Complex Systems Concurrent Engineering

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Complex Systems Concurrent Engineering

Collaboration, Technology Innovation and Sustainability

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Preface

It is our great pleasure to welcome you to go through the Proceedings book of the 14th ISPE International Conference on Concurrent Engineering, CE2007 held at an impressive facility of complex systems development, the Laboratory of Integration and Testing (LIT, http://www.lit.inpe.br) of the Brazilian Institute for Space Research (INPE, http://www.inpe.br) in São José dos Campos, SP, Brazil. The previous events were held in Antibes-Juan les Pins, France (CE2006), Dallas, Texas, USA (CE2005), Beijing, China (CE2004), Madeira Island, Portugal (CE2003), Cranfield, UK (CE2002), Anaheim, USA (CE2001) , Lyon, France (CE2000), Bath, UK (CE99), Tokyo, Japan (CE98), Rochester, USA (CE97), Toronto, Canada (CE96), McLean, USA (CE95), Pittsburgh, USA (CE94). CE2008 and CE2009 are planned for Nothern Ireland, UK and Taiwan, respectively.

The CEXX conference series were launched by the International Society for Productivity Enhancement (http://www.ispe-org.net) and have constituted an important forum for international scientific exchange on concurrent engineering. These international conferences attract a significant number of researchers, industrialists and students, as well as government representatives, who are interested in the recent advances in concurrent engineering research and applications. Concurrent engineering is a well recognized engineering approach for productivity enhancement that anticipates all product life cycle process requirements at an early stage in the product development and seeks to architect product and processes in as simultaneous a manner as possible. It works via multi-functional, multi-discipline and multi-organization team collaboration.

The theme of this CE2007 proceedings book is complex systems development focusing on innovative product and process solutions that requires collaboration for architecture, design, implementation and build in order to deliver sustainable value to stakeholders. Concurrent engineering methods, technologies and tools are well established for the development of parts and for enhancing the productivity of isolated product life cycle processes (e.g., manufacturing or assembly). However, there is nothing that prevents us from exploiting the potential to use the concept of concurrent engineering for complex systems development.

Complex systems (e.g. automobiles, aeroplanes, spacecrafts, space vehicles and launchers) development requires the collaboration of many organizations around the globe. So it is necessary to expand current collaborative engineering and management concepts from already traditional multidisciplinary collaboration to multi-cultural through to multi-organizational collaborations. The CE2007 proceedings book offers you the opportunity to keep track of the latest trends on knowledge and collaboration engineering and management.

Concurrent engineering used together with systems engineering provides the necessary framework for not only product innovation but also for process and organization innovation. With particular reference to complex products, the product, its life cycle processes and their performance must be developed in an integrated manner from the outset otherwise complexity escalates. Concurrent engineering provides the right conceptual framework for that. The CE2007 proceedings book shows you state of the art for concurrent systems and software engineering, systems architecting, product development process, concurrent methods and tools and the anticipation of manufacturing and environmental requirements for sustainability.

Complex systems development affects the interests of a multitude of stakeholders. Nowadays, environmental requirements are of increasing importance in product development. Concurrent engineering has already been an approach for anticipating such requirements. This is the so called sustainable product development. The CE2007 proceedings book intends to expand this concept of sustainability towards sustainability of value delivered to all stakeholders; including stakeholder value sustainability, enterprise architecture for innovation, product development management, and supply chain collaboration.

Contributions that compose this proceedings book can be arranged around 5 main tracks identified for the CE2007 conference:

1)Systems engineering, architecting, analysis, modelling, simulation and optimization;
2) Product realization process, methods, technologies and techniques;
3) Information modelling, technology and systems;
4) Knowledge and collaboration engineering and management;
5) Business, organizational and managerial issues.

We would like to take this opportunity to thank to all of the contributors of this book for the high quality of their papers. We would like also to acknowledge the contribution of the track chairs, session chairs and of the International Program Committee for ensuring the high quality of the work compiled into this book. We thank sincerely the members of the executive and organizing committees who helped in all aspects of organizing CE2007. Finally, we would like to gratefully acknowledge the institutional support and encouragement that we have received from our sponsors (ISPE, INPE/LIT, FUNCATE, EMBRAER) and the funding received from the Brazilian science, technology and innovation funding agencies FINEP, FAPESP, CAPES and CNPq.

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FAPESP: Foundation for Research in São Paulo State

FUNCATE: Foundation for Space Science,
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	EMBRAER: Brazilian Aeronautics Company
	ITA: Aeronautics Technology Institute
	PPI: Project Performance International
	INCOSE: International Council on Systems Engineering
	ABCM: Associação Brasileira de Engenharia e Ciências Mecânicas
	FCMF: Fundação Casimiro Montenegro Filho

Contents

Systems Engineering

Towards A General Systems Theory Approach for Developing Concurrent Engineering Science

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Abstract. Information, as a specific commodity, sustains our knowledge production in every domain of human activities. But the Knowledge-based Economy (KbE), requires intensive information and Knowledge Management. The KM is the key-factor of enterprises competitiveness (LS- large scale enterprises; SME- small and medium size Enterprise ;µE- micro size enterprises). Even the e-workers, immersed in Professional Virtual Communities must use efectively both basic concepts, methodology, methods and techniques from concurent engineering science. To design the Complex Adaptive Systems, is our our long-term research target. The present paper is an ambitious attempt to initiate a global collaborative project for the DCCE scientifically foundation based on General Systems Theory holistic approach.

