzuki & GM).
An infrastructure for exports (1965 the number of exported cars was the first time higher than truck exports) was raised.
The oil crisis 1971 had a profound impact on the auto industry resulting in the demand for small and fuel-efficient cars, yet the total vehicle production plunged 12% the following year.

- *1975 – 1985: Results of the oil crisis and a maturing domestic market*

Lighter vehicles with less fuel need had to be developed. To achieve those requirements different changes were realized (lighter parts and materials, electronic fuel injection systems, reduced air resistance, new technology materials like fibre-reinforced metals / plastics or ceramics, diesel engines). The domestic market with emphasis on small and mini cars recovered 1975 and grew steadily. The auto industry maintained a 10% share of the manufacturing output and 10% of Japan's working population was employed directly or indirectly by that industry.
International Japanese cars had a growing reputation for excellent performance and fuel efficiency but the rapid increase of car exports was not overall welcome. Some countries (US, France, Italy) called for import restrictions. In response, the Japanese government implemented a voluntary export restraint to the US.

- *1985 – 1995: Internationalisation and Globalisation*

1985 with the "Plaza Accord" the value of the yen rose suddenly, which affected Japan's exporting industries severely. The strong yen and increased local production lead to a long-term decline in automobile exports since 1985. Between 1987 and 1991 Japan's industry is referred to as the "Bubble Economy" that collapsed in 1991 which started a recession that lead to severe restructuring measures for the auto industry.
Japanese OEMs expanded their local production (first with focus on US) and developed closer ties with overseas manufacturers. In 1994 the "Voluntary Export Restraint" policy was abolished as the result of the yen appreciation and increased local production. In Europe as well as in the ASEAN countries the local production played an increasing role for the globalisation.

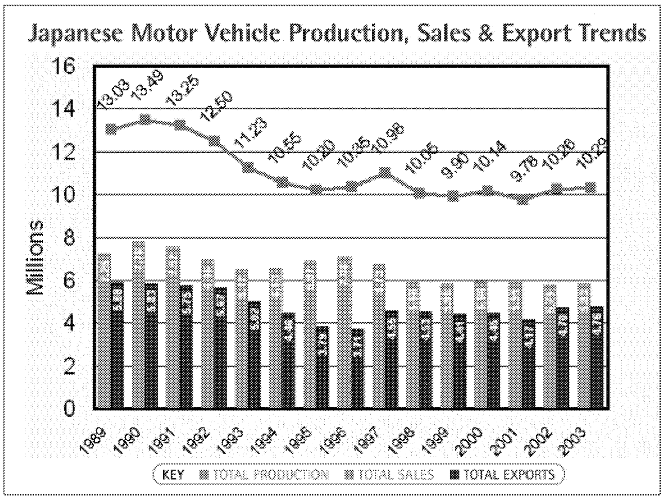

Figure 1: Japanese Motor Vehicle Trends [www03]

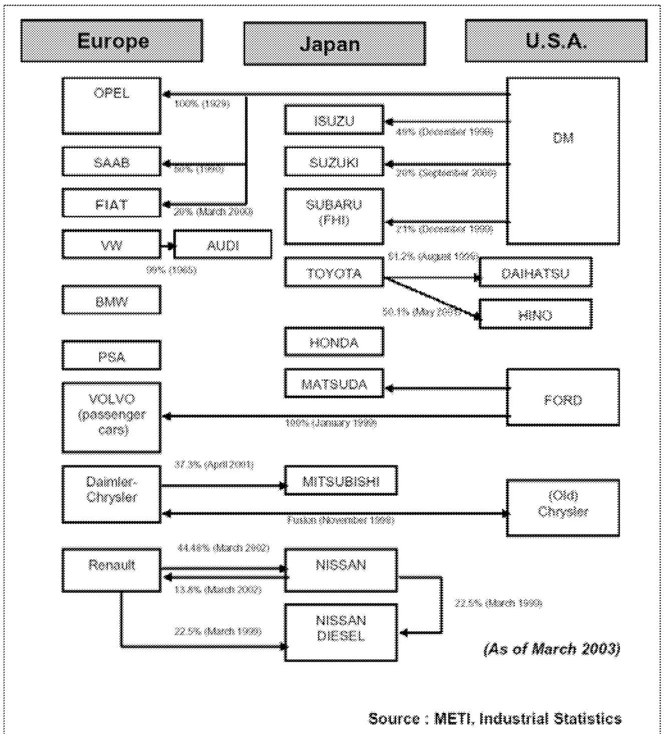

Figure 2: Worldwide automotive alliances

Is there a Japanese automobile crisis?
Exports, inland sales and inland production stagnate or even recede. The cause may be seen in the revaluation of the yen, the competitor's imitation of Japanese management concepts (lean production / toyotismus with the following techniques: consistent team orientation, total quality management, kaizen (consistent improvement), reduction of buffers with just-in-time and kanban-systems) and the pressure of the Asian neighbours.

Future Challenges - Outlook
Cost reductions and restructuring, further globalisation, diversification, development of new business segments and transfer of the production in low-cost countries are means to leverage the situation.
The OEM-supplier relationship, former dominated by the so-called "vertical keiretsu" is no longer obligatory. Suppliers themselves have a severe cost and restructuring pressure to deal with and tend to have various purchasers instead of a single binding business relationship with one OEM.

INTERCULTURAL CHALLENGES JAPAN

Japan – A quick Country Overview
Japan, with a population of approximately 126 million people is a parliamentarian democracy under the rule of a constitutional monarch, packed tightly into a rather small geographic area (about 377.000 sq km – about the size of California). Regarding economy there is a tight government – industry cooperation, a strong work ethic, mastery of high technology and a comparatively small defence allocation (1% of GDP – GDP $3.55 trillion (2002 est.) that helped Japan advance with extraordinary rapidity to the rank of the second most technologically powerful economy in the world after the US and the third largest economy in the world after US and China [www01]. Industry, the most important sector of the economy, is heavily dependent on imported raw materials and fuels.
One notable characteristic of the economy is the working together of manufacturers, suppliers, and distributors in closely-knit groups called keiretsu, however the importance of the keiretsu start to recede.

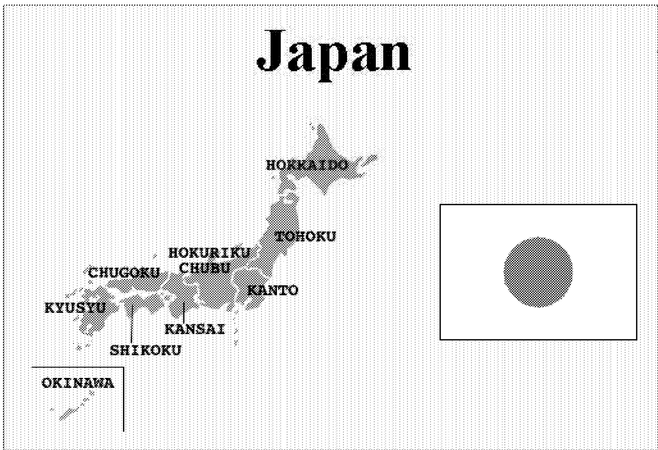

Figure 3: Japan

Differences in National Cultures

Culturally, the Japanese tend to be introverted and are not receptive to outsiders. For conducting business in Japan you should be aware that relationships and loyalty to the group is critical for success.

Geert Hofstede, a Dutch professor, conducted a study (starting in the late 60s) of how values in the workplace are influenced by culture. He developed a model that identifies four primary dimensions to assist in differentiating cultures; the fifth dimension (Long Term Orientation) was added later.

A short description for each of Hofstede's dimensions [HOF97] and [www02] follows.

- *Power distance*

Focuses on the degree of equality or inequality between people in the country's society. A high Power Distance ranking indicates that inequalities of power and wealth have been allowed to grow within society. A low Power Distance ranking indicates the society de-emphasizes the differences between citizen's power and wealth, where in these societies equality and opportunity for everyone is stressed.

- *Individualism*

A focus on the degree the society reinforces individual or collective achievement and interpersonal relationships. A High Individualism ranking indicates that individuality and individual rights are paramount within the society. Individuals in these societies may tend to form a larger number of looser relationships. A Low Individualism ranking typifies societies of a more collectivist nature with close ties between individuals. These cultures reinforce extended families and collectives where everyone takes responsibility for fellow members of their group.

- *Gender and gender roles*

Focuses on the degree the society reinforces, or does not reinforce, the traditional masculine work role model of male achievement, control, and power. A High Masculinity ranking indicates the country experiences a high degree of gender differentiation. In these cultures, males dominate a significant portion of the society and power structure, with females being controlled by male domination. A Low Masculinity ranking indicates the country has a low level of differentiation and discrimination between genders. In these cultures, females are treated equally to males in all aspects of the society.

- *Uncertainty avoidance*

Focuses on the level of tolerance for uncertainty and ambiguity within the society - i.e. unstructured situations. A High Uncertainty Avoidance ranking indicates the country has a low tolerance for uncertainty and ambiguity. This creates a rule-oriented society that institutes laws, rules, regulations, and controls in order to reduce the amount of uncertainty. A Low Uncertainty Avoidance ranking indicates the country has less concern about ambiguity and uncertainty and has more tolerance for a variety of opinions. This is reflected in a society that is less rule-oriented, more readily accepts change, and takes more and greater risks.

- *Long-Term Orientation*

Focuses on the degree the society embraces, or does not embrace, long-term devotion to traditional, forward thinking value. High Long-Term Orientation ranking indicates the country prescribes to the values of long-term commitments and respect for tradition. This is thought to support a strong work ethic where long-term rewards are expected as a result of today's hard work. However, business may take longer to develop in this society, particularly for an "outsider". A Low Long-Term Orientation ranking indicates the country does not reinforce the concept of long-term, traditional orientation. In this culture, change can occur more rapidly as long-term traditions and commitments do not become impediments to change.

Hofstede's dimensions - Japan and Germany

Hofstede's analysis for Japan differs from other Asian countries (Hong Kong, Korea, China): masculinity is the highest; the lowest is individualism, which coincides with high uncertainty avoidance. Japan represents a collectivist culture that avoids risks and shows little value for personal freedom.

Comparing Hofstede's dimensions from Japan and Germany the following differences may be seen:

- Individualism is higher in Germany.
- Masculinity is significant higher in Japan.
- Uncertainty Avoidance and Long Term Orientation is higher in Japan.

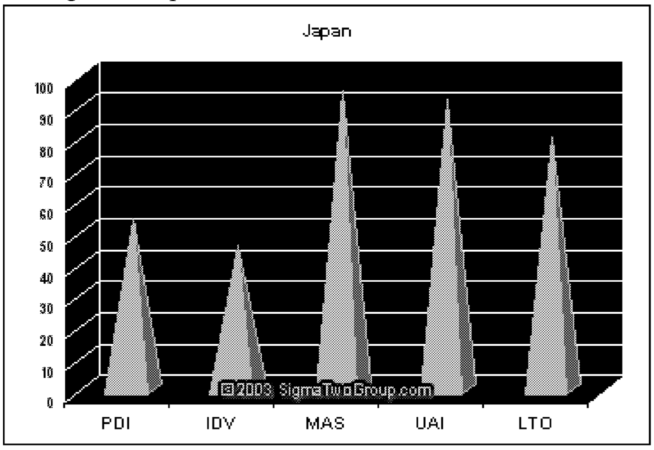

Figure 4: Hofstede's dimensions for Japan [www02]

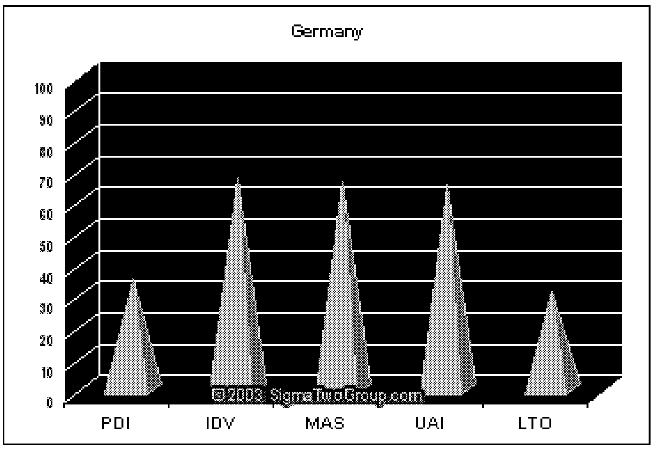

Figure 5: Hofstede's dimensions for Germany [www02]

The following consequences should be taken into account when conducting business in Japan

- Value the relationship and show loyalty to the group (your team, your company, etc.).
- Women in business relations need to be aware of the high masculinity dimension: Japan experiences a high degree of gender differentiation.
- Uncertainty and ambiguity are usually not accepted in Japan, i.e. unstructured situations. Therefore plan carefully your meetings, business trips and get used to typical cultural differences in conducting business.
- Along with the high Uncertainty avoidance focuses the Long-Term-Orientation on the value of long-term commitments and the respect for tradition and rules.

Examples for Japanese tradition and rules

Next an excerpt of Japanese tradition and rules. Generalizations tend to polarization, but they give helpful hints for do's and don'ts.

- Handling and exchange of business cards is important.
- Dress conservative – dress to impress.
- Avoid large gestures and facial expressions.
- Be comfortable with silence.
- Business entertaining is done in restaurants or bars after business hours.
- Drinking is an important part of Japanese culture.
- Learn some Japanese expressions to show your respect to the language and culture (i.e. "kampai" for toasting, "sumimasen" for excuse-me, "meishi" for business card).
- Gifts and gift-wrapping is an important issue.
- Japanese prefer not to use the word no, quite important to avoid misunderstandings in negotiation.

PROCESS MANAGEMENT

Regarding "Concurrent Engineering", our focus is on the relationship between OEM and suppliers, it is necessary to have a set of rules and regulations for conducting business over the different stages of collaboration.

A process library for

- Procurement
- Collaboration preparation
- Active Collaboration
- Close off

helps to manage effectively new business relationships.

The existing reference processes are guidelines and should be modified according to the company's needs to ensure process security and efficient workflows. A dedicated process manager is responsible for maintaining and for the further development of the processes.

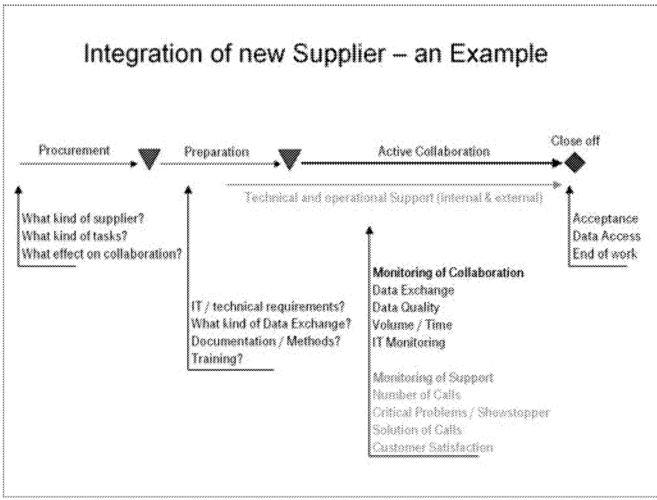

Figure 6: Example for process library

REORGANIZING THE SUPPLIER INTEGRATION

Status quo – At a great Japanese OEM

In contrast to the data transfer via OFTP/ENGDAT [VDA02] as it is common in Europe, the Japanese data transfer is usually organized proprietarily. That's why simple mailbox systems are quite common. In the OEM under discussion, the suppliers have been connected via the „Susumukum" system.

'Susumu-kun' is the current CAD data exchange system for Japanese suppliers developed in 1996. The development of the application was finished and doesn't comply with the development of OS. Therefore it is very important to develop the new data exchange system on the current mainstream OS environment.

The delivery note differs for every OEM and since it is difficult to reuse the information, it takes the suppliers a manhour for an informational check and management.

In order to reduce the effort of the suppliers, the new data exchange system needs to support the JAMA [JAMA] standard known as ENGDAT.

CURRENT DATA EXCHANGE PROCESS

Confirmation of data

The confirmation of data is an important matter of the Japanese data exchange.