Keywords. General System Theory, Interoperability, Distributed Smart concurent Engineering, Concurent Science.

1 Introduction

The Concurrent Engineering is a quite "young" (25 years) multidisciplinary domain of interest, but the time has come to convert it from "best practices" – oriented methodology engineering - to a smart Distributed Concurrent & Collaborative Engineering Science (DCCE)

Web science and Internet Technology provide enterprises (Large Size, SMEs, µSMEs) with better and more flexible ways to fully satisfy their customers on the global e-market. Enterprises are increasing their efforts, even more in order to improve their (intra and inter) business processes, in order to reach a more

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competitive level, as well as become more agile actors [Loss, Rabelo, Perreira-Klen 2005a].

Available estimates indicate that SME 's are the main employers in Europe, representing 60% of the Job market [5]. It is also estimated that industrial subcontractors represent roughly 20% of al industrial jobs.

1st of January 2007 marked the beginning of the 'new wave' to enlarge the European Union (27 countries) after Romania and Bulgaria, both joined in. In the newly integrated 'members' economy, the real ratio of SMEs contribution is more spectacular (e.g. 92% in Romanian economy). The challenges to develop a sustainable digital and global economy by using the advanced ICT-platforms are the key-drivers of Knowledge based Economy. The academic research community has received this 'message' since the '80s. In a huge effort to fill the gap between remarkable scientific achievements and the real socioeconomic needs, a "new requirements list" has been developed during the last three decades.

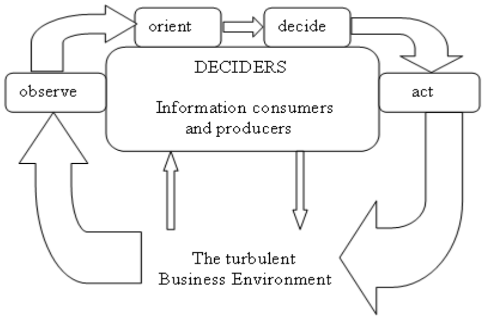
Altough many Reference Models, Standards, Frameworks and IC-Technologies have been created, 'Enterprise Interoperability' (IST-FP6-successful projects: ATHENA, ECOLEAD, INTEROP, [9, 10, 11] a.s.o), still represents a key-problem to be fully solved in the years to come**.** The main paradigm that concerns many authors with in their present research is 'Virtual Organization'/Collaborative Networks [1]. Taking into consideration the international research context, one could notice that the "concurrent engineering "(CE) paradigm, that has been rapidly developed since 1982, has to be re-balanced from an advanced methodology useful in engineering science including methods, tools, techniques into a collaborative sciences foundation.

The paper is structured in the following sections: Section #2 is concerned with the GST (General systems theory oriented framework); Section #3 deals with a new approach for the ICT- Infrastructures Architecture of collaborative platforms supporting the nowadays geographically-distributed Concurrent Engineering (DCE);Section, Section #4 provides a case-study (REMEDIA- project).

2 General System Theory-oriented Framework

2.1 Paradigm Shift

The companies are overheated by ICT- technologies. The well-known MONITOR/ANALYSE/PLAN/EXECUTE (MAPE) has been provided by the Department of Defense-USA some time ago, but we also stress on another J.R. Boyd FEEDBACK PARADIGM O.O.D.A .(OBSERVE /ORIENT /DECIDE /ACT) addressing the decision-makers for every domain of real economy.



1. The OBSERVE-ORIENT-DECIDE-ACT (OODA) loop

The 'classical behaviorist' (psychology) uses to explicitly deal with uncertainties the 'S.H.O.R.- STIMULATION-HYPOTHESIS-OPINION-RESPONSE' paradigm is useful for [8].

In the following we must consider the meaning of these general features:

- Extending and enhancing scientific knowledge and truth about our existence.
- Using management of existing knowledge and truth about existence.
- Producing new technological knowledge through innovation.
- Unprecedented dissemination of knowledge to address citizens through new channels of modern communication.

The five 'pillars' of knowledge-focused education as described by UNESCO bring into attention the 'step like-staircase' of 'Lifelong Learning' paradigm: Learn to know / Learn to do / Learn to live together / Learn to be / Learn to choose

Jussi T. Koski, professor at Helsinki Technical University compares the idea of learning to be to the future wish of various organizations and working life by Charles Mandy, that an increasing number of people would stop working increasingly earlier in life in order to become what they really are. This means that the transparency of values is essential. J.T. Koski was the one who completed the UNESCO four-dimension LEARNING space with the fifth: LEARNING to CHOOSE . This is highlighted as part of personal, skilful competence. Choosing presumes 'mastery of values, without which people may lose their ability to act. Mastery of values is the individual's capability to prioritize matters based on a personal life experience on his or her capacity to learn'. Skilful competence consists of developing 5D-Learning in a stable, harmonious fashion.