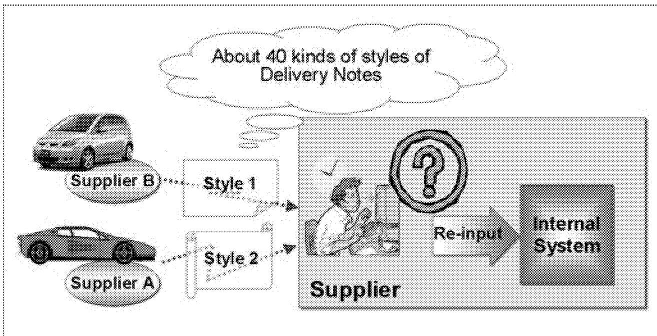

Figure 7: Data confirmation

The delivery note differs for every OEM and since it is difficult to reuse the information, it takes the suppliers a man-hour for an informational check and management.

Long process until data is delivered
The Japanese tradition requests an approval process when sending data to the supplier. It is not possible for an engineer on a staff level to send CAD without the permission of a manager or general manager.

It takes about one day to three days from data sending request by designer to receipt by supplier at the online data exchange, because of operator's working hours are limited.

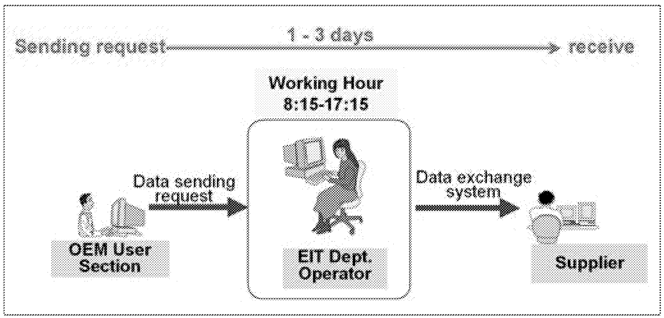

Figure 8: Delivery process

Different systems for local an overseas suppliers
Since OEM and Overseas (plant, R&D) use a different system depending on the area where the data needs to be sent, it is not possible to exchange data with different areas using the same system.

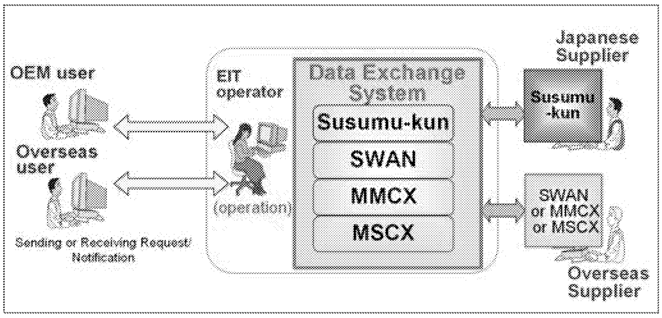

Figure 9: Different systems in use

PROJECT PLANING

Project goals

- *Phase 1:*
  Installation of the new CAD data exchange system instead of 'Susumu-kun'. (Supporting the JAMA/VDA standard ENGDAT). Make the new system available for the designers. The new system can exchange data directly with suppliers.
- *Phase 2:*
  Deployment of the new CAD data exchange system overseas.

Key Performance Indicators (KPI)

- Designer can exchange data at any time - 24 hours a day.
- 100 percent access from overseas is possible.
- Usage on current mainstream OS environment is possible.

Opportunities & Risks
The following opportunities have been identified:

- Globalisation of a data exchange system
- 24-hour data exchange
- Real-time provision of information on transmission and reception

The following risks have been identified:

- Increase in load on a network, because of increasing data exchange capacities.
- Increase in operation man-hour.

Project analysing
The project was analysed regarding the three factors:

- Strategy
- Opportunity
- Readiness

The result of the analyses is presented in the following diagrams. In all three categories green boxes highlight the project.

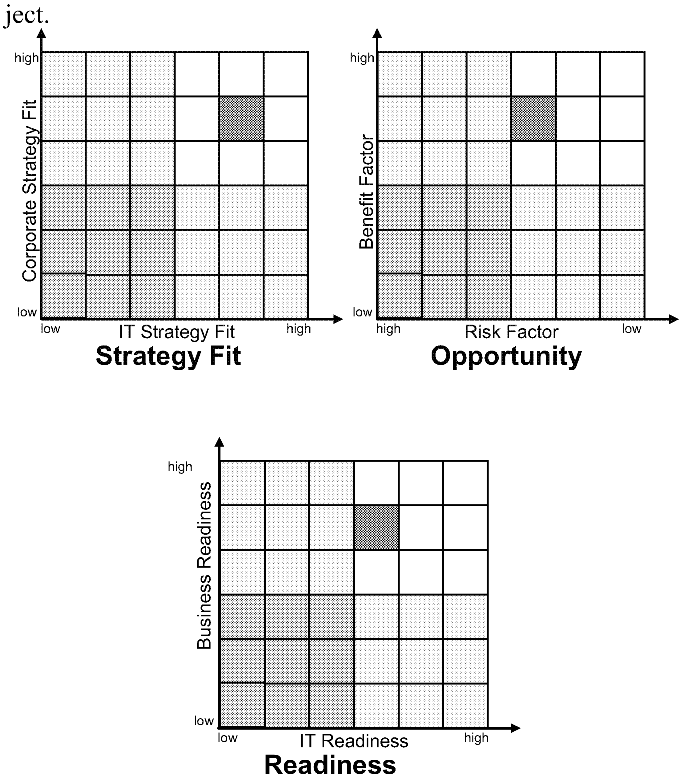

Figure 10: Portfolio Criteria

The following arguments finally brought about the decision to use the data exchange system SWAN [SWAN] as the "next generation data exchange system":

1. The solution meets the system requirements for the OEM

- Solution meets the basic function requirements (key operation for user, system operation, system management, etc)
- Has already been in field-tested (system reliability)
- Support of ENGDAT/OFTP (the plan of SASIG and JAMA)
- Support of the deployment to overseas plants

2. It promotes the standardization of the CAD data exchange system at the OEM

Usage of a common system for OEM designers to send and receive data from German OEM.
This will lead to the reduction of system operation hours.

3. The commercial vehicle department is also planning to use SWAN as the next CAD data exchange system for Japanese suppliers

- Cooperation on the new system deployment to common suppliers.
- Cooperation of system supports to common suppliers.

4. Advantages for the suppliers

- Usage of one common system to send and receive data from German OEM and the commercial vehicle department.
- Possibility to use one common system to send and receive data from other suppliers.

The decision was made to realize the project „next generation data exchange system".

PROJECT REALIZATION

Schedule

After the decision to move to the "European style" of supplier integration, a schedule for the implementation of the new data exchange system was made.

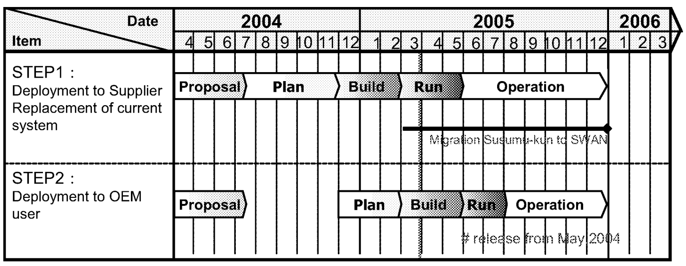

Figure 11: Schedule for Roll Out

The deployment of the implementation was divided into two steps. Step 1 is the connection of the suppliers, step 2 the internal usage for the OEM users.

Realization

The software installation was made remotely from Germany. The Japanese OEM made long time tests, also with suppliers.

According to Japanese standards, the tests were carried out very thoroughly. In order to promote a good cooperation, the following procedure has been chosen:

- There is a list of requirements, which need to be discussed and solved before SWANweb may be used in Japan
- Regular video conferences
- Workshops in Japan: August 2004, January 2005 and May 2005
- Communication in English, at workshops sometimes with Japanese-English translators
- Remote installation and system administration from Sindelfingen
- Email-correspondence
- Very careful proceeding in Japan
- After the launch of SWANweb MCOR/T-Systems takes on the first level support and SSC the second level support

DIFFERENT DEMANDS FROM JAPAN

During the cooperation with the Japanese colleagues, some problems occurred, which would be categorized as much less important in Europe and therefore probably wouldn't really occur. These problems may partly be put down to cultural differences.

Which problems have already been solved?

- *Adaptation of the SWAN e-mail notification.*

In Japan it is very important to inform the superior in charge as promptly as possible about a data exchange. For this reason some functions need to be modified. For the European user it was sufficient to include the information about the sender and the recipient. Now it is necessary to have three more persons, who might be selected to receive a notification.

- *Limitation of possible recipients*

From now on the number of recipients, who might be selected, can be limited. In Europe this function was not really required.

- *Support of ENGDAT V3*

The new international standard has been promoted under Japanese cooperation. The Japanese efforts helped to push the integration of the new standard. In Germany there is no immediate demand to introduce ENGDAT V3 very soon, because of the mainstream Engdat standard V2.

- *Using Asian characters*

The requirement to continuously send 2-byte characters was implemented. The programming necessitated a Japanese specialist.

New requirements

The following items have been discussed and will be integrated in the system step by step.

- *Confirmation function*

The sending of a job is to be authorized by the respective superior. This requirement partly results from the hierarchic structure of the Japanese system and has so far never occurred in Europe.

- *Definition of user capacities*

The administrator needs to be able to administer and control the storage capacity of the single users. The exceeding of this capacity needs to result in adjustable reactions.

CONCLUSION

The development of new data exchange processes for a great Japanese automotive manufacturer is in full swing. There have been some troubles during the design and planning phase, which so far didn't occur in this form in Europe. Nevertheless, the cooperation has been very constructive. The proverbial Japanese accuracy has helped to promote the improvement of the data exchange system. In this way the introduction of international standards like ENGDAT V3 have been pushed.

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[www03] http://www.jama.org

[www04] http://www.dijtokyo.org/

Figure 6 © Ariane Ittner 2005

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DESIGN APPROACH AND COMMUNICATIONAL STRUCTURES FOR DEVELOPING MASS CUSTOMIZED MECHATRONIC SYSTEMS

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ABSTRACT

As mechanics, electrics, electronics and software follow a synthesis trend to mechatronics, customer specific variation can increasingly be offered at competitive prices. This competition strategy known as "Mass Customization" is implemented using a methodology of designing a construction kit for customer specific solutions based on classic German design theories. A modular product architecture forms the logical backbone of this construction kit. Deduced variants and applications are individualized by selection of standardized, discretely and continuously varying components and cross-disciplinary variation mechanisms.

Furthermore, critical success factors of industrial implementation are discussed. Using a case study of a platform development project, informational and communicational structures as well as cross cultural team-work are pointed out. By applying the presented methods and success factors, product lines with many variants can be offered at affordable prices in short delivery times. This contribution summarizes contents of the recently published book „Kundenindividuelle Massenproduktion" (Graessler 2004).

COMPETITIVE STRATEGY OF MASS CUSTOMIZATION

The term "Mass Customization" combines the two contrasting approaches of Mass Production and Customization. Mass Production implies cost reduction due to scale effects and gained production experience. Customization focuses on exact fulfillment of customer's requirements and results in an unique competitive position. Mass Customization therefore aims at producing products to meet individual customer's needs with mass production efficiency (Tseng 1997). Thus customized products are offered at prices comparable to standard products and continuous individual relationships are established between each customer and the manufacturer (Toffler 1971, Davis 1987, Pine 1991, Kotha 1995). The combination of cost leadership and differentiation results in a simultaneous, hybrid competition strategy (figure 1).

For producing companies, the focus of Mass Customization lies on individualizing material core products. Often, tailored services related to the core products are offered in addition. Prerequisites of economic success of Mass Customization are mature markets and flexible technologies. Mature markets are characterized by heterogeneous, rapidly changing customer requirements, which can hardly be predicted. Flexible product technologies, such as adaptable materials or mechatronic systems, allow easy adaptation to the individual customer's preferences. Furthermore, generative or Laser driven production technologies make economic production possible in spite of varying characteristics and low lot sizes.

POTENTIALS OF MECHATRONIC SYSTEMS

Mechatronic systems emerge from functional shift and extension of mechanics to electrics, electronics and software. As a result of closely interacting disciplines, adaptive and intelligent systems are formed (figure 2). Due to functional integration of mechanics, electrics, electronics and software, the borderline between standard and variable system functions can be moved into areas of low efforts. Software thus advances to a variety driver within mechatronics and

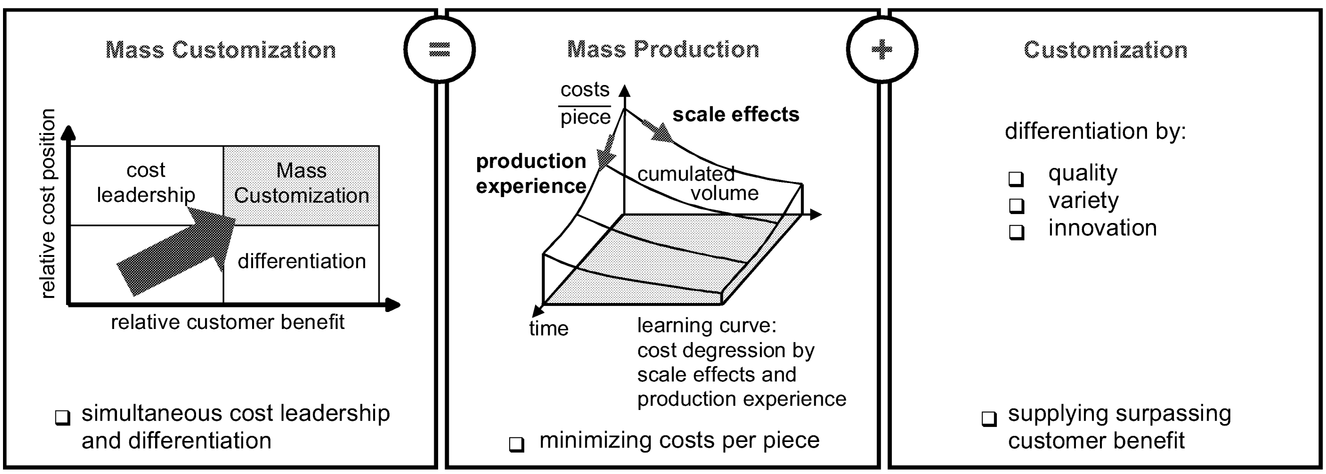

Figure 1: Definition of Mass Customization

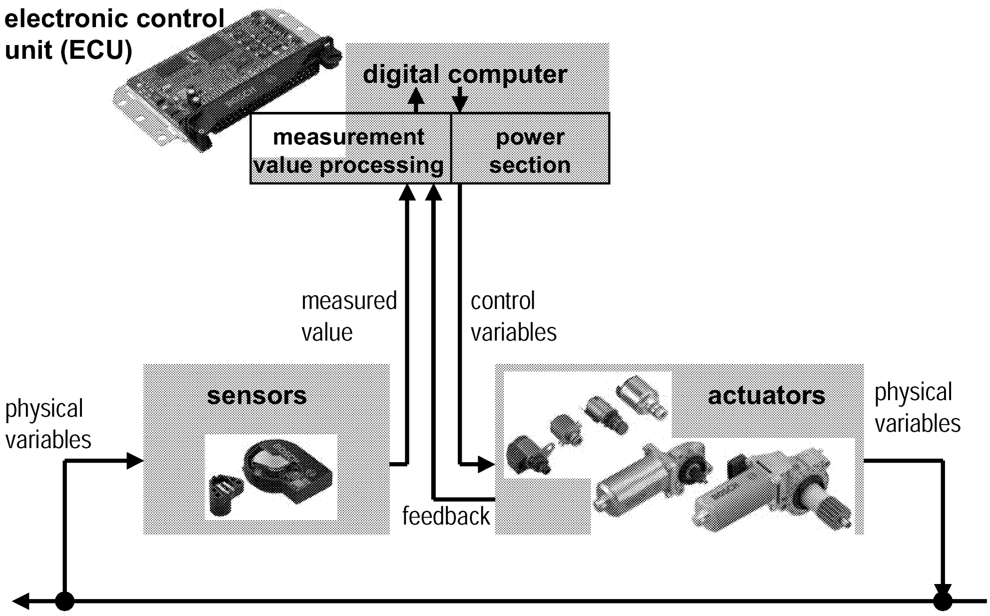

Figure 2: Principle of mechatronic system

increasingly depends on application specific knowledge. Therefore, mechatronic systems are the most promising application field of Mass Customization for producing companies.

CUSTOMER SPECIFIC CONSTRUCTION KIT

In order to realize a wide range of variation, development must focus on order neutral creation of construction kits for customer specific solutions. With the term "customer specific construction kit" a construction kit is described, from which a defined range of customized products is deduced. In contrast to conventional construction kits, the customer specific construction kit is based on a prospective and revolutionary development approach. Prospective means that the construction kit is developed in order to meet future requirements of new products and synergies shall be opened up from the first deduced product on. Revolutionary adds the challenge of a concept which does not rely on already processed customer orders, but provides a foresighted development frame for potential future customer orders.

A common product architecture of all deduced products serves as logical backbone of the customer specific construction kit. Deduced variants and applications are individualized by selection of standardized, discretely and continuously varying components and cross-disciplinary variation mechanisms.

DESIGN METHODOLOGY FOR CUSTOMER SPECIFIC CONSTRUCTION KITS

In order to put such a customer specific construction kit into industrial praxis, a corresponding design methodology has been developed. The design methodology supports a systematic, methodical procedure of order neutral creation of construction kits for customer specific solutions with regard to specifics of mechatronic systems. The methodology meets the following three demands. First, classic German design theories are integrated. Thus, the methodology is based on proven, universal design knowledge and a systematic, methodical procedure is ensured. Second, known methods and tools of creating standards and discretely varying components are used and supplemented by new approaches of designing continuously varying components. For each design phase, a selection of appropriate solution approaches is provided in a clear and well structured manner. Third, cross-disciplinary variation mechanisms are created by integrating and coordinating involved disciplines. According to the respectivedesign phase, needs of coordinating partial solutions between involved disciplines are changing. Therefore, focus of design methodology lies on defining appropriate interfaces between partial solutions in order to form a balanced overall solution.

Due to underlying prospective and revolutionary development approach, the design task is characterized by

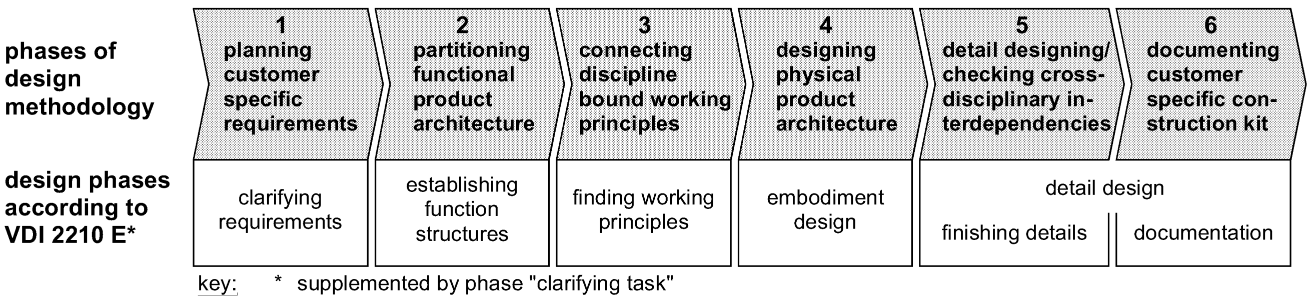

Figure 3: Phases of design methodology

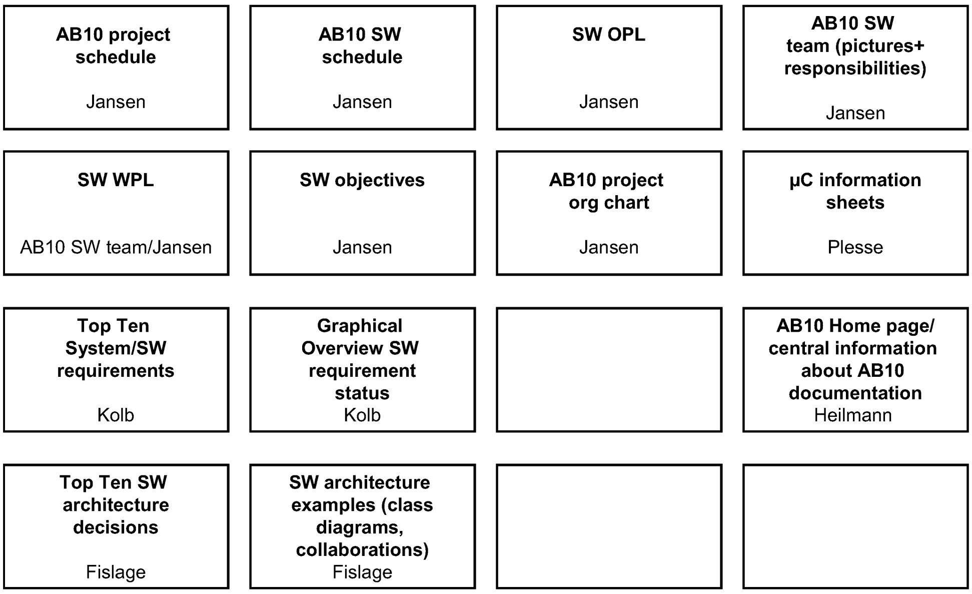

Figure 4: Team information board

a high degree of innovation which results in the need of early design phases, e.g. “establishing function structures” or “finding working principles”. As reference, VDI guideline 2210 E is taken, in which a multitude of German design approaches were unified (VDI 1975). Based on this phase model, the design methodology for customer specific construction kits is structured into six phases (figure 3).

During initial phase “planning customer specific requirements” clear limits between standards and variation are drawn within specification. This separation of product characteristics into “standards”, “discretely varying” and “continuously varying” is kept up within entire subsequent design process. Based on specification, a functional product architecture is derived (phase 2). Partial functions and functional structures are partitioned according to provided variability and involved disciplines. In phase 3, appropriate working principles are selected and cross-disciplinary connected. Special attention is paid on mutual interactions between chosen principles, effects and algorithms.

Physical product architecture derived from principle solution makes up the logical backbone of the customer specific construction kit (phase 4). On condition of this common structure, standardization and individualization are balanced. Standard, discretely varying and continuously varying components are designed to be mainly independent from each other and to be recombined. Due to standardized interfaces, the construction kit can be expanded order neutrally as well as order specifically. In phase 5, modular structures and components are detailed. Functionality and compatibility of connected variation mechanisms are checked. Finally, results worked out in phases 1-5 are comprehensively documented in phase 6. Besides product documentation, procedures and rules of handling the construction kit are defined.

INFORMATIONAL STRUCTURES

In order to economically develop mass customized products, the proposed design methodology has to be supplemented by a network of informational and communicational structures. Only if individual developers work together efficiently as a team, entire positive effect of design methodology will unfold. Main critical success factors of industrial implementation are illustrated by the following case study of a platform development project.

The project’s goal is to develop a platform of electronic control units (ECU’s) for airbag solutions. Core sub project is the software project since software becomes more and more the variant defining component of the whole mechatronic system. Initial situation of the software project team was characterized by unsufficient availability of team members, missing meeting culture as well as deficient information exchange and project management.

Therefore, informational structures had to be established as prerequisite of coordinated team-work. One core element of informational structures was the definition of a team information board by the whole team. In the first run, the project leader had already concepted a structure of such a team board by himself. However, it was not accepted nor applied by the team members. Consequently in the second run, each team member was involved in defining contents of the team information board, responsibilities and refresh periods (figure 4). The factual result of this team process was hardly better than the initial attempt of the project leader, but since input of everyone was taken and discussed in a facilitated team workshop, the result was thoroughly accepted and really put into action.

COMMUNICATIONAL STRUCTURES IN A CROSS-CULTURAL TEAM

Besides team information board, meeting rules were defined and cross-cultural behaviour patterns were analyzed, in order to establish harmonized communicational structures. Cultural diversity of the software project team is characterized by team members originating from Germany, India and America. The defined rules address meeting preparation, meeting results and meeting discipline. For example, it was agreed upon that together with an invitation to a meeting, participants receive meeting objectives as well as preparation material at least two days before the meeting takes place. Thus everyone can prepare for the meeting and discussions improve in focus and results. Another example is the rule that each discussion point must lead to a decision. Each decision agreed upon, such as selection of programming language, and each resulting measure has to be documented and tracked thoroughly. In order to ensure meeting discipline, a facilitator is named at the beginning of each meeting who takes care of time keeping, result orientation and other meeting rules. At each meeting, a new facilitator is chosen, so that everyone is once put into responsibility of coordinating a meeting, which in the whole has a positive impact on meeting culture.

Further, team development was self evaluated and discussed by the team members. As shown in figure 5, team-work usually develops within four phases. These phases can be followed subsequently, but rebounds into an earlier phase can also take place, e.g. when a new person becomes team member. In the case study, an initial self evaluation was taken in a facilitated workshop when Indian team members arrived at Germany (figure 5). Everyone gave his impression

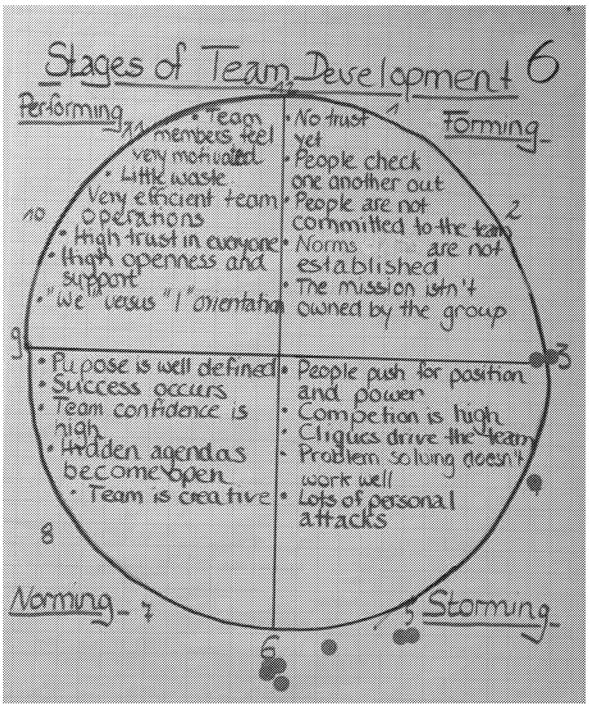

Figure 5: Self evaluation of team development

of the team situation and explained his viewpoint and feelings to the others. After this initial situation anlysis, this "team development clock" was regularly taken up in team meetings in order to make the progress of team work and mutual understanding a topic.

CONCLUSIONS AND FUTURE PERSPECTIVES

With the presented design methodology for customer specific construction kits, producing companies are enabled to open up potentials of mass customizing mechatronic systems. However, economic success is not only influenced by goal-oriented new development of customer specific construction kits, but also by efficient informational and communicational structures. Using a case study of a platform development project, applicable methods and success factors are pointed out. Thus product lines with many variants can be offered at affordable prices in short delivery times.

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ENGINEERING PROCESS MANAGEMENT

REAL TIME SYSTEM FOR METALLURGICAL PLANTS

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KEYWORDS: Real time systems, process control, optimization, control of distributed parameter systems, simulation, intelligent cell

1. ABSTRACT

Automation systems use more and more communication systems to be able to carry out right their task. Therefore, today it's already available a wide catalogue of products that allows the embedded systems used for the automation to interface to one or more field bus networks and to one or more wide range communication networks (telephone network, Internet, etc.)
But currently the systems both for the industrial automation and for the building automation, and for other kinds of control need several devices to be able to work within the network.
In particular, the main device containing the CPU foresees some interfaces for being able to be programmed, some interfaces for being able to talk with the I/O devices, some interfaces for being able to talk with the communication lines.
Steel making is one of the most important industries in the world nowadays because of the great variety of products that are made of this material. The paper is focused on an integrated system designed for the agglomeration factory and cowper stove process control and optimization. The system is based on a RT-ARCH (Real Time ARCHitecture)[1], an architecture of software tools used in process control. The system is composed by classical algorithms running on a network of PLC-s and controlling algorithms implemented in a process computer. Some of them are typical numerical algorithms, and the others are adaptive control algorithms.
The Open Source movement has developed new concepts of making process control algorithms based on transparent and co-operative ownership of software.

2. DESCRIPTION OF TECHNOLOGICAL PROCESSES

The paper presents a system with large capacity about calculation and communication in real time but at low cost.
The low cost, compared to the devices currently available on the market, is obtained thanks to the fact that the "Intelligent Cell" has an architecture very simple constituted by a microprocessor very powerful with only three single connectors: one for the power supply and two for the communications.
The "Intelligent Cell" is produced by the factory only with communication abilities and it can immediately be installed where it will have to reside during its operation activity.

AGGLOMERATION FACTORY

The raw materials used in the technological process are iron ore, coke, limestone and dolomite. The production result at the agglomeration factory is exclusively destined for feeding blast furnaces. The agglomeration factory is composed of the following technological fluxes: measuring station, agglomeration machine, and sorting and dispatching device
Iron ore, coke, limestone, the returning agglomerate from sorting, and iron offal, are piled in containers of measuring station. The raw materials are extracted from containers with running belts conducted by the programmable logic controllers (PLC) that receive signals from the electronic measuring device. Then, they are homogenized and sent to the agglomeration machine.
The agglomeration machine does the pyro-metallurgical process of sintering, the resulting agglomerate being riddled at high temperature, then cooled, sorted and dispatched to the blast furnaces. The agglomerate is sifted and sorted by size and granulation.

COWPER STOVE

The role of the cowper stoves (pre-heaters) is to heat the air up to 1100 ^{0}C and to supply this to the blast furnace. In almost all the cases there are four pre-heaters. They have a focus where gaseous combustible burns. The body of the pre-heater has a refractor cellular structure that keeps the warmth made by burning gases.

The pre-heater has two fazes of working:

a) The heating period, when the refractor structure is heated at a high temperature by burning the gaseous combustible into the focus

b) The blowing period, in which the cold air circulating on the contrary of the burned gases in the recent period takes the heat accumulated by the refractor in the heating period

3. THE INFORMATIONAL STRUCTURE OF THE SYSTEM

The overall goal is to foster the usage of F/OSS backend platforms and services and to generate new business opportunities for the Open Source developer community. The open source-based set of tools is supposed to have a high socio-economic effect for both, the providers and users of F/OSS, with a special focus on SMEs.

The informational system is designed first for data and technical parameter acquisition and then for operative supplying of information required for the process control, for exploitation and maintenance of the equipment. The entry information is received as digital or analog signals from transducers through the process interface. As a result of data processing, the computing system elaborates the output information, analog or numerical, that can be used for controlling, adjusting or for displaying on video terminals.

The system has a database for data and programs on the mass memory (one or more magnetic hard drives).

The automation system receives the following information:

- From electrical powering it receives on/off information regarding the following events: starting / stopping the devices; device status (working / not working); alarms; damages and the nature of damages; existence of power and controlling tensions
- From weighing machines in containers, on the running belt, or on the measuring devices the system receives analog or digital signals regarding: status; damage; kind of material; debit of transported or measured material; quantity transported or measured; place of stocking or transporting; proportion of different components of material.
- From measuring, controlling and adjusting devices the system receives analog or digital signals regarding: temperatures taken in different zones of thermal processing; debits of water and gas; dynamical analysis of different gases; speed of equipment
- From the superior hierarchical level, the system receives data regarding: production planning; programs of raw material supplying; material, fuels and energy consumption; maintenance programs

4. TECHNIQUES DESCRIPTION

Typically, classical control techniques use analog PID (PI, filtered PID) controllers, or on/off controllers for slower processes. Controllers are used in structures like:

- Simple adjusting with imposed reference
- Cascade adjusting
- Combined adjusting by perturbation and reference

These types of controllers have the advantage that they can be easily implemented, but very often their parameters are fixed. That's why classical control structures can be used only for those subsystems of technological installation that have very well defined models, or have modest control requirements.

From all the diverse modern control techniques we have chosen to implement some algorithms by computer programs. This implementation has a great flexibility: it is very easy to modify the dates of the program that contains the adjusting parameters.

5. HARDWARE AND SOFTWARE ARCHITECTURE

The hardware platform used as a support of the control programs is a personal computer with a Pentium IV processor, 64 Mb RAM, 64 bits video graphic accelerator, SCSI 80Gb HDD, data acquisition card, one multiplex for 16 serial ports and a network of 16 PLC-s. On this machine we have used Unix operating system. This system offers multitasking facilities for parallel managing aspects regarding data acquisition, data transmission, adjusting and data displaying. Using multitasking we could manage more control loops on the same computer even though some of the processes are controlled only by PLC-s.

The development platform used was Visual C++ 4.0 because it can compile programs for Unix operating system and it has the following facilities:

- Permits creation of separate threads with different adjusting algorithms for each of the processes.
- Offers communication methods inter-threads for transferring data between data acquisition processes and controlling processes. Communications are made using message boxes and critical sections.
- Permits realization of communication modules in a TCP/IP network. That makes possible implementation of the hierarchical architecture.
- Offers the possibility to create a user-friendly interface for the product, in Unix environment.