Taking into consideration this trendy 'societal positive tsunami' that involves every citizen of the Planet in the future (Knowledge-based economy that is sustained by lifelong learning), several research projects have studied the 'Virtual Organization' area. Usually the focus was on issues supporting creation rather than on management actions (e.g. IST-FP6-ECOLEAD, 2005 [10]). The 'Learning Organization' remains a challenge for our Information Society! [6]

A paradigm shift is required to dynamically meet the needs of 21st Century experts' for exploiting information as well as to speed up the decision making processes! [6].

2.2 Von Bertalanffy's General Systems Theory reloaded

Keeping in mind such turbulent "Research Eco-Systems", an "ad-hoc" buzzword with respect to Business Eco Systems [1], the authors have just made an attempt to find which could be the 'CENTRIPETIC' force to reduce the 'entropy' of our days scientific life. Our response focuses on re-evaluating the key-role of General System Theory (for Collaborative Concurrent Engineering), but is not limited to this.

From 1930 until 1976, the famous "parent" Ludwig von Bertalanffy has provided a solid-ground scientific foundation for General System Theory. Von Bertalanffy wondered: Is cultural change and evolution essentially expression of an inherent and auto continuous dynamics or is it brought about by cultural diffusion? Is history a sequence of individual, unrepeatable and therefore merely describable events, or does it show recurrences and regularities as, respectively, the opposing "idiographic" and "homothetic" views of history contend? However, by changing the structure of organization, perhaps culture, and the business environment in which it exists can progress. Bela Banathy's concept of a "Human Activity System" offers great promise. Banathy describes a Human Activity System as 'an assembly of people an other resources organized into a whole in order to accomplish a purpose. The people in the system are affected by being in the system, and by their participation in the system they affect the system. People in the system select and carry out activities- individually and collectively- activities that will enable them to attain a collectively identified purpose'.

"The behaviour of complex, adaptive systems cannot be captured by constrained optimization models. This is a fundamental departure from the presumptions inherent in conventional economics. Such systems have to be analyzed 'in' time and this limits the way in which mathematics can be used. The historical trajectory is that the value of an economic network in a complex adaptive system can be represented mathematically, e.g. as a logistic equation, but it is not derivable from a set of axioms set in a timeless context". However, conventional deduction can still be used to specify adjunct hypotheses concerning the factors that shift historical trajectories around. It follows that, in complex adaptive systems, the stationary states such trajectories attain are not analytical equilibriums but, rather, end states of cumulative historical processes.

The state of the art in "Enterprise Interoperability & Integration" domain proves the Information Systems axe integrated successfully with Business & Management Layer [7]

"An Information System can be any organized combination of people hardware, software, communication networks and data resources that COLLECTS, TRANSFORMS&DISSEMINATES INFORMATION in an ORGANIZATION" [4]. People have relied on IS to communicate with each other using a variety of physical devices (hardware), information processing instructions and procedures (software), communication channels (networks) and stored data (resources) since the dawn of civilization.

Considering the difficulties noted above, they also require capabilities to initiate and lead transformation as well as understanding the wider social, economical and cultural implications of proposed transformations. The interdisciplinary character will increase as claims that IT is no longer a source of strategic advantage have generated a growing concern over the loss of pure technology-oriented jobs and increased the demand for business-oriented IT jobs. It is expected that demand will increase for integration, enterprise architecture, information management and business process management. The integration between Business Process Systems and Information System in progress of being consolidated by the interoperability research issues.

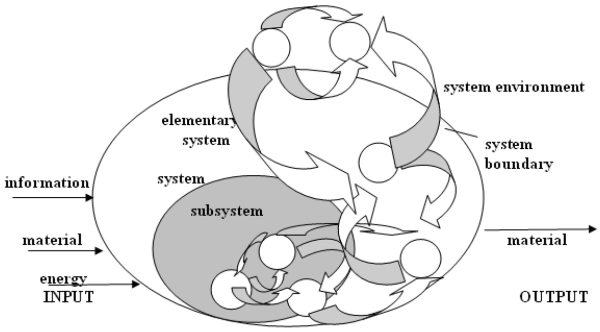
The researchers will establish numerous knowledge links to other enterprises or co-workers with which they combine rapidly and flexibly to respond to market changes or to create new markets. The size of an enterprise will matter less than its ability to collaborate, its ability to adapt, and its ability to interoperate [3].

The most important challenge raised by the new focus on the interoperability is to determine a way to represent the complex system specification semantics according to sustain collaborative work.