The only disadvantage of this platform is that it hasn't any dedicated functions for complicated mathematical calculus needed in adjusting algorithms, so that we had to write them ourselves.

The process computer is placed in the control room of technological installation because it must be protected from the vibrations and from the environment of the technological process.

6. PROCESS OPTIMIZATION

The rigidity of the mathematical problem posed by the general optimization formulation is often remote from that of a practical design problem.

The optimization problem is "given a dynamic system (S) that evolves on a finite time interval $[T_0...T_f]$ and the performance index J (u) it is required a command that minimizes J". In this standard formulation there are no restrictions, but it follows a movement in the states space for minimum energy consumption. Using the computer we have chosen dynamic optimization, that relies on the idea of finding a procedure for generating a "relaxing" array defined by the following condition:

X1, X2, X3, …Xn, so that $f(X1) \geq f(X2) \geq f(X3) \geq \ldots$ with the property that if $Xk \to X$, then $f(Xk) \to f(X)$, where X is the extreme value of the objective function in a specific domain.

The relaxing arrays generating procedure has two components:

- Choosing the descending direction of the function with the modified Newton method. This is a gradient method that means successive approximations of the function.
- Determining the step on the descending direction.

Newton-type method calculate the Hessian matrix H directly and proceed in a direction of descent using a line search method to locate the minimum after a number of iterations. Calculation H numerically involves a large amount of computation. Quasi-Newton methods avoid this, by using the observed behavior of f(X) to build up curvature information, in order to make an approximation to H using an appropriate updating technique.

7. CONTROL SYSTEM FUNCTIONS FOR AGGLOMERATION FACTORY

The automation system works in a collecting-processing way, interfering with and conducting the controlling processes. The system does the following functions:

- Supervision of technological equipment and devices
- Displaying and printing any damage that may occur, showing the moment of appearance, the kind and the place of the damage
- Displaying and printing the alarms at the moment of the occurrence
- Showing the entries and outputs from the programmable logic controllers for debugging any anomaly or damage
- Controlling the measuring equipment and supervising the process of combining of raw materials
- On demand, displaying the parameters of the technological process
- Calculating the consumption of the raw materials by sorts, indicating the norms of consuming for combustibles and electrical energy
- On demand, transmitting data regarding the level of production, the structure of consumption, etc., to the superior hierarchical level

Some of the subsystems of the technological installation are variable in time due to action of stochastic perturbations. That determines large variations of the parameters of the attached mathematical model, but fortunately the structure of the model remains the same.

The control takes place at the level of the central computer, and also at the level of the PLC-s. We have used a hybrid adjusting method, i.e. some adjusting loops are implemented with classical algorithms (PI, PID), and the others are adaptive.

The system is composed by:

- Classical algorithms running on the PLC-s that also have implemented data acquisition modules, and analog and digital command modules. Programs are written in the PLC's language (PL 7-2).
- Controlling algorithms implemented with the process computer. Some of them are typical numerical algorithms, and the others are adaptive control algorithms.

8. CONTROL SYSTEM FUNCTIONS FOR COWPER STOVE

The primary objective of numerical controlling of the pre-heaters is optimization of the technological process. The purpose of this optimization is obtaining a high efficiency and combustible saving. The computer controls and effectively optimizes the technological process. The intelligent control of the process takes place at the level of the process computer. It realizes the following functions:

- Compute the quantity of warmth required for heating the pre-heaters. The optimization of the technological process imposes an exact correlation between the quantity of warmth required for heating and the quantity of warmth taken by the air blown into the furnace By this correlation it can be determined a minimum combustible consumption for heating. The objective function is:

$$W = \int_{t=0}^{t=t_s} Q_w(t)dt$$

where Q_w is a thermodynamic equation depending on the quantity of warmth taken by the air blown in a blowing period t_s.

- Compute the caloric power of the combustible gaseous mixture. Pre-heaters are supplied with a mixture of gases in different proportions. It is required to calculate the minimum debit of mixture, function of caloric power of components.

The relation is: $F_b = \frac{Q_W}{H}$, where:

F_b is the gaseous debit

H is the caloric power of the mixture of gases

Q_W is the quantity of warmth

- Compute the debit of air required. For a complete burning, the proportion of gaseous combustible mixture and air in the focus must be optimal. This value is calculated starting from the quantity of air required by any of the components of the combustible mixture.

The relation of calculus is:

$$F_a = \frac{k_1 F_1 + k_2 F_2}{F_1 + F_2} F_b,$$ where:

F_a is the debit of air

F_b is the debit of combustible mixture

k_1 , k_2 are variable coefficients

F_1 is the debit of the first component of the combustible mixture

F_2 is the debit of the second component of the combustible mixture

Depending on the values obtained, the computer commands and adjusts the debits of gaseous combustible and air, and the time between the two working fazes of the pre-heaters.

9. CONCLUSIONS

Implementation of this system in Romanian metallurgical plants has the following advantages: obtaining a high efficiency and combustible saving, limited efforts for developing a new application in a short period of time, and high performance of the system in solving the demands of applications.

The system uses secure socket connections (SSL) to transmit all sensitive information during the control process. The application has been tested in an integrated system, with several servers running Unix, connected in a network. The system was configured easily, and it has worked very fast because the communication protocol transmits just the information needed. The aim of the system is to realize a network of Intelligent Cells with large capacity about calculation and communication in real time but at low cost.

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REQUIREMENTS FOR THE WORKFLOW-BASED SUPPORT OF RELEASE MANAGEMENT PROCESSES IN THE AUTOMOTIVE SECTOR

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KEYWORDS

Workflow management, release processes, hierarchical workflows, workflow synchronization

ABSTRACT

One of the challenges the automotive industry currently has to master is the complexity of the electrical/electronic system of a car. One key factor for reaching short product development cycles and high quality in this area are well-defined, properly executed test and release processes.

In this paper we show why workflow management technology is needed to support these processes and how this support should look like. We further confront these requirements with the features of contemporary workflow technology and discuss which extensions become necessary.

INTRODUCTION

In modern cars up to 70 electronic control units (ECU), wired by kilometres of cable, cooperate to realize innovative functions for drivers and passengers. But with growing complexity, product quality has become a serious issue in this domain. In this context the development process plays a key role since its quality is correlated with the resulting product quality. Therefore the automotive industry makes great efforts to improve this process and to provide computerized support for it (Knippel and Schulz 2004).

In the development process of the electrical/electronic system (EE-system) of a car one can distinguish four phases (Wehlitz 2000): The requirements analysis and conception phases are followed by the phase during which the different components of the car (e.g. control units and corresponding software) are developed. This is done in parallel and in cooperation with external suppliers. Before producing the car, the components have to be integrated, tested and released. In order to obtain high quality, these steps are continuously repeated during the ongoing development process (cf. Figure 1).

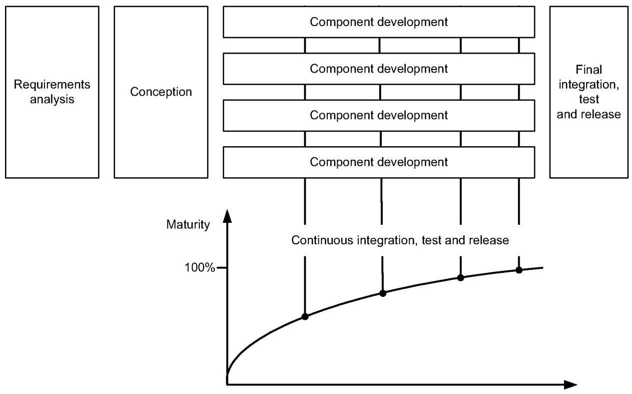

Figure 1: EE-development process according to (Wehlitz 2000)

RELEASE OF HIERARCHICAL PRODUCT CONFIGURATIONS

Subject of integration, test and release are (product) configurations which may comprise different versions of components. As a simple example consider the configuration for a particular ECU, which consists of a version of the ECU's hardware and a version of the ECU's software.

In our context a configuration expresses a certain degree of compatibility in the sense that components contained in the configuration correctly work together as specified.

Before testing and releasing a configuration this compatibility is assumed by the person who assembles the configuration. After these test and release steps, compatibility is considered as verified such that other activities in the development process can rely on a certain degree of maturity. However, this does not guarantee total correctness since tests only contribute to identify errors but cannot prove their absence.

In this context a promising approach is to incrementally assemble hierarchical configurations according to the logical structure of the total EE-system and to integrate the

EE-system in a bottom-up approach (cf. Figure 2). This means that, first of all, configurations are assembled, tested and released at the lowest level. Based on this, further configurations can be assembled from lower level configurations and can be tested and released as well. This is continued until the top of the configuration structure is reached.

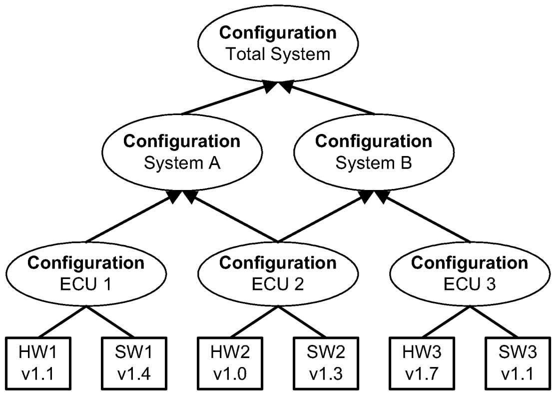

Figure 2: Example of hierarchical configurations

An example is depicted in Figure 2. In this example, the configuration of a *single* electronic control unit (here consisting of a hardware and a software component in certain versions) constitutes a configuration at the lowest level of the overall configuration. A configuration on a level above could be a system configuration, comprising all ECU configurations for a specific subsystem.

Taking a process-oriented view, each configuration is associated with a release process (cf. Figure 3). The term "release process" is used for *all* steps executed in a certain order to ensure compatibility between the components of a configuration. These steps can be real dynamic tests like breadboard-tests or Hardware-in-the-loop-tests. Steps can also be of formal nature like the official approval of the configuration by a committee.

Only if all steps of a release process are executed successfully (i.e., all steps are completed and no errors are found) the respective configuration is considered as correct and can therefore be "released". By contrast, if errors are found in one or more process steps the configuration is considered as incorrect and can therefore be not released.

If the release processes were executed in a strict sequential order across the different levels of a configuration hierarchy (as described above), this would require a significant long time until the top configuration could be released. For this reason, release processes on different levels are allowed to be executed in parallel. However, in this context certain conditions must be met:

- A configuration on a higher level may only be released after all of its subconfigurations have been released.
- Certain steps of a release process may only be executed after particular steps in the release processes of the corresponding *sub*configurations have been executed successfully.

Reason for the latter restriction is that test activities on a higher level are usually more expensive than those on a lower level. Therefore a certain maturity of the lower level configuration has to be reached before steps on an upper level should actually be carried out.

One example for such a dependency between processes at different levels of a hierarchy is the test step of "flashability" for an ECU: Nowadays many ECUs can be flashed, which means that their software can be replaced arbitrarily often. Testing the flashability of an ECU verifies whether the hardware is able to be flashed in accordance to the rules the automotive manufacturer has specified for the ECU software. On the level of an ECU configuration this test step constitutes the precondition for all dynamic tests on the configuration level above (the systems level). At this level tests cannot be carried out if the software cannot be flashed on the ECUs. This example illustrates just one of many possible inter-process dependencies.

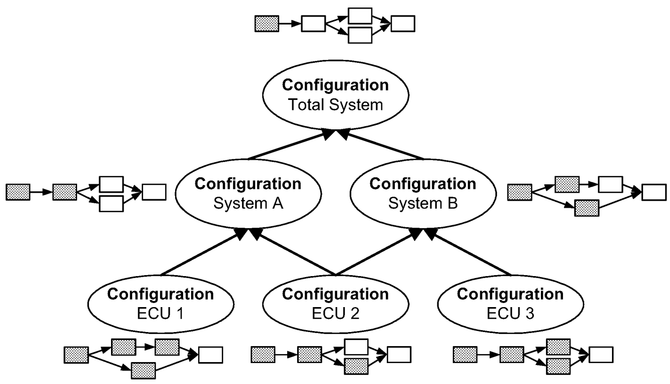

Figure 3: Configurations and associated release processes

WHY DO WE NEED WORKFLOW-SUPPORT?

In a modern car there are up to 70 ECUs. During development time this results in hundreds of hierarchical configurations, as for each ECU numerous versions for hardware and software exist. Each configuration is associated with a corresponding release process, which does not only coordinate related tasks, but also controls the dependencies to other release processes.

Given these facts it becomes obvious that users need an adequate IT support for coordinating the execution of these processes in terms of workflow management. The main goal for the computerized support of release processes is to ensure their correct execution. In particular, this includes the control and monitoring of their dependencies with other release processes. Manual process coordination and synchronization would be too time-consuming and error-prone in this context. By achieving this main goal workflow support contributes to reach economic goals like cost-reduction and shortening of process cycle times.

VISION OF WORKFLOW SUPPORT

How should an ideal workflow support for the release processes look like? Important requirements are discussed in the following.

1. Starting release workflows for configurations

The person in charge should be able to start a release process for a specific configuration at an arbitrary point in time. However, a release process for a super-configuration may only be started if the release processes of its subconfigurations have already been started or have already been finished successfully.

2. Giving users support to execute test steps

For each step in a release workflow the corresponding actor should have access to the configuration and the test task he must carry out with this configuration. After completion of this task the user should be able to report to the system whether any error was detected or not. The kind of workflow support therefore does primarily not concern the automation of single test steps (e.g., by calling software applications) but the coordination of the release workflow and its synchronization with other release processes. This means tests steps of a release process are thought to be executed outside the scope of the workflow system – only the result of a test step (whether errors were found or not) is reported back to the workflow system. Thus the test steps here are considered to be coarse-grained.

3. Enable flexible reactions to test errors in a particular release process

If one or more errors are found in a configuration the person responsible for this configuration should be notified and be able to decide about further actions. Doing so, he should have the following two options:

- Cancel the workflow as further tests are unnecessary and would not lead to (more) important test results.

- Let the workflow execution continue with the possibility to exclude certain steps from execution. There may be some steps that produce interesting test results that are important for the ongoing development process, whereas other steps may not do so (like formal approval steps).

4. Set appropriate release state of configuration

After completing a release process the appropriate release state of a configuration should be set. In case at least one error was found the state is set to "not released" otherwise to "released". This release state can be accessed and viewed by all actors needing access to the configuration during the development process.

Note that a configuration must not obtain the release state "released" if not *all* of its subconfigurations own the same state.

5. Consider hierarchical control flow dependencies

The various control flow dependencies between release processes of configurations on different levels should be enforced. The release process of a configuration on an upper level may not be continued at a certain point until *all* release processes of its subconfigurations have reached particular states in their execution.

6. Enable flexible reaction on test errors in sub- and superconfigurations

Assume that errors are found in a configuration during the release process. This has not only consequences for the release process of the directly affected configuration (see Requirement 3) but also for the release processes of sub- and superconfigurations. Like for Requirement 3 the persons responsible for these configurations should be notified. In particular, they should then be able to react in the same flexible way to detected errors in sub- and superconfigurations. As this reaction may depend on the state of the respective release processes of the other configurations they must be able to get a quick status overview of these related processes.

But which configurations (and respectively their release processes) have to be considered when an error is detected for a particular configuration?

First of all – taking the notion of "bottom-up error-handling" – all superconfigurations have to be considered consecutively to the top (cf. Figure 4). This is required since a configuration may not reach the state "released" if any subconfiguration has not been successfully released. Therefore, when an error has been detected for a particular configuration, the person responsible for the super-configuration has to decide whether it makes sense to continue (or even start) the corresponding release process although the superconfiguration cannot be released. In addition to Requirement 3 he must also decide which dependencies to other processes are still important and which are not.

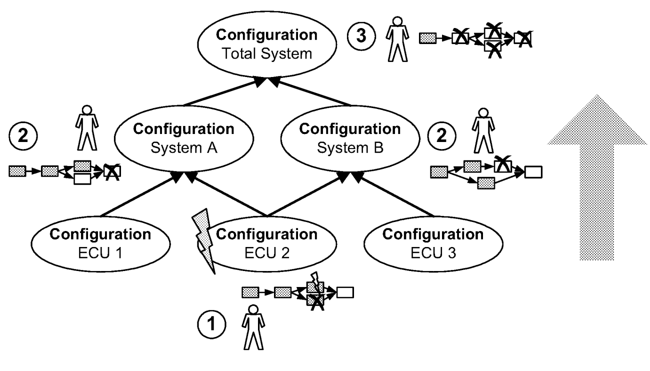

Figure 4: Bottom-up error-handling

Let's consider the example above: An error was detected, when executing a step in the release process of the configuration *ECU 2*. At first the corresponding person in charge of this configuration is notified and can make his decision. In a second step persons in charge for configurations of *System A* and *System B* are notified and can react to the situation. Finally the person in charge for the release process of the whole system configuration is notified.

Additionally, when detecting an error in a configuration it is possible that the subconfiguration causing this error can be identified. If the release process of this subconfiguration is still running the responsible person should be notified and have the possibilities as described in the context of Requirement 3. This "top-down error-handling" usually causes additional "bottom-up error-handling" for all of its superconfigurations.

Figure 5 shows an example: An error is detected in the configuration *System A*. This error can be deduced to an error in the configuration *ECU 2*. So after reaction to the error of configuration *System A* the person in charge for *ECU 2* is notified and can influence the release process. To maintain consistency the "bottom-up error handling" starts for the *System B* configuration and afterwards for the total system configuration. (Remark: Since the total system configuration is a super configuration of the *System A* configuration the error handling for the total configuration would also have been initiated if the top-down error-handling had not been executed.)

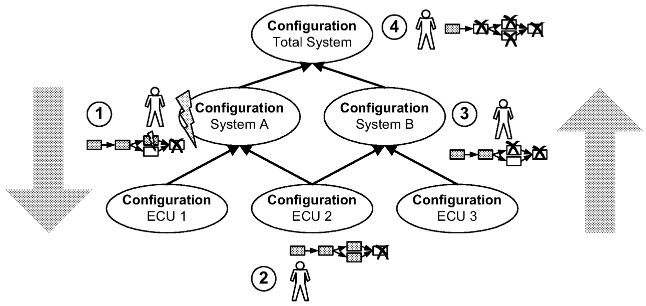

Figure 5: Top-Down and resulting bottom-up error-handling

SPECIAL REQUIREMENTS FOR WORKFLOW-MANAGEMENT-SYSTEMS (WFMS)

Attempts to capture the discussed requirements by means of contemporary workflow management systems have been unsuccessful. In particular, they have revealed the fact that it is not possible to implement these requirements without expensive and cumbersome workarounds – mainly by invoking external applications implementing the above described requirements as a hard-wired black-box. Possible consequences of this approach are high maintenance costs, bad adaptability to organizational changes and new processes, etc..

The following *special* requirements (not supported by contemporary workflow management systems) can be identified:

- Modelling and enforcing of control flow dependencies between parallel workflows depending on data associated with a workflow.
- Dynamic adaptation of these dependencies at runtime.
- Dynamic deletion of steps from a workflow instance (and its impact to concurrently running workflow instances).
- Built-in-support for special kinds of "error-handling" as described in the context of Requirements 3 and 6. It is important to notice that these errors may not be mistaken for errors as normally considered in the context of workflow management systems (cf. Eder and Liebhart 1995). In contrast to the common understanding where an error of an activity means a failure in the execution of the activity itself, in our context *error* denotes a regular result of an activity.
- Features enabling decision makers to get a quick overview of the state of all release processes directly or indirectly associated with a configuration, e.g. in case of test errors and the decision about the further proceeding.

RELATED WORK

In the conventional workflow world hierarchical workflows are understood quite differently. For example, in MQ Series Workflow hierarchical means, that an activity of a workflow can also be implemented as another workflow. During runtime then another workflow is initiated as a subworkflow for this activity. After completion of the subworkflow the calling workflow continues with its execution (Leymann and Roller 2000). This understanding of hierarchical workflows is also shared, for example, by many workflow execution models like Petri Nets (Aalst and Hee 2002), FunSoft Nets (Deiters and Gruhn 1994), or State- and Activitycharts (Harel 1987).

By contrast, in our case *hierarchical* means that workflows are executed in parallel with control flow dependencies between them depending on the hierarchical structure of the configurations they are associated with. As discussed this raises a number of requirements with respect to the workflow execution model not covered by today's approaches.

The synchronization of "real" parallel processes has been subject of some research approaches (e.g. Kamath and Ramamritham 1998, Hagen and Alonso 1999, Heinlein 2001). However, none of them allows to express control flow dependencies based on data associated with a workflow the way it is needed here. Control and data flow dependencies between parallel workflows are also relevant in the context of cross-organizational workflows (Jordan et al. 2002, Kulendik et al. 2001).

Many research approaches (e.g. Reichert and Dadam 1998, Weske 1998, Casati et al. 1998) are dealing with adaptive workflows. But as far as the authors knowledge concerns, the issue has not been considered in combination with synchronization of workflows and dynamic adaptation of dependencies between them.

CONCLUSIONS AND OUTLOOK

For a successful implementation of release processes in the electrical/electronic domain it is a necessity to support them by workflow technology. However, the requirements identified for such a support are not met by current workflow technology. Research has already been dealing with main issues here – but in a rather separate and non-integrated approach. So the next step is to develop an integrated, coherent workflow concept for this domain.

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COLLABORATIVE CE ENVIRONMENTS AND VIRTUAL TEAMS

Integrated Technology for Collaborative Engineering in Aerospace

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KEYWORDS
Aerospace, Integrated Technology Evaluation Platform, Data Repository, Collaborative Engineering, Simulation

ABSTRACT

Collaborative engineering techniques increase the efficiency of the aerospace industry by providing solutions for the use and sharing of information. In this paper an integrated collaborative engineering environment is presented, that has been developed by the Netherlands National Aerospace Laboratory NLR in the context of the European Union project FACE (Friendly Aircraft Cabin Environment). This environment supports all partners with design and evaluation of new technologies for the improvement of aircraft cabin environments. The technology applied is generic and can be reused in future R&D projects, where collaborative engineering is required.

INTRODUCTION

As described by Thierry Pardessus, Vice President Design Methods and Deployment of Airbus, in (Pardessus 2004), contemporary aerospace engineering benefits from concurrent engineering: *Through the significant reduction of the lead-time, concurrent engineering leads to significant cost reduction. Also, the need to share a lot of information and data with numerous users from different skills has induced the implementation of strong structuring concepts.* As cited, concurrent engineering techniques, or in a broader sense, collaborative engineering techniques, increase the efficiency of the aerospace industry by providing concepts for the use and sharing of information. In this paper, we present how solutions for efficient information processing and sharing positively contribute to the required collaboration.

The technology, underlying the solutions, comprises years of experiences gained at NLR with the development of multi-disciplinary working environments. This technology is reusable for future applications in all the domains where system design, analysis, and validation is performed. NLR developed several aerospace collaborative engineering environments, for example, in the projects ATC-Wake, ASICA, MOB, OPAL (Van Eenige 2003). An example of another collaborative environment in aeronautic engineering is the Integrated Technology Evaluation Platform (ITEP) developed in the integrated European Union project FACE by the National Aerospace Laboratory NLR. The FACE project (Paonessa 2003) focuses on development and evaluation of new multi-disciplinary technologies to treat noise, vibration, and air quality in order to improve environmental comfort of passengers and crew in civil turbofan aircraft. The newly developed technologies will be applied in European aircraft projects in the near future. ITEP supports the project partners throughout Europe to collaborate on the validation and evaluation of new design concepts, with appropriate security measures. The platform provides the engineer with integrated access to, organisation of, and easy sharing and re-use of tools, data, simulation models, evaluation procedures, and test results. All of which may be located at the various partners' sites.

This paper first presents a case study on multi-disciplinary collaboration in aircraft engineering, in particular, in engineering of the sound levels in aircraft cabins. Next, the implementation of ITEP is described, thereby highlighting the generic building blocks for collaborative engineering in the aeronautic industry.

CASE STUDY ON MULTI-DISCIPLINAIRY COLLABORATION

The case study is restricted to the field of structural acoustics, representing the greater part of the FACE project. The field of structural acoustics studies the acoustic transmission of sound through structures, and as such is a multi-disciplinary field involving the disciplines of (experimental and theoretical) acoustics and (experimental and computational) structural mechanics. A typical problem under investigation in the FACE project is the optimisation of the transmission of external sound (engine noise, boundary layer noise) through the aircraft barrel into the aircraft cabin. The investigation applies both experimental and computational techniques, either using the experiments to validate the simulations, or complementing each other's results.

FACE context

For the validation and assessment of the concepts, implemented and tested in the FACE project, evaluation procedures have been developed. An evaluation procedure is a recipe describing how to perform an evaluation, in terms of instructions on how to execute a graph of interrelated tools and how to deal with the data involved. Such a recipe is essential for consistent and reproducible execution of extensive evaluations of novel design. Figure 1 displays the experimental and computational framework of the FACE project for the evaluation of the performance of various fuselage panels. A typical evaluation starts with the definition of the fuselage panels (geometry, material properties, etc.); Figure 1 shows a blueprint of a sandwich panel. The panel information test specimen is stored in the *Specimen* database. Subsequently, the acoustic experiments are defined and executed (the figure shows a photograph of the stringer of the TANGO panel). The description of the experiment and the results of the experiments are stored in, and available for evaluation from, the *Experiment* database. The database ensures data consistency. Its web-based interface allows easy and secure data sharing. After definition of the experiments, the experimental panel geometry is converted to a computational model using a CAD package, and stored in the *Specimen* database. In the figure the CAD description of the TANGO panel is shown.

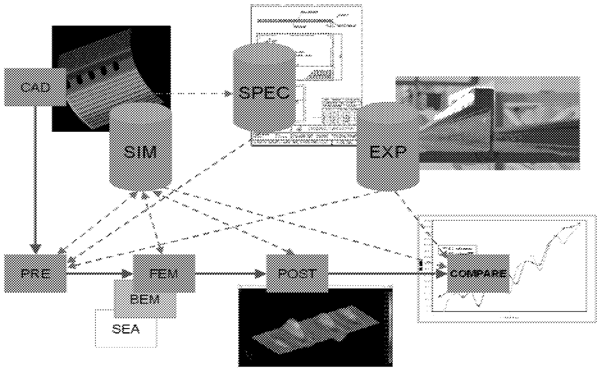

Figure 1 Schematic representation of the experimental and computational framework of the FACE project for the evaluation of the performance of various fuselage panels (Abbreviations used: SPEC, specimen; SIM, simulation; EXP, experiment; PRE, pre-processing; POST, post-processing; CAD, Computer Aided Design; FEM, BEM, and SEA are different analysis techniques)

Depending on the kind of analysis tool, the CAD model is pre-processed to an input model in a format suitable for the analysis tools, by including, amongst others, material properties, boundary conditions, and modelling of the air volume. The input model in these formats is stored in the *Simulation* database. Given the input models in the *Simulation* database, the model can be analysed using FEM and BEM techniques for the low to medium frequency range, and SEA techniques for the high frequency range. Subsequently, the simulation data is post-processed (in the figure the third mode shape of a small panel is shown), and post-processed data is stored in the *Simulation* database. Finally, experimental and computational data are combined for validation and evaluation.

FACE-ITEP environment

ITEP is set up to support the process of evaluating the different technologies developed in the FACE project. It provides the engineer with a web-based access to the necessary tools and data in a way that is intuitive to the engineer. This is established by mapping the evaluation procedures one-to-one onto their ITEP implementations, both in visual context as presented by the graphical user interface (GUI) of ITEP, and in data flow context as implemented by the workflows of ITEP. ITEP facilitates both information sharing (through the data repositories) and information processing (through the workflows). Workflows, of which an example will be given in the next section, consolidate and control standard work processes, and, in the context of the FACE project, thus ensure consistent evaluation of the performance of fuselage panels. Moreover, different parts of the workflows may be executed by different partners, depending on the availability of expertise and tools. In the following two subsections some application examples with ITEP will be given.

A simulation workflow

A greater part of the evaluation of the transmission loss through computational means is the computation of the eigenmodes of the panel under investigation. At NLR, structural simulations are performed using a customized version of the B2000 finite element (FEM) environment (Merazzi 1994). A typical simulation consists of a pre-

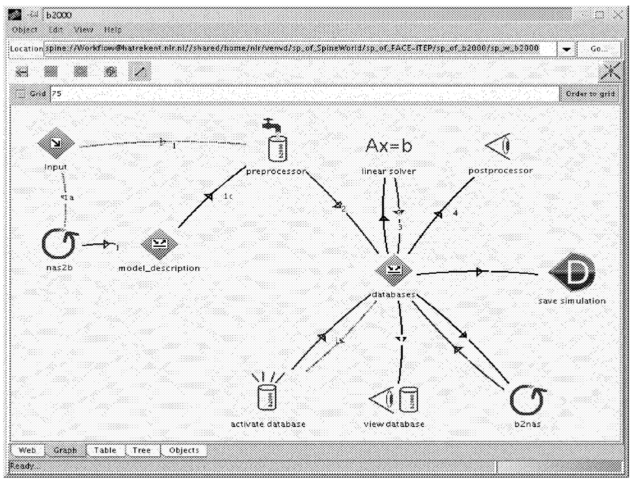

Figure 2 B2000 workflow

processor step (defining the simulation, possibly from a CAD description), a processor step (computing the eigen modes), and a postprocessor step (visualisation and analysis of the results). These steps are shown in the top of Figure 2, which shows the ITEP simulation workflow for the B2000 environment. Located in the centre of the workflow is a data container 'databases', containing all B2000 databases describing the user's simulations. The B2000 database is central in the B2000 environment, and hence is central in the workflow. Implementation and visual representation of the workflow closely reflects the engineer's view on the simulation process.

Also included in the workflow are two conversion tools, `nas2b` and `b2nas`, which convert Nastran BDF files to B2000 files and vice versa. These conversion tools are particularly useful in multi-site collaboration, since it supports data sharing also for different file formats. Once the simulation is finished, the results can be stored in the

Simulation database using the 'Save simulation' tool, which provides direct access to the data repositories described in the next section. An example of a result of a B2000 simulation using this workflow is shown in Figure 3, showing the eleventh mode shape of a small panel with stringers.

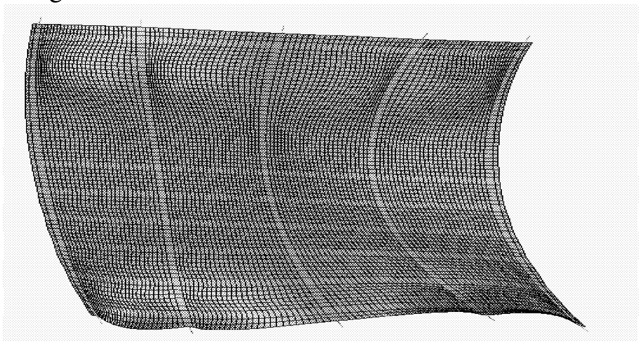

Figure 3 The eleventh mode shape of a small panel with stringers (deformation is exaggerated)

The complete set of results is stored in the data repository, in Nastran BDF format, and can be re-used by other partners to complete the transmission loss analysis.

The evaluation data repository

The three databases are combined in a single repository, the evaluation data repository (EDR). The databases are shown as three different categories, together with an extra category *Evaluations*, which contains synthesized data from experiments and simulations. Each category has its own data structure and data description. A view of the EDR is presented in Figure 4. .

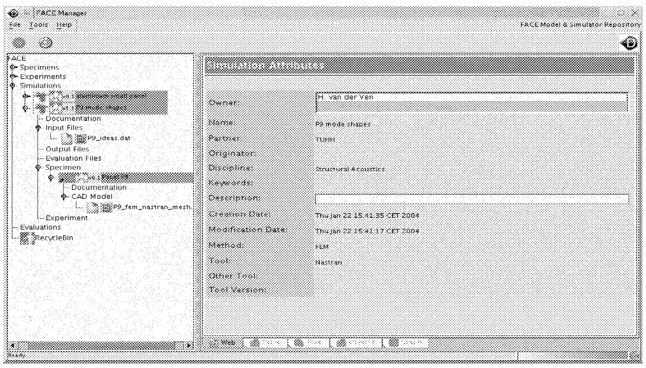

Figure 4 A view of the EDR

The left pane of the window shows the hierarchical structure of the repository. The four categories, *Specimens, Experiments, Simulations*, and *Evaluations*, can be seen, and a detailed look into the *Simulations* category is presented. The right pane shows information on selected items on the pane. The information in this window can be used to construct search queries on the entire contents of the repository. Because of the sheer size of the data generated within the FACE project, this search utility is essential for efficient data sharing.