4 Interoperability - focused Distributed Collaborative Concurrent Engineering Framework

Coming back to the CE - focused domain, a distinction can also be made between meta-system / hyper-system / functional system / subsystem / aspect system / application module (API) / granular micro-system. A distinction can also be made between subsystems and aspect systems in order to gain a better insight into complex adaptive systems. A subsystem is a subset of elements in a system, in which all original relationships between these elements remain unchanged. An aspect system is a subset of relationships in the system, in which all elements remain unchanged. Furthermore, a distinction is made between *static systems* and *dynamic systems*. Contrary to dynamic systems, in static systems no events occor. This behaviour is the manner in which the system reacts to certain internal and external changes. A process is defined as a series of transformations in the course of the throughput, as a result of which the input elements undergo a change in regard to their place, position, size, shape, function, property, or any other characteristic.

In regard to the presence of the process, permanent and temporary elements can be distinguished in the system. The permanent elements are the subsystems or components of the assembly system, such as feeding systems, robots and sensors. These subsystems fulfil functions in the assembly process, and form, through mutual relationships, the structure of the system. The temporary elements are continuously imported into the assembly system and transformed into an output desired by the environment (market). These elements entail a flow of material (product parts), an energy flow and an information flow. The emphasis lies on the flow of material. Hence, only the flow of material is considered in regard to the output .



2. Graphical representation of dynamical system

A e-Collaborative Enterprise as a geographically dispersed meta-system is a meta-system with a SoS or FoS topology supported by the following mathematical model [Stanescu 2002]

$S^{e-CE}(.) = \{ \text{MVIEWS}, \text{MPLATF}, A, R, G \}$

MVIEWS is a N views modelling framework of the meta-system

MPLATF is a tool cases set based subsystem defining a software environment (e.g. model-driven meta-modelling. object oriented tools, a.s.o) (RFID oriented)

A is a multi-agent system

R is 3-Dimensions resources set (human, financial technology)

G is a shared goal for set of actors of enactment of a reference scenario)

The most important challenge raises by new scientifically achievements on the interoperability "problem-solution".

"Numerous Knowledge links between various "actors" with a Collaborative Network enactment (enterprise, e-workers, a.s.o) have to rapidly and flexible be combined to respond efficiently to market rapid changes. The size of an "enterprise" will matter for less than it's ability to collaborate its ability to adapt or its ability to interoperate [3]"

A new very important challenge is generated by new" trendy" research on operability.

The problem is concerned with the representation of the complex System Specifications addressing technical, semantic and pragmatic interoperability. [2].

5 Interoperability-based "REMEDIA" Case Study.

One of the entities of the project coordinator, the “Center for Human Resources Training” of the University POLITEHNICA of Bucharest (UPB-CPRU) was a partner (1 out of 39) in the project UE-IST Framework FP5 (2001-project-38379) whose main objective was to elaborate the vision and roadmap for virtual organizations in EU countries.

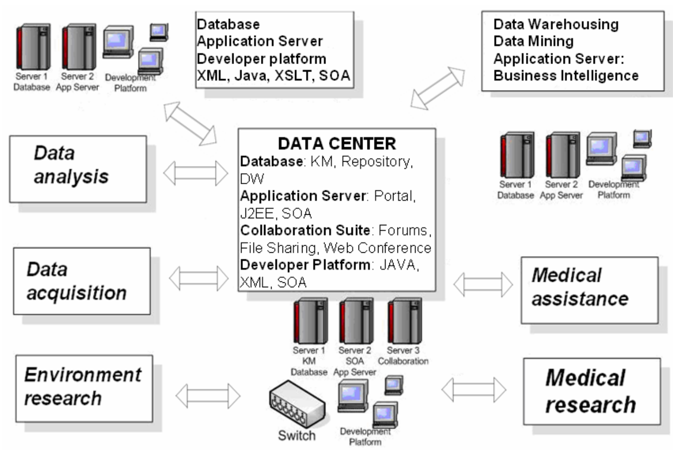
The main conclusion of the final report was:

"In ten years, in response to fast changing market conditions, most enterprises and specially the SMEs will be part of some SUSTAINABLE COLLABORATIVE networks that will act as breeding environments for the formation of DYNAMIC VIRTUALORGANIZATIONS." [12]

The activity of identification of a high priority problem for research in common Europe has had the following results:

The necessity to create and consolidate a Profesional Community capable to use information and virtual GROUPWARE communication technologies to do research into the relation of great social impact Environment – Chemistry – Biochemistry – Pathology – Medicine – Information Systems – Automation.

The share of technological, human and financial resources by different organizations involved in a collaborative network in common Europe including academic research, industry, governmental and non-governmental organizations.



3. Solution Architecture

6 Conclusions

The paper is focused on reporting the synthetical results of a seven years "long term" research, including the "FABRICATOR" ISP_FP6, Vision & Roadmap for Virtual Organization, Education & Research Ministry founded project "Interoperability Based "REMEDIA" Environment-Health (2006-2008).

The present paper supports the following key conclusion:

The General System Theory could play the role of "centrifugal force" for the D.CC.E.