Uploading and downloading of data to and from the EDR is easily accomplished using a drag-and-drop interface. Users can create their own objects, manipulate them, and, once the object is to the user's satisfaction can publish the object to (selected groups of) other users of the EDR.

Naturally, the data contained in the repository can be used within the workflows described above, for instance by drag-and-drop. Conversely, data within a workflow can be easily stored in the repository, both as a means of data storage and data sharing of intermediate and/or final results.

REALISATION OF ITEP AS COLLABORATIVE ENGINEERING WORKING ENVIRONMENT

The development of a specific engineering environment starts with the definition and analysis of the user requirements and needs, such as proprietary/transfer rights, heterogeneous or homogeneous network, collaboration, performance, secure communication, human/hardware in the loop, data format for pre/postprocessing. These requirements constitute the baseline for the design and development process. For FACE-ITEP according to the needs in the project, a distributed approach has been applied while the resources are integrated seamlessly into a single, coherent system. ITEP is developed according to the framework depicted in Figure 5. The framework comprises years of experiences gained with the development of multi-disciplinary, distributed working environments supporting engineers to collaborate in multi-partner projects in aerospace R&D.

The framework is used as blueprint for collaborative engineering platforms, which provide the engineer with integrated access to the resources (computers, tools, data sets) that support the engineering activities. In addition, generic results of the development of such working environments were - and still are! - collected in an NLR product suite. The suite applies and combines state-of-the-art and off-the-shelf techniques (such as CORBA, JAVA and the web), middleware products, and security technologies (e.g., virtual private networks, Secure Shell, Secure HTTP, signed applets) to support the realisation of platforms on top of existing computing infrastructures.

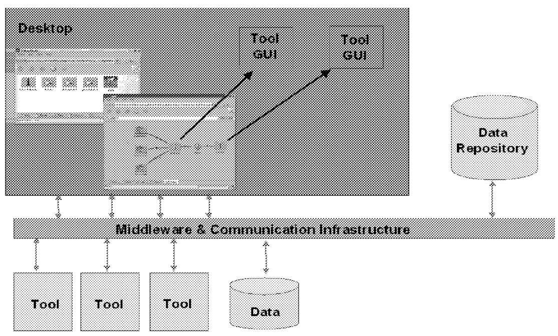

Figure 5 Framework for collaborative engineering platforms

To define security measures on access to the hosts of FACE-ITEP, the concept of Project Zone is applied (Baalbergen et al. 2003). In addition, only authenticated users should be able to access particular FACE-ITEP components. Security – involving user authentication and trusted network connections – is an important issue in the design of FACE-ITEP.

ITEP is available as a web application. It can be accessed by the FACE project partners via the Internet, via a single entry point, *faceitep.nlr.nl*. Its web interface enables the users to access the platform using the local desktop's Java-enabled native browser, without the need to install any additional specific software. This makes ITEP easily accessible to the engineers in the project. The web interface and the provisions for concurrent access to and use of its contents, ensure that ITEP is a suitable platform that serves the collaborative engineering needs of the FACE project.

ITEP consists of three main components: The Web Portal, which facilitates access to ITEP using the user's native web browser; the Evaluation Data Repository, which supports the sharing of data; and the ITEP Working Environment, which provides the workflows that support the processing of data.

The *Web Portal* is a collection of web pages, which provides the user with easy and coherent access to the documentation, the help desk, and entry points to the other ITEP subsystems.

ITEP's *Evaluation Data Repository* supports the storage and sharing of information. It is implemented as a Deposit repository. NLR's Deposit is a distributed and web-based general-purpose knowledge base (Moelands and Baalbergen 2004). It supports collaborative work by providing multiple concurrent and possibly geographically dispersed users with a (logically) central repository for storage, search, retrieval and sharing of any kind of information (e.g., data, models, code, manuals) involved with engineering and simulation, irrespective of the used file format. In addition to world-wide access via its web interface, the repository supports controlled access to its contents, automated configuration management, and is hence suited for the management of information in collaborative engineering environments. Access to the repository and any data transfer involved is secured.

ITEP's *Working Environment* is realised using the SPINEware middleware tool kit from NLR (Baalbergen 1999). SPINEware supports the integration of possibly distributed and heterogeneous resources, such as computers, applications, data, and documentation, into an end-user oriented, easy-to-operate, virtual single computer. The user operates this computer using an intuitive graphical user interface (GUI), available via a web interface. The GUI enables the user to manipulate data, to execute tools, and to define and execute workflows, via simple point&click and drag&drop operations on icons in windows. Primary goal of the Working Environment is to let the user concentrate on the actual job instead of struggling around with loosely coupled applications, undocumented scripts and programs, a variety of computers and operating systems, files, and interfaces. Legacy tools may be integrated easily into the Working Environment through tool wrapping, which allows integration of any tool as is, without need for rebuilding the tool. The GUI of an integrated tool is that of the tool proper, but remote operation of the tool's GUI is enabled by the Working Environment. Integrated tools provide a uniform way for the engineer to start tools (thereby providing input data and tool options, and dealing with output data) and combine and use tools in workflows.

A SPINEware *workflow* (e.g., Figure 2) supports the (automated) processing of information. It allows definition and controlled and automated execution of a chain of tools. This concept supports the definition and application of engineering procedures. A workflow is a chain precisely, of tools. It may be composed by positioning tools and so-called data containers (representing data sets involved with the tools) on a canvas, and drawing connections among the tools and data containers. In ITEP, a workflow is used for definition and execution of evaluation procedures in terms of scenarios comprising tools and data, which may be located with and owned by the various partners of the FACE project. Execution of a workflow typically involves the execution of tools running on, and sharing of data in a network of heterogeneous computing systems, possibly including parts of the partners' networks. Mechanisms are available to co-ordinate the concurrent use of workflows and workflow elements. As such, the workflow supports collaboration with respect to evaluation procedures, and, consequently, is an essential building stone for collaborative engineering platforms.

In general, workflows will be designed and implemented by the ITEP *administrator*, who is fluent in the application area and SPINEware. The design of a particular workflow and of the tools in the workflow is based on user requirements. For the workflow shown in Figure 2, the design phase has been executed iteratively based on user comments and took about 20 hours; the implementation took 12 hours. Considering the fact that this workflow can now be used by all partners in the FACE project, this is a relatively small investment.

Within the FACE project, workflows are used for implementing procedures, that is, preferred ways to work. As such, the workflows are 'read-only'. If necessary however, a user can copy the workflow to his own workspace, and modify the workflow.

In ITEP, the Evaluation Data Repository and the Working Environment are integrated seamlessly. For example, the engineer may select applicable input data using Deposit, drag and drop selected data on a workflow, and finally store the output data from the workflow in the repository. Although various solutions (such as FIPER, TENT, PointerPro, Citrix, Tarantella, WebMethods, Windchill) are available for building a distributed environment, SPINEware was considered the best choice to support the identified requirements and potential enhancements for the

ITEP facility. Advantages of this approach are that legacy tools can be integrated seamlessly using wrapping technology, and that it supports total user orientation, due to its holistic approach and tailoring facilities (Baalbergen 1999). The approach is essentially independent of a specific application discipline, and as such, ideally suited for the creation of multidisciplinary collaborative engineering environments.

DISCUSSION

This paper outlined how solutions for efficient information processing and sharing positively contribute to the required collaboration between engineering teams located at different sites around the world. In the development of a distributed simulation facility, the current and available infrastructure and business policies of the organizations and sites involved have to be taken into account. These constraints could clearly limit the ability to achieve certain objectives. Further, when organizations allow remote access to their software/hardware applications, all kinds of conditions may be imposed because of security policies.

The technology applied in the realisation of ITEP is generic and can be reused in any future R&D project, where efficient information processing and sharing is required. This technology comprises years of experience gained at NLR with the development of multi-disciplinary, distributed working environments supporting engineers to collaborate in multi-partner projects in aerospace R&D. The advantages of the distributed approach making tools and data available through FACE-ITEP to the FACE partners can be summarized as follows:

- Collaboration. Knowledge of tools and data that are needed to do an evaluation may be distributed over more than one partner, and must be gathered in one environment.
- Standardisation. Partners have access to the same tools, data, and procedures.
- Hardware performance requirements. Some software tools only run on certain specific hardware. Hence, installing it locally may not be feasible, but can be made available at the users desktop as if it runs locally.
- Reduced Maintenance costs. Updates and new releases only have to be installed in FACE-ITEP.

In the project FACE, the current and available infrastructure and business policies constituted the starting point for the development of the distributed environment ITEP. Collaborative engineering is still a relatively new way for aircraft design. Although there are procedures in place on how to implement collaborations, there are still issues to be addressed regarding some of the "intangibles" such as trust and willingness to share knowledge, which is critical for any R&D organisation. More applications of collaborative engineering environments in future R&D projects will increase acceptance within companies.

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BIOGRAPHY

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ERIK BAALBERGEN received his MSc. degree in mathematics and computer science from the Vrije Universiteit in Amsterdam in 1985. He received his Ph.D. degree on a topic in distributed operating system research from the Vrije Universiteit in Amsterdam in 1992. He joined the National Aerospace Laboratory NLR in 1991. He managed several projects at NLR involved in research and development of middleware software, including SPINEware. As senior system architect, he is also involved in several projects in which intra- as well as inter-enterprise working environments are developed.

HARMEN VAN DER VEN received his Ph.D. in Mathematics from Utrecht University in 1993. He joined the National Aerospace Laboratory NLR in the same year. As a senior scientist, his main interest is aerodynamics, covering the related disciplines of computational fluid dynamics, high performance computing, and disciplines that interact with aerodynamics, such as structural mechanics and acoustics.

eCollaborative Concurrent Engineering and PLM services

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KEYWORD

Concurrent Engineering, PLM services, Service Oriented Architecture, Interoperability, ATHENA, Collaboration, ISO 10303 STEP, PLM, Networked Organization, IDEAS, RISESTEP, SAVE

ABSTRACT

The present paper describes how, in Concurrent Engineering and Networked Organisations context, Service Oriented Approaches dealing with Product Data Management could support e-Collaboration and interoperability, all along the Product Lifecycle Management phases, but also within the design phase where needs of the next phases are anticipated. After describing the current trends, a state of the art and drawbacks of previous solutions for industrial companies (aerospace, automotive), it introduces Framework Program 5 (FP5) IDEAS roadmap and Framework Program 6 (FP6) ATHENA Integrated Project (IP) European research projects. Then, it describes the Service Oriented Approach and existing proposals to defined standardised Product Lifecycle Management (PLM) services that could be a key component for collaborative workspace of networked organisations. Then some prototypes based on standardised Application Programming Interfaces are presented. Finally, from the lessons learnt, place of standardised PLM services to support interoperability as address by ATHENA is proposed.

INTRODUCTION

Concurrent Engineering has been developed to short time to market of industrial products, in conjunction with Computer Aided Digital models (Mock-ups, Virtual Products, Simulation). In parallel, in order to concentrate on high added value core activities, industrial projects are more and more performed by federations of enterprises, so called "Virtual Enterprises". Organisations have consequently to be able to quickly join, participate and leave several projects, sometimes as partners, sometimes as competitors, despite accelerating re-organisations (merging, creation of new subsidiaries, etc).

Virtualisation for Technical Information Systems is also true, as more and more Commercial Product of the Shelve are used for Product Models definition and for Product Data Management. These software products are heterogonous between the different partners, and are to be integrated with legacy Enterprise Information Systems.

In such a context, non-interoperability between Technical Information Systems of Virtual enterprise partners and actors of the Product Life Cycle management is a serious drawback. It is a serious brake to reach the objectives that drives development of Concurrent Engineering and virtual enterprises.

Several attempts to reach interoperability, through projects like RISESTEP or SAVE, based on ISO STEP and CORBA, were not sufficient.

Or, during the FP5 IDEAS Roadmap European project, it was identified that such interoperability can't be achieved only at Information and Communication Technologies level, but is also to be addressed at disciplines/process/resources level (knowledge) and organisation/decision level (governance of industrial project, enterprise and technical information systems).

The FP6 ATHENA IP project is partially implementing this roadmap, developing new or integrating existing approaches in the Enterprise, Process, Knowledge and ICT modelling in order to respond to this new challenge for interoperability by providing instrumented methodologies, based on emerging technical platforms and standards, to support the new challenges of European industry.

STATE OF THE PRACTICE

By following presentations made during several concurrent engineering related events, by several industrial enterprises, and participating to several expert workgroups addressing e-Collaboration for product design, common trends and practices can be identified today.

Virtualisation of enterprise and internationalisation of virtual enterprise is more and more a reality. For example, aeronautic programs imply now countries from Asia that will contribute to the production of aircrafts. European and American automotive industry is working with Japan.

Concurrent engineering is now a reality for industrial enterprise, as several presentations done during "Les Etats Généraux du Micado" illustrate it (Pardessus 2004). The challenge now is to involve within the design phase the actors and stakeholders of the future phases. As business and technical environment are evolving faster and faster, capability to manage the product all along its lifecycle lead to pilot programs using Product Life Cycle Approach.

Equipment suppliers are working for numerous OEMs, that each have their own heterogeneous information systems and processes. In such context, their approach is first to defined by themselves their ICT environment and then to manage product data exchange and sharing. It is the case for example for landing gears or engines (Péchaud 2004).

For SMEs, the situation is more difficult, have they don't have necessarily the capacity to negotiate with OEM usage of their own tools. They consequently have to invest in order to use the same tools than the OEMs, and consequently to use multiplicity of tools, without any way to capitalise.

Finally, especially in Aerospace area, as the investment is huge and can't be supported by only one company without difficulty, it is proposed to supply chain partners to contribute to the risks and to the design of the product. These partners consequently become "risk sharing partners" and have to collaborate to produce product models, being 2D drawing, 3D digital mock-ups and very soon Simulation models.

Consequently, needs for Product Data Exchange, Sharing and Retention are growing, that were already addressed in research projects like RISESTEP or SAVE, are evolving : models to exchange and share are more complex, and capability to share and exchange them becomes critical. It is the reason why governance of Technical Information System and of Interoperability infrastructures become a major challenge for industry. It is partially addressed by adopting a Product Lifecycle Management approach (Bernard 2004). Industry is nevertheless only starting to deploy such approach as a study of IBM illustrates it (Béguinot 2004). Finally, long-term Product Information retention is an important issue with emerging approaches and technologies (Figure 1 : Long Term Retention issue for Aerospace programs).

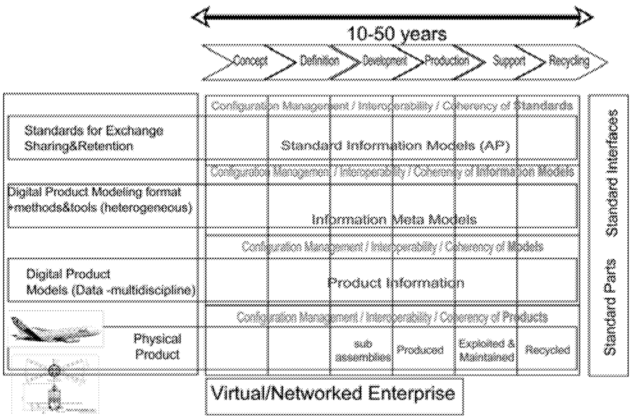

Figure 1 : Long Term Retention issue for Aerospace programs

STATE OF THE ART

Interoperability for e-Collaborative Concurrent Engineering is not new, and was already addressed by numerous research projects, like for example RISESTEP and SAVE. Analysis of these projects results, through evaluation of some of the results exploitation, illustrate drawbacks of the adopted approaches and new needs to address interoperability.

RISESTEP

RISESTEP research project (Esprit 20459) started in January 1996, duration of 26 months. Problematic addressed by RISESTEP and today's issues are similar:

"Industry is increasingly competing in a global marketplace where strict control over cost and 'time to market' are vital to remain ahead. At the same time there is a growing need to work within international partnerships or groupings. These pressures increase the need to improve the integration between the participants in these global or 'extended' enterprises. A key tool in this integration is the sharing of standardised data throughout the enterprise. In this context the implementation of a 'specialised' middle-ware environment allowing the cooperation of distributed digital mock-up units appears as a pre-requisite for concurrent engineering applications (design engineering, after-sales documentation)."

The RISESTEP project aimed at developing such a middle-ware environment based on the STEP and CORBA (Object Management Group) standards taking into consideration the distribution aspects. This Advanced Information Technology related project was strongly user driven. All the developments were tested in real life scenarios, in particular in the automotive and aerospace industries, were CAD/CAM applications are needed allowing them to share standardised product information between partners or main contractor-suppliers. STEP Application Protocol AP214 offers some key facilities. Development of Test Cases on IT vendors' STEP distributed database prototype products demonstrated feasibility of interoperability based on STEP and CORBA. It was nevertheless identified the need of a High Level Interface for Product Data Sharing, as granularity of STEP Standard Data Access Interface was to high on consequently not efficient enough. A new emerging standard, proposed by OMG MaNTIS, PDM Enablers, was identified as a potential candidate to provide a standardised HLI.

SAVE

SAVE (Step in A Virtual Enterprise) project, CEC Bright-Euram and industry funded, started on September 1998, with 28 months duration, approximately 13 man-years of effort and a cost of 2.4 MECU. It was the opportunity to evaluate PDM Enablers for information sharing, compared to emerging AP214 for information exchange. SAVE was also more focussed on Virtual Enterprise and different kind of partnerships, in particular risk sharing partnership that is today common. More precisely, the SAVE project aimed to enhance the competitiveness of European Industry through the use of standards in support of the Engineering Supply Chain. It showed how data and information can be delivered to the right place at the right time in the right format and with the right CAD-CAM tools and applications being made available at lower cost for SME members of the supply chain. A working prototype was delivered showing how a supplier can gain remote access to the lead contractor CAD-CAM/Product Data Management (PDM) systems to "pull" the latest data and information relating to a particular task he has been asked to carry out.

The technical objectives of SAVE were the following:

To develop a Virtual Enterprise Data Model, taking and extending existing information modelling standards (STEP AP 203, AP214, AP232, PDM Schema and OMG PDM enablers) to create a central model, which represents the different contractual relationships and business protocols, which govern engineering information exchange in a Virtual Enterprise.

To develop tools to support a mapping methodology which will allow members of a Virtual Enterprise to translate their own, proprietary models and ways of working into the Virtual Enterprise Data Model.

To implement a Virtual Enterprise Framework based on standards (CORBA, AIT Reference Model, AIT Implementation Platform) which will enable companies at whatever level from prime contractors to 2nd tier suppliers (and beyond), to, at low cost, rapidly join, participate in, and leave a Virtual Enterprise, exchanging and sharing information and applications with high degrees of integrity. The use of Java Applications and remote access to high cost tools through Intranet/Internet technology was a key element of reaching this goal.

If results for Product Data Exchange were exploited in operational environment, as for example for exchange between Aeronautic OEMs and Equipment suppliers providing engines, the results concerning Product data sharing were highly software providers dependant, as they were committed to provide PDM Enablers Interface in future version of their Software Products. Several months were necessary before to be able to evaluate industrial implementation.

EADS CCR performed this evaluation in year 2003. It was not only an evaluation of a provided interface, but also of the specification.

Evaluation of PDM Enablers

To complement SAVE project, several studies were performed at EADS CCR to complete evaluation of PDM Enablers.

First study, in 1999, consisted in developing a PDM Enablers server from scratch based on PDM Enablers specifications and PDM Enablers Interface description (in IDL) (PDM Enablers 2000). Two computer scientist students were assigned to this study, during 6 months. After 5 months, the development was not started. It was due to the fact that PDM Enablers are built on top of common services of the Object Management Architecture. There were consequently about ten specifications to study, with some of them under-specified. At this time, it was also impossible to find open source implementation of the required common services. The lessons learnt follows.

High complexity of Object Management Architecture that requires CORBA experts to develop PDM Enablers specification.

Importance to have available Object Request Broker with implementation of required common services underlying PDM Enablers, to be able to implement a PDM Enablers servers.

The second study, in 2003, consisted in studying an existing implementation of a PDM Enablers server, provided on PTC's Windchill R6.2 Core, and resulting in part from SAVE project prototype. As submitter of PDM Enablers specification, PTC was committed to provide an implementation of the PDM enablers on the market (OMG rule). The study was also the opportunity to make a deeper study of PDM Enablers specification, from implementability viewpoint.

As a result, it appeared that this implementation was incomplete (Figure 2 : Status of PDM Enablers Implemented modules), and not stable enough to be used in operational context. Basic services (CORBA, PDM Responsibility, PDM foundation are partially addressed. All the other modules are not addressed except PDM Framework, PDM Document Managemetn and PDM Product Structure.

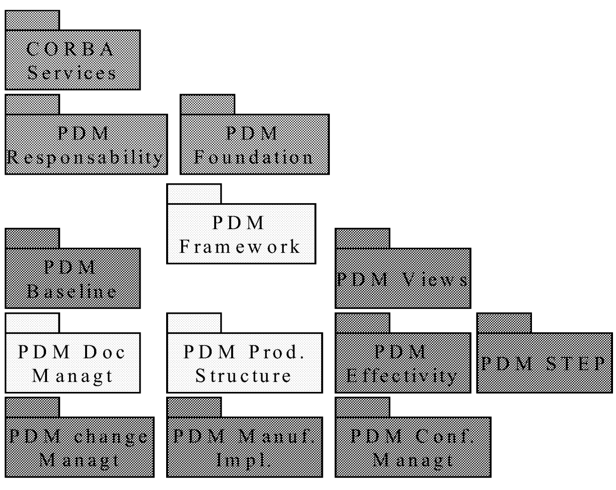

Figure 2 : Status of PDM Enablers Implemented modules

It also highlighted the difficulty to perform wrapping of PDM Enablers specification on an existing software application. In particular, same issue exists for common services that were not implemented nor wrapped for the server, as similar services exist in Windchill.

After some debugging of the PDM Enablers, a very interesting point was the demonstration that it was possible to reflect customisation of Windchill through usage of PDM Enablers without any complementary development, by the mean of "attributable" interface. This responds to an important requirement, to have automatically access to an application customisation without extra development.

Other important point, PDM Enablers specifications don't provide any information on how evaluate or certify a PDM Enablers server implementation. In particular, as no sequence diagrams nor use cases provided, we had to build our own philosophy and systematic test scenario to be able to evaluate other PDM server implementations.

Lessons learnt were the following:

- ❑ Complexity of Object Management Architecture (OMA) a break even for a solution provider;
- ❑ Importance of providing sequence diagram and testing rules for a standardised API;
- ❑ No way for certification of a server, that is a major break for industry to rely on such enablers.

These studies were performed in parallel with STEP import/export interfaces studies based on AP214 and PDM schema, and their deployment in operational context. It appears that:

- ❑ The fact that PDM Enablers are not fully based on an application protocol is a major problem for informational and engineering viewpoints coherency, according RM-ODP (Starzyk 1999);
- ❑ Within enterprises, an accurate governance of Technical Information Systems is required, implying the different stakeholders with their current practices and standardised process and models.

To address interoperability and e-Collaboration in 2005, it is necessary to have an idea of emerging technical platforms and emerging business practices.

EMERGING TECHNICAL PLATFORMS

In 2005, technical platforms evolve significantly to address some of the existing drawbacks.

At OMG, the development of the CORBA Component Model, that encompasses Enterprise Java Beans as a specific implementation for Java, is a way to address the Object Management Architecture complexity.

CCM or EJB based application servers provide a server side environment, were all the common services that are not directly business oriented (e.g. persistence, security, access, transactions, etc) are delegated to a container of business object.

The consequence is that developers can concentrate on the business logic, while IT experts address other aspects.

In addition, several open source platforms with industrial quality are today available (e.g. Jboss, JONAS, Open CCM, etc), that can be integrated on n-tiers architectures (Figure 3 : EJB based architecture).

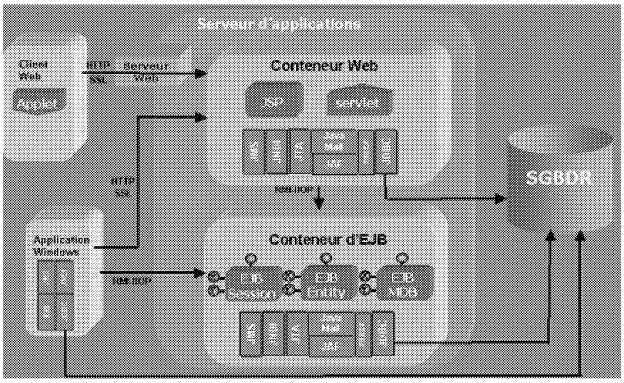

Figure 3 : EJB based architecture

Finally, SUN propose certification of EJB application servers that is free for open source application. As these tools are standards based, it means that implementation can be performed on free platforms, and very easily deployed on commercial software products, when compliance with standards is respected.

Finally the developed business logic becomes specific software products independent.

In parallel, numerous standards are being developed for Internet, based on Internet Standards (XML, SOAP, etc) and Service Oriented Approach (Web Services) to support eBusiness (ebXML, etc). As other classical Enterprise Application Integration platforms (.Net, J2EE,etc), WEB services technical platforms allow integration of heterogeneous applications, development and middleware platforms.

In the manufacturing area, ISO STEP community, in order to respond to new industry needs, performed several activities:

- Development of new application protocols covering new phases of the Product Lifecycle Management, as Requirements & Systems Engineering (AP233) or Customer Support (AP239 – PLCS project).
- Development of new application protocols supporting usage of new modelling tools of engineers (GD&T, System Engineering, Tolerancing).
- Modularisation of the application protocols, for a better integration of the Application Protocols and a faster development of Application Protocols.
- Adaptation of schema modelling language and neutral file exchange format to support modules and multi-application protocols exchange and sharing.
- Study on Return on Investment and saving perform through STEP usage in US Transportation Industries (NIST 2002).

Finally, as number of open technical platforms operationally used is increasingly growing and as evolution of these platforms is very fast:

New approaches that are platform independent, Model Driven Approaches, allow disconnecting application models from the targeted platform (Platform Independent Models and Platform Specific Model of the OMG's Model Driven Architecture).

Cooperation between different standardisation organisations are established in order to increase impact of their initiatives, as for example collaboration between ISO STEP Community (AP233) and OMG (SysML). AP233 is used as conceptual informational model of SysML, in order to connect SysML solutions with other solutions that are not SysML based.

Finally development of the Semantic WEB creates some interesting perspective for knowledge sharing for e-Collaboration. Several projects and studies are establishing links between STEP and Semantic WEB, through language as OWL.

EMERGING BUSINESS PRACTICES

One lesson learnt from projects like RISESTEP or SAVE is that technical ICT issues are not the only aspects to address when aiming interoperability and e-Collaboration. To share best practices, if possible modelled with Enterprise modelling, Business Process Modelling or Workflow standards, is one of the enablers of efficient e-Collaboration.

Such standardised practices and framework are today emerging, addressing needs and practices of the different implied stakeholders: software product engineers (CMMI) (Nevoux 2004), ICT integrators (within enterprise – Enterprise Application Integration – or between enterprises - Business 2 Business), IT departments (ITIL, COBIT, Balance Scorecard) (Lejeune 2004) (Corniou 2004) (Golfetto 2004) (Bourdariat 2004) (Mandel 2004), , Urbanism teams (Figure 4 : Urbanism Cartography), Design Office (STEP Application Protocols, Change Management, CMII), Programs (PLM, Project Management).

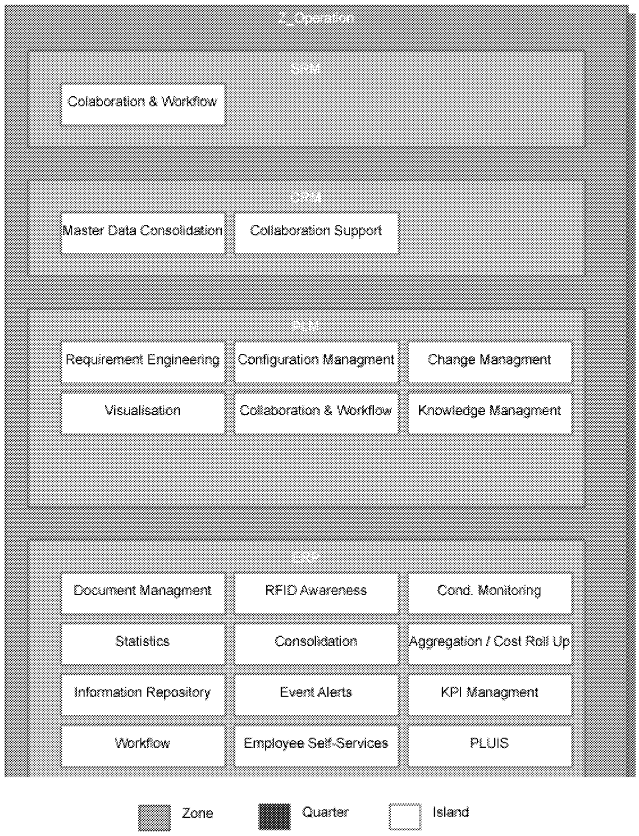

Figure 4 : Urbanism Cartography

In addition to complex and fast evolving ICT technical platforms, enterprises are consequently also more and more using standardised business best practices, supported by dedicated applications that become part of the enterprises legacy information systems.

When all this kind of approach are used simultaneously within an enterprise, an important issue today is to define a global governance of the Technical Information System aligned with e-Concurrent Engineering on networked organisation and enterprises/industrial program objectives.

INNOVATIVE WAY TO ADDRESS INTEROPERABILITY: IDEAS AND ATHENA

In such a context, to deal with complexity of the business and technical context, and to address the challenges of industry to short time to market for their product, acting within a networked environment, important innovation is required. Two important research initiatives were launched to address this need, FP5 IDEAS roadmap project and FP6 ATHENA Integrated Project.

IDEAS (ROADMAP PROJECT)

IDEAS project was a FP5 research roadmap project (2002-2003), aiming to create, from the IDEAS European thematic network, a research roadmap on interoperability of enterprise applications.

Problematic addressed by IDEAS is the following: as Internet eliminated the barriers to develop electronic infrastructures, organizations are increasingly required to more actively participate in Virtual Organisations, Extended Enterprises, Electronic Marketplaces or Supply Chains. It leads to more dynamic trading practices in virtual networks, constant large-scale change and variations. Organisations are consequently to become flexible and adaptable.

It implies underlying Information Systems and Applications that contribute and support enterprises processes to be reconfigured and coupled in short time, being as de-coupled as possible.

But establishment of virtual and networked organisations remains a difficult tasks, and most of the requirements of participants of these organisations are still not addressed, as in particular holistic approach, rights to local choices and solutions that constitute legacy systems, protection of information property independently from the tools used, adapted access rights managements, etc.

To address such issues, innovative approaches are required for design and definition of models, protocols, and mechanisms to support the management and exchange of information in every kind of organisations, companies or enterprises.

Based on IDEAS network's expert group vision (Interoperability is to be addressed at enterprise, knowledge and ICT levels, federated by means of ontology as illustrated –c.f. Figure 5: IDEAS Simplified Interoperability Framework), IDEAS proposed research roadmaps that were the basis of FP6 ATHENA Integrated Project and FP6 INTEROP network of excellence.

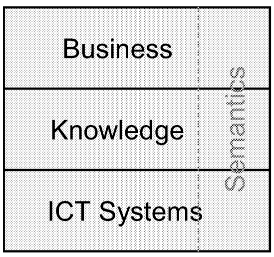

Figure 5: IDEAS Simplified Interoperability Framework

Strong links were established with UEML project (Unified Enterprise Modelling Language).

ATHENA (INTEGRATED PROJECT)

ATHENA – Advanced Technologies for interoperability of Heterogeneous Enterprise Networks and their Applications - is an Integrated Project sponsored by the European Commission in support of the Strategic Objective "Networked businesses and government" set out in the IST 2003-2004 Work programme of FP6. Building upon an ambitious Vision Statement "By 2010, enterprises will be able to seamlessly interoperate with others", ATHENA aims to make a major contribution to interoperability by identifying and meeting a set of inter-related business, scientific & technical, and strategic objectives. The ATHENA programme of work is defined for producing results that span the full spectrum of interoperability from technology components to applications and services, from research & development to demonstration & testing, and from training to evaluation of technologies for societal impact. In ATHENA, Research and Development is executed in close synergy and collaboration with Community Building, for ensuring that solutions to multi-disciplinary research challenges are of optimal industrial relevance leading to broad uptake by the end user.

Vision

"By 2010, enterprises will be able
to seamlessly interoperate with others".

Objectives

Overall ATHENA objective is the following:

"Contribution to enabling enterprises to
seamlessly interoperate with others".