The following issues are to be debated during conference :

- information System development solves the problem to integrate (Collaborative P2P Co-Research platform) Business Process Monitoring and Management System (BPMMS) and Information System (e-decision Support System).

- Dual Embedded system (Supervisory Control Data Acquisition lower layer & Service Oriented Architecture upper layer) is the final target.
- The UPB / Faculty of Automation & Computer Science, Department of Automation & Informatics has already installed the IC5 Infrastructure System Integration (Operability Oriented) Oracle 10g full application environment (upper layer), wireless Java based module application middle (layer) and respectively, SCADA lower layer.

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A Method for Systems Analysis and Specification with Performance, Cost and Reliability Requirements

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Abstract. In the past, space design activities mainly emphasized the system requirements. The available methods focused on functional aspects only. The cost was estimated at the end of the process. Recently, new design methodologies have been proposed. Among them, the design-to-cost (DTC) method was developed to include the cost as a parameter. In this work we propose an extension of the DTC method for systems analysis and specification. In other work we applied it to the design of a reaction wheel. Its basic components are described. General information on system development is related. The object-oriented approach is used as a modeling tool. Performance indexes are defined. A set of algebraic equations describes the cost behavior as a function of system parameters. Reliability is evaluated secondarily. The proposed model embodies many approaches to solve and/or optimize a problem with any level of complexity.

Keywords. Concurrent engineering, system engineering, design to cost method, reaction wheel.

1 Introduction

Reality shows that aspects not directly tied to the performance of equipments have equal or, in certain cases, greater role than the performance itself. This conducted to

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the development of design techniques in which aspects as cost became treated as design constraints, and not more as something to be evaluated at the end of it. This fact brought a reordering of priorities; and, in this new scheme, the performance obtained became the possible one that, even so, ensures the technical success of the mission, and not the desired one anymore, that could be unacceptable due to its cost [1-2].

In this work we present a method for systems analysis and specification with performance, cost and reliability requirements. In other work it is particularly applied to the reaction wheels destined to microsatellites, with emphasis in the electronic control system. It is desirable that actuators of such nature have the following characteristics of performance: high efficiency, low power, good dynamic response, long and useful life, and possibility of highly integrated implementation.

Besides the requirements of performance, the system shall also to satisfy criteria of cost and reliability , quantities usually evaluated after the conclusion of the project. For that, the method to be presented shall be an extension of the method known as "design-to-cost" (DTC) [3], where the requirements of performance and reliability are "negotiated" during the project as functions of the limitations previously imposed to its cost [4-5]. This work is the first part of a larger previous work [13].

2 Methods of Conception and Design of Systems

2.1 Phases of a project based on requirements ("Design-To-Requirements"-DTR)

NASA adopts a design cycle based in phases that organize the activities of a project in a logical sequence of steps [3, 6]. This systematic method defines a series of progressive steps with well defined goals that conducts to the realization of all objectives of the project. A summary of the project phases and their respective objectives is shown in Table 1. The activities in Pre-phase A, in Phase A and in Phase B are denominated phases of project formulation, since the emphasis is on requirements analysis, project planning, concept definition and demonstration of realization. Phase C, Phase D and Phase E are denominated phases of implementation because the operational software and hardware are designed, fabricated, integrated and put into operation.

Table 1 – The project cycle of NASA. Source: [3]

Project phases	Objectives
Pre-phase A: advanced studies	Preliminary requirements and conceptual analyses
Phase A: preliminary analysis	Definition of requirements and comparative studies
Phase B: definition	(B1) Definition of the conception and preliminary design (B2) Process of selection of service suppliers (if necessary)
Phase C: design	Final design and development
Phase D: development	Fabrication, integration, tests and evaluation
Phase E: operations	Pre-flight and in-flight operations

2.2 Method "Design-to-Cost" (DTC)

In the **method "design-to-requirements" - DTR** the resources are generally allocated in such a way to satisfy a set of functional specifications. This approach brings to several problems. The designers of subsystems tend to optimize the performance of its module instead of trying to optimize the performance of the project as a whole. Generally, they keep attention to the technical aspects, that results in a reduced exploration of the possible alternatives. So, the traditional mentality of matching requirements is a barrier against the continuous improvement and the reduction of costs [7].

The **method "design-to-cost" - DTC** searches to obtain the maximum return of a system maintaining its cost at levels previously determined (Figure 1). It consists in the choice of a set, maybe among many others, of technical parameters of perfor mance and attributes of design that represent an alternative capable of satisfying the objectives aimed by a system within a program and a range of costs [3].

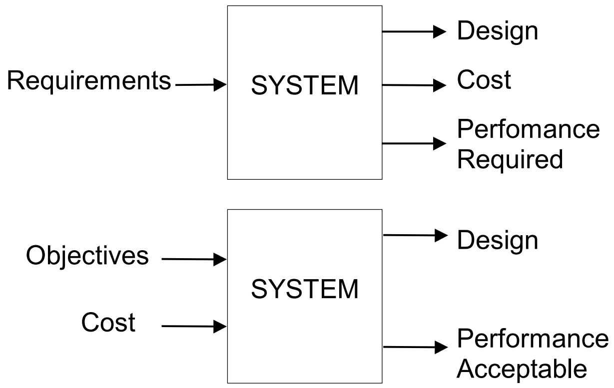

Figure 1 - Comparison of methods of design. Adapted from: [3].

The method DTC helps the project teams to take decisions based in more precise information on how the technical parameters of performance and attributes of design affect the cost.

Despite the method DTC may be regarded as a problem of optimization subject to constraints, its approach is not always done by conventional analytical or computational methods, since the functions that describe it are not, many times, possible to be found. Instead of this, it is up to the project teams to search and negotiate possible alternatives to build a system.

The model DTC is formed by the integration of various models and tools. They include: models of cost, models of performance of subsystems, models of reliability, and tools of analysis and decision.

The model DTC is primarily filled with equations and values of parameters that describe a preliminary implementation, the **base model**, common to the project teams. Initially, this model can only include basic and elementary descriptions of the project. The detailing increases in each phase, jointly with the understanding of the designers. These details include technical information - typically mass, power and reliability, all related in a list of equipments - and equations of performance. The next step consists in establishing equations that show the inter-relations among variables of performance and **equations of cost**. The costs must be expressed by equations that reflect their relations with design attributes. The equations of cost must be structured in such a way that they can express gradients of cost – as the cost varies when attributes of performance are altered.

Once the base model is implemented , we can initiate the iteractive process of system optimization. An increase of costs that violates the restrictions, brings the team to reject the proposed change or initiate a search for compensation in another subsystem. In this process, when an alternative implementation is found, it shall become the new base model.

Summarizing, the model DTC shall capture the objectives and knowledge of the system and the cost information associated, and shall be capable of doing reliable cost projections for alternate implementations. There resides the major difference with respect to the traditional methods of design. About the phase of implementation of the design, they follow the method DTR presented previously.

2.2.1 Modeling of Cost

The modeling of cost has been used to analyse the feasibility of a proposal. However, this use becomes inadequate to take decisions when treating complex systems. The modeling shall not have the objective of decision making on what or how we should do something. On the contrary, it shall give a deep comprehension of the methods used, data involved and it shall be sufficiently flexible to estimate the cost in all phases of a project.

The cost can figure as a parameter of engineering that varies with physical parameters, with technology and with methods of management.

Experience shows that models more refined than the specific cost (cost per unit mass) are needed. This brought to an estimation of costs using **parametric models**. These models are based on physical, technical and performance parameters. Starting from an **historical data base** we define coefficients and expressions that show how the cost of a system or subsystem varies as a function of the characteristic parameters.

Other adjustment factors correct uncertainties on the level of development of determined **technology**. The worst case occurs when new technolgies are introduced with which the design teams have not any familiarity.

Another criteria refers to the **risk** of employment of a technology as a function of its **degree of qualification**. New technological resources tend to increment the cost when their use in special conditions is less determined.

An analysis of risks treats the uncertainties that can jeopardize the objectives of a system. Two sources are considered: uncertainty in the estimation of costs and growth of cost due to unexpected technical difficulties.

We use to approach all the mentioned criteria through an integrated analysis, called **Methodology of Concurrent Engineering**, where technical specialists and cost analysts cooperate in the mapping and interconnectivity of all points that affects the cost and the performance of a complex system. They rely on valid and flexible statistical analyses originated from models and data base updated with the advancement of the technology and the acquired experience [3, 8].

2.2.2 Considerations on Reliability

The cost of a fault depends on the instant it occurs, its scope and the available measures. The scope of a fault refers to its effect on the other components. Measures allow a rearrangement of command in such a way to minimize the consequences of a fault [3, 4, 9].

2.3 Extended Methodology Oriented to Objects ("Design-to-Objects" - DTO)

In the design oriented to objects (OO), the decomposition of a system is based on **objects**, the basic units in which a system is decomposed. It contrasts with **functional strategies**, where the basic units for decomposition are **functions**. In functional methods, each module represents a function or an operation that performs an activity in the system. In the approach oriented to objects a module is an object, which is not a functional entity that represents an operation, but an entity that represents some data in the system toghether with the operations that can be realized on the data during the activity of the system [10].

2.4 Method of Representation of Knowledge by Frames

The **"frames"** were introduced to permit the expression of the internal structures of the objects, mantaining the possibility of representing inheritances of properties as semantic networks. In general, a frame consists of a set of attributes that, through its values, describe characteristics of the object represented by the frame. The values given to these attributes can come from other frames, creating a network of dependence among the frames. The frames are also organized in a hierarchy of specialization, creating another dimension of dependence among them. The attributes also present properties that relate to the type of values and to the restrictions of numbers that can be associated to each attribute [11].

3 The Method Proposed

3.1 Introduction

The method presented here intends to provide elements that help the process of decision making during the entire cycle of a project. The analysis based in objects was inserted in this method for having a direct correspondence with physical elements that constitute the system, which makes it more clear and practical than a functional analysis. The objects are identified through information based on bibliographical searches, simulations and experimentations. The proposed tool presents two main parts **: a global analysis and a specific analysis**. The first one treats of an object to be acquired/designed as an unique element characterized by its attributes. The second one constitutes a refinement of such object.