From this overall objective, an integrated set of objectives are derived, with respect to Businesses (Business Objectives), Science and Technology (Scientific and Technological Objectives) and Strategy (Strategic Objectives).

In order to meet the business objectives, the commercial exploitation of the ATHENA scientific and technological results and the adoption of resulting products and services by user organisations would be required. ATHENA is dedicated to achieving technical results that will support the business objectives from a scientific and technological point of view. To enable uptake of these results, ATHENA will lay the groundwork by identifying, and creating a beneficial environment for the growth of such a community that will eventually have the critical mass and the sustained and sustainable momentum necessary for the uptake of results in the user community.

The business objectives target are:

- More economic businesses through improvements in efficiency, productivity and cost effectiveness;
- More flexible, fluid and nimble businesses which are able to move into new markets and product areas rapidly;
- More knowledge-intensive businesses which are based on the wide diffusion and re-use of knowledge assets;
- More robust businesses through stable and dependable solutions which are scalable and recoverable;
- More valuable businesses from a long term and more general perspective.

The business objectives need to be supported by the definition and development of new concepts and solutions that create and define an infrastructure that enables seamless interoperability. ATHENA's main scientific and technological objectives define and provide:

- Technologically neutral reference model that provides a stable, generic foundation for specific technical innovations
- Interoperability requirements for applications, data and communications and solutions that meet these requirements

- ❑ Methods which enterprises can use to manage organisational roles, skills, competencies, and knowledge assets for its own operation and for collaboration with other enterprises
- ❑ Semantic mediation solutions which enable and support the above
- ❑ Components of interoperability infrastructures.

Underlying principles

Interoperability is to be addressed at all the layers defined by IDEAS, as illustrated in Figure 6 : Interoperability on all layers of the enterprise.

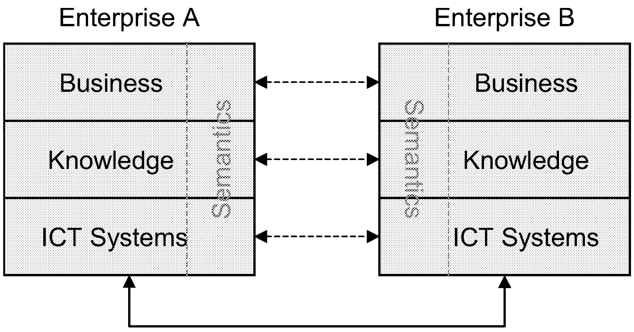

Figure 6 : Interoperability on all layers of the enterprise

Implied disciplines

The implied disciplines are Enterprise Modelling, Ontology, Business Process modelling and execution, Information System Architecture.

Collaborative Product Development

Collaborative Product Development is one of the business processes addressed by ATHENA, that also include Supply Chain Management, Portfolio Management and e-Procurement.

Scenarios

From current situation and to-be situation modelling, and based on Dynamic Requirements Definition for interoperability, different scenarios are defined , within the B4 project, to illustrate and pilot research activities. Two scenarios are defined for Collaborative Product development, one in the automotive area, and an another one in the Aerospace environment. Aerospace scenario focus on Product Data Exchange and Sharing all along the product lifecycle, within a networked organisation.

Pilots and test bed

The project B5 is the place were pilots are launched, on a test bed platform, in order to validate the research results for the different implied industrial sectors (currently Aerospace, Automotive, Furniture and Telecommunication).

PLM SERVICES

In the described context, to define business services to support e-Concurrent Engineering in networked organisation seems appropriate.

OMG's ManTIS, is currently developing a specifications for PLM services (PLM Services, 2004). What is the level of maturity of this specification? Are all the drawbacks addressed? A study performed in 2004 provides some provisory responses to these questions.

ManTIS and PLM services specification

ManTIS was chartered by the OMG Domain Technical Committee on Friday, 4-Oct-2002, as the Manufacturing & Utility Domain Task Forces were dissolved. This new group effectively represents the merger of the two task forces and expansion into subject areas closely related to Manufacturing and Utilities, but with interest groups that go beyond those two categories.

The mission of the "Manufacturing Technology and Industrial Systems Domain Task Force", ManTIS DTF, is to foster the emergence of cost effective, timely, commercially available and interoperable software components for the Manufacturing and Industrial Systems domain through the development of standard interfaces using the OMG process. The ManTIS DTF will issue specifications in the following industrial sectors:

- ❑ Manufacturing
- ❑ Industrial Processes
- ❑ Control Systems

Several objectives are defined for ManTIS. First ManTIS aims recommending technology specifications based on OMG's Model Driven Architecture (MDA) that enable interoperability, reusability and modularity. ManTIS also targets encouraging development of standard interfaces that encapsulate legacy systems, enabling their integration and easing migration to new technologies. Another target consists in encouraging adoption of ManTIS-related OMG specifications by other standardization organizations, and establishing a working relationship with other Task Forces in both Platform and Domain Technology Committees of the OMG to provide mutual support and leverage for each other's specifications. Finally ManTIS aims establishing and maintaining active liaison relationships with appropriate external organizations in support of the preceding goals.

A ManTIS working group, PPE Product & Process Engineering, has produced PDM Enablers, as PLM services specifications.

A request for proposal was issued for PLM services in October 2002 (Product Lifecycle Management Services V1.0 RFP – 37 pages).

The PLM Services submission was considered to be ready for an issuance vote in April 2004 (Product Lifecycle Management Service). If accepted, the submitters, that are mainly German, will have to provide an implementation on the market for end 2005 beginning 2006 (unclear according ManTIS provided information).

The use cases addressed by PLM services are the following: import and export of assembly data, authentication/start up cession, authorization, start node authentication, browsing down and up product structure data, download of product data, download of meta-data including structure, download of a single digital file, generic object query and finally upload of product data.

The PLM services managed information is the following: part identification, part structure, document and file management, shape definition and transformation, classification, properties, alias identification, authorization, configuration management, change and work management, process planning and multi language support.

As services; PLM services specifications defines PLM connection factory, resource adapter, object factory, container interface, query- and traversal mechanism, services as defined in the OMG PDM Enablers V1.3, services for flexible traversal and filter mechanisms, services for query capability for PLM systems, services for handling Bill of Material (BOM), services supporting increased performance and reduced client complexity with respect to OMG PDM Enablers V1.3 and finally services for simple relationship navigation and management of PLM data elements [6.6.1.6].

Several models are provided:

- Platform Independent Model Equivalence Model
- Informational Platform Independent Model
- Computational Platform Independent Model
- XML Platform Specific Model

More precisely, PLM services specifications include an Express-X mapping, from STEP PDM Schema extended by AP214 CC8 (Configuration Management), PIM Equivalence model. A PIM Equivalence Model is provided, based on STEP PDM Schema and AP214 Subset (Configuration Management CC8, using ARM extended by AIM construct). Some simplifications and new concepts (Multilanguage, simplification of property mechanism) are proposed, in order to obtain more suitable PIM and PSMs. A Express to XMI mapping is used, based on part 25 (binding EXPRESS-UML), with PIM Equivalence Model (in Express). It constitutes the informational PIM (UML/XMI), that is made of UML Class Diagrams with informational aspects (c.f. managed information). It is extended by the computational PIM, that provides functional aspects (c.f. services). Finally a WEB services PSM is proposed, that is build using a UML Profile for XML Schema. The proposed PSM is an XML Schema Profiled PIM. Example of resulting XML Schema is finally given.

Analysis

From a technological point of view, the integration of some important approaches that will have impact on the future in the area of Product data sharing is performed.

Specification is based on usage of Model Driven Architecture (MDA), with business models that are technical platform independent.
Integration of Application Protocols is performed, as basis of an Informational PIM. It allows an efficient reused of ISO Manufacturing communities.
Specification is adapted to Emerging Service Oriented Architectures.
PLM services also correct serious drawbacks of PDM Enablers, for example providing connection, authentication and authorisation, or simplification of client development (especially navigation, queries)

But several points can be improved.

First Multiple mapping and transformation may lead to important lost of information (impedance mismatch). It is difficult to know if it is suitable. Some formal transformation, with a textual language, should be important to allow evaluation of the models.
Other point, numerous technologies are used and have to be mastered. To have an idea of a business process implying different actors and stakeholders should be of help. Federation models for interoperability, as proposed by ATHENA, should be very valuable.
Next, the reference model, between all those provided, should be clearly stated, especially for iterative development. Models management and governance principle should be proposed, linked to several candidate business scenarios.
Also important, precise links and reuse of PDM Enablers should be more specifically précised. It is difficult to understand it from the current specification. In particular, difference of philosophy between CORBA vertical interface and Service Oriented Architecture should be clarified (c.f. Pasley 2005).
Other issue, no formal Express to XMI mapping is provided, targeting PLM services UML model. It is not sure the ISO STEP Part 25 (Express to UML binding) should be sufficient, as the targeted UML model is organised in order to separate informational and computational viewpoints. No XMI file are provided, making it difficult to exploit paper based specification.
Finally PIM to PSM approach is to be reinforced, by proposing an adapted profile for the PIM, by proposing other PSM than XML Schema PSM (that is not a very significant example), and finally by proposing UML PSM not only based on profiling but on transformation (an OMG workgroup is working on such a language).

From a business point of view, PLM services are based on concrete business and operational cases, coming from PDT.net and iVIP projects that led to operational sharing in Automotive (Daymler Chrisler). They integrate different communities viewpoints and performed work (Manufacturing with ISO STEP, information technologies providers with OMG MDA, UML, CORBA and W3C XML schema). Consequently it is easier to have impact has efforts of these communities are considered and reused. Finally PLM services are following same trends than other initiatives like ATHENA, OASIS PLCS or UML2.0/SysML/AP233 harmonization activities

But some difficulties can come from the fact that the proposed specification comes mainly from Germany and Automotive. No major applications providers nor Systems Integrators contributed to the proposal. What is consequently the position of Application providers and integrators.
Potential value added process for business scenarios are not so clear looking at the proposal. What are the different potential business scenarios that create values for the different stakeholders in a B2B and PLM strategy?
There is no reference to major application protocols under development today, that should be important to cover the whole product lifecycle. What about the integration with AP239 and AP233?

In conclusion, if going in the good direction, it is definitively needed to go further to provide standardized PLM services of interest for networked e-Collaborative Concurrent Engineering.

How to go further

As Model Driven Approach and Service Oriented Architecture are emerging, the practices are not necessarily already mature.

The way to integrate them with already existing technical framework and standards, being manufacturing and product oriented (ISO STEP, PDM Enablers), Technical Information Governance oriented (Controlled Urbanism, COBIT, ITIL) or Enterprise/Program oriented (Governance, ISO 9001, ISO15288) is definitively not an obvious topic, but should be addressed if willing such a specification to be used and having an impact. Just having a look at the acronym section of the paper may give an idea of complexity of such a task.

It is definitively an expectation from some ATHENA Industrial partners to explore how definition of PLM services, based on ManTIS proposal but addressing the identified improvement points, can support building of Collaborative Product Development networked environment allowing fast collaboration and federation of implied applications and technical infrastructures.

Some Business Scenarios and pilots are being developed that will allow to experiment the specification and how it can be leverage by ATHENA Interoperability Framework and other research results, taking into account the interoperability different actors and stakeholders (Figure 7 : Interoperability actors for Aeronautic Integration)

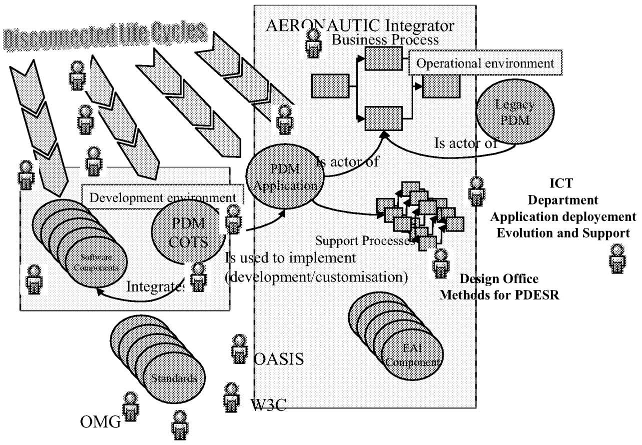

Figure 7 : Interoperability actors for Aeronautic Integration

CONCLUSION

Serious needs for interoperability of technical enterprise applications, to support Virtualisation of the enterprise and virtualisation of the product.

To support e-Collaborative Concurrent Engineering, interoperability should be addressed at different levels, enterprise, knowledge and ICT, that deals each with dedicated methodologies, tools, approaches, process and objectives of the concerned stakeholders, in particular Industrial programs, Design Office and IT department. These needs were formalized in IDEAS that produced a research roadmap for interoperability, and new solutions are being developed through the ATHENA project that implement subpart of the IDEAS roadmaps, in particular for Collaborative Product Development.

For such a process, introduction of standardised PLM services approach supported by the ATHENA Interoperability Framework seems appropriate, but current standards and practices seems still not mature enough, and some drawbacks or not yet addressed needs exist, as several research projects and studies demonstrated it.

ATHENA IP provides the opportunity to go further by addressing these drawbacks and providing innovative solutions appropriate to current trends.

It will be addressed in the Collaborative Product Development scenarios and pilots, dedicated to several sectors as aerospace, automotive, furniture, telecom but also in a further stage to any other domain interested to contribute to ATHENA or to join the Enterprise Interoperability Centre, for which several consultation meetings are launched by the ATHENA project. It is expected to support dissemination and exploitation of ATHENA results through several Industrial clusters, in particular effective support and governance for PLM services for e-Collaborative Concurrent Engineering in networked organisation.

ACRONYMS

AIT	Advanced Information Technologies
AP	Application Protocol
AP203	Configuration Controlled 3D Design of Mechanical Parts and Assemblies
AP214	Core Data for Automotive Mechanical Design Processes Application Protocol
AP214 CC8	AP214 Class Conformance 8
AP233	System Engineering Application Protocol
AP239	Product Life Cycle Support Application Protocol
API	Application Programming interface
ATHENA	Advanced Technologies for interoperability of Heterogeneous Enterprise Networks and their Applications
CMII	Configuration Management
COBIT	Control Objectives for Information and related Technology
CORBA	Common Object Request Broker Architecture
EIC	Enterprise Interoperability Centre
EDI	Electronic Document Interchange
ESB	Enterprise Service Bus
FP5/6	Framework Program 5/6
ICT	Information and Communication Technologies
IDEAS	Interoperability Development for Enterprise Application and Software – Roadmaps
IP	Integrated Program
ITIL	IT Infrastructure Library
ISO	International Standard Organisation
ISO15288	System Life Cycle Processes International standard
ManTIS	Manufacturing Technology & Industrial Systems Task Force
MDA	Model Driven Architecture
MOF	Meta Object Facilities
OEM	Original Equipment Manufacturer
OMG	Object Management Group
PIM	Platform Independent Model
PLCS	Product Lifecycle Customer Support
PDM	Product Data Management
PLM	Product Lifecycle Management
PSM	Platform Specific Model
RISESTEP	enterpRISE wide access to STEP distributed databases
RM-ODP	Reference Model for Open Distributed Processing
SAVE	Step in A Virtual Enterprise
SME	Small and Medium Enterprise
STEP	Standard for the Exchange of Product data
SOA	Service Oriented Architecture
SysML	System Modelling Language
UEML	Unified Enterprise Modelling Language
UML	Unified Modelling Language
WfMC	Workflow Management Coalition
XML	eXtensible Markup Language
XMI	XML Metadata Interchange
XPDL	XML Processing Description Language

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BIOGRAPHY

Nicolas FIGAY received in engineering degree from E.I.S.T.I. (Cergy, France). He joined AEROSPATIALE Group in 1991. Expert within the Information Technology department of EADS CCR, he is in charge of introducing new methods (data exchange, sharing and long term archiving based on standards such as STEP, CORBA, EJB, MDA, Internet technologies), new concepts (virtual and extended enterprise, collaborative work) and new tools (PDM systems, ERP systems, Enterprise Application Integration and Engineering Portals) for industrial sharing. He has successfully managed several projects both on system and structure computer aided engineering. He has participated in a number of European projects: RISESTEP as project leader, SAVE as technical expert, FP5 IDEAS roadmap projects. Since 2003, he's in charge to animate AFNOR working group dealing with ISO 10303 STEP (GT1), that represents French industry in the ISO standardisation process for this family of standards. Since 2005, he's in charge to animate MICADO Commission on Integration and interoperability. He is currently involved in the FP6 ATHENA project dealing with interoperability of enterprise applications and organisations.

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