3.2 Global Analysis

The most confortable and certain situation to obtain a quality product is to acquire it from some manufacturer. The method presented in this section offers a solution to the question of choice of a product among other similars. Departing from a superior hierarchical level, a frame is built with a list of attributes of the product with information obtained from different companies. These attributes are then filled with values desirable for the realization of the objetives of the mission, resulting from a preliminary study. Such data constitute the initial **base model. Commercial models**, with characteristics similar to the base model, are then justaposed.
A comparative analysis shall determine which models available in the market are compatible with the necessities of the mission. For this, the values of the attributes are normalized (Equation 1). So, the nominal value of each attribute (*Vn*) of the commercial models can be expressed as a relative value (*Vr*) in relation to the value of the variable in the base model (*Vb*).

$$Vr = \frac{Vn}{Vb} \times 100 \qquad (1)$$

To indicate a variation or dispersion of the *n* relative values of a commercial model, except cost, around the base value, 100, it is defined a deviation given by Equation 2, inspired in the calcul of the standard deviation.

$$Desvio = \sqrt{\frac{\sum_{k=1}^{n}(Vr_k - 100)^2}{n}} \qquad (2)$$

We can also attribute a weighting factor f_k to each difference to express the relevance of a datum with respect to the others, according to the objectives of the project, according to Equation 3.

$$Desvio = \sqrt{\frac{\sum_{k=1}^{n} f_k(Vr_k - 100)^2}{n}} \qquad (3)$$

In this way, the greater the deviation of a commercial model, the greater will be its dissimilarities with respect to the ideal model.
The costs associated to each model are represented by a fraction 1/1000 of a monetary unit and are assumed invariant in time. the cost of the base model is a value previously stipulated that will serve as one of the parameters o acceptance of

the project. It is desirable to stablish a level of tolerance above which the project is rejected immediatelly.
With this global analysis we intend to provide greater subsidies to the design teams in the choice of asystem or other equivalent in a rapid and systematic way.

3.3 Specific Analysis

In discrepant cases or in the existence of limiting factors, as cost for example, the reliability of parcial or total realization/acquisition of the object can be analised with greater rigor by partitioning it in smaller objects. The refinement in the base model will furnish data for a new comparison. Having as reference the base model, we proceed with the identification of the objects that constitute the system and the disposition of the attributes of these objects in frames. Over the attributes are defined concepts and indexes for evaluation of performance, cost and reliability of these inferior objects and, therefore, of the product in question. All these parameters are related in such a way that the system can be evaluated and optimized. Since the attributes of the smaller objects do not have the same values as the base model, they pass to constitute the **current model**. The current model presents the same attributes of the base model, despite with distinct values. Their values are filled as soon as the inferior objects are built.

3.3.1 Frames of the Inferior Objects

In this step the main objects of the system are explicited through their respective frames. The quantity and specificity of the selected objects depend on the design team. The attributes can be expressed as quantitative or qualitative variables. To each value of an attribute is associated a numerical concept, *C*. This concept is attributed by an specialist (example in Table 1). The function of this concept is to characterize the attributes given to the objectives of the system. The numerical range adopted for the representation of concepts expresses the level of knowledge of the specialist on the object in question.

Tabela 1 – Shapeof the frame of a generical object

Attributes	Units	Value	Concept
Attribute A	cgs	1,7	5
Attribute B	-	bom	3
Attribute C	mks	3000	2

3.3.2 Correlation

The information on the influence that each attribute exerts on other is expressed in the matricial form. This table substitutes analytical expressions, that are, many times, of difficult obtention. It is formed by the contiguous disposition of the attributes of the objects, as a model presented in Table 2. The cell correspondent to a pair (attribute-row, attribute-collumn) is filled with a value, the degree of correlation, that express the relation among them. The degree of correlation (*r*) adopted is designated by an integer number belonging to an interval previously especified. In the same way, this range is a function of the knowledge of the specialist. The matrix formed is symmetrical in relation to the main diagonal. The elements of this diagonal are considered null, reflecting trivial correlations.

Tabela 2 – Correlations among attributes of objects

			Object	
		Attribute A	Attribute B	Attribute C
Object	Attribute A	0	1	3
	Attribute B	1	0	5
	Attribute C	3	5	0

3.3.3 Evaluation of Performance

The performance of the system can be evaluated by many modes. In all situations we desire an index of easy obtention that characterize the actual state of the system and that serve as a basis for the processo of refinement of it. For the present case two indexes are proposed: **the index of coupling (α) and the index of performance (η).** These indices make use of the concepts of the attributes and of the correlations among them.

The index of coupling of the i-th attribute is defined as the aritmethical mean of the *n* degrees of correlation referred to it. That is,

$$\alpha i = \frac{\sum_{j=1}^{n} rij}{n} \tag{4}$$

The index of performance of i-th attribute is given by:

$$\eta i = \frac{\sum_{j=1}^{n} Cj^2 .rij}{n} \tag{5}$$

where C_j is the concept of the *j*-th attribute. The form of expression 5 was defined in function of the limits of the ranges adopted for the concepts of the attributes and the degrees of correlation.

The index of coupling expresses a correlation of an attribute in relation to the others. In this way, when comparing the concept of an attribute with its index of coupling, we can evaluate whether or not the resources expended with it are really necessary for a satisfactory performance of the system. Whereas the index of performance shows the balance between the concept and the relevance of an attribute in relation to the superior object. These relative indexes can be used in comparisons among different alternatives of a design.

3.3.4 Estimative of Cost

The cost of a project is a function of many factors.The cost of an object is obtained by expressions whose parameters are one or more of its attributes. Then it is a parametric model of cost, formed by mathematical equations that relate the cost to physical and performance parameters. Its application is limited to a pre-defined range of values. Here the costs are also expressed by a fraction of the monetary unit and considered invariant in time. The total cost is given by the weighted sum of the estimated costs of each object of the system. Two factors of ajustement of cost are inserted to correct uncertainties on the familiarity of the design team and the technological qualification of the object in question. These adjustement factors are presented in Tables 3 and 4 and are based in [3]. There is no a formal relation among the units in which the parameters are given and the unit of cost. Costs of design, integration and tests shall be included in the model. The complexity of the model is reduced when the attributes of greater relevance of the system are used as parameters in the equations. We propose that the attributes chosen to represent the cost of each object be extracted among those that possess the greater indexes of coupling. The forms of equations are purely empirical. Their coefficients are given by an statistical analysis based in studies of cases already conducted.

Table 3 - Factors of adjustment of cost according to the level of knowledgement of the team. Adapted from [3]

Level of knowledgement of the team	Factor of adjustment
The team is totally familiar with the project and already completed many identical projects.	0,7
The team has much familiarity with the type of project and realized similar projects.	0,9
The team has experience in similar projects but not identical.	1,0
The project introduces many aspects with which the team does not have familiarity.	1,2
The team does not have any familiarity with this type of project.	1,5

Tabela 4 - Factors of adjustment of cost according to the degree of technological qualification of the system. Adapted from [3]

Degree of technological qualification	Factor of adjustment
The system is used largely in identical applications.	0,90
The system is already in similar applications.	1,00
The technology proposed is recent and only engineering models use it.	1,05
The system is qualified in tests performed in controlled environments.	1,15
The technology employed is new and no test was performed.	1,20

Upon varying the parameters of the system, the cost also alters. To relate such percentual variations the concept of sensitivity is introduced. **The sensitivity (*S*) of the cost of an object (*c*) in relation to a given attribute (λ)** is given by Equation 3.6, according to [12]:

$$S_{\lambda}^{c} = \frac{\partial c}{\partial \lambda} \frac{\lambda}{c} \qquad (3.6)$$

In this way, the value of S can be used to determine a change per unidade in c due to a change per unit in λ. For example, if the sensitivity of cost relative to an attribute is 5, then an increase of 1% in λ results in an increase of 5% in the value of c.

3.3.5 Reliability

The model of rate of faults of an object is obtained with the manufacturer or obtained experimentally. The expectation of the useful life of a system is fundamentally determined by the environmental conditions of use and by its topology. The investiment on the planning of quality can contribute to obtain a reliable system and with minimal redundancy, that can diminish the cost of production.

The reliability was inserted in the proposed model as an attribute: the useful life of each object. Despite this concept is not adequate for electronic systems, it was chosen by a question of uniformization. The matrix of correlations determines which are the parameters that have some relation with the useful life of the object. Starting from that, the phases of project and test can be better planned.

3.3.6 Atualization of the Current Model

Starting from the frames of the objects formed and the tables of performance, cost and reliability, the current model is structured. The attributes of the current model are extracted directly from the attributes of the smaller object or obtained through simulations and/or experimentations with the data of these objects. Having one or more candidates to current model resulting from the specific analysis, we shall submit them to a global analysis to select a new base model. The function of this procedure is not to provide a definitive answer, but to clarify doubts, arise questions and point possible solutions.

The procedures described in the specific analysis shall not necessarily be followed in the order presented. The flexibility of the model implemented shall permit alterations a any instant. The iteractivity shall be always valued.

4. Conclusions

In this work it was presented a method for the analysis ans specification of systems with requirements of performance and cost, according to the model DTC. This method was then applied to reaction wheels in other paper. A flexible tool was proposed that aggregates different modes of treatment and modeling of complex systems with the same objectives. It is capable of assembling information of diverse kinds and treat them globally. As other methodologies, presents advantages and disadvantages. The initial implementation can be difficult, either by financial, organizational or human questions. Due to this, in this work were related the most different approaches and used parts of what is of best among them, without deepening the concepts involved. This work is the first part of a larger previous work [13].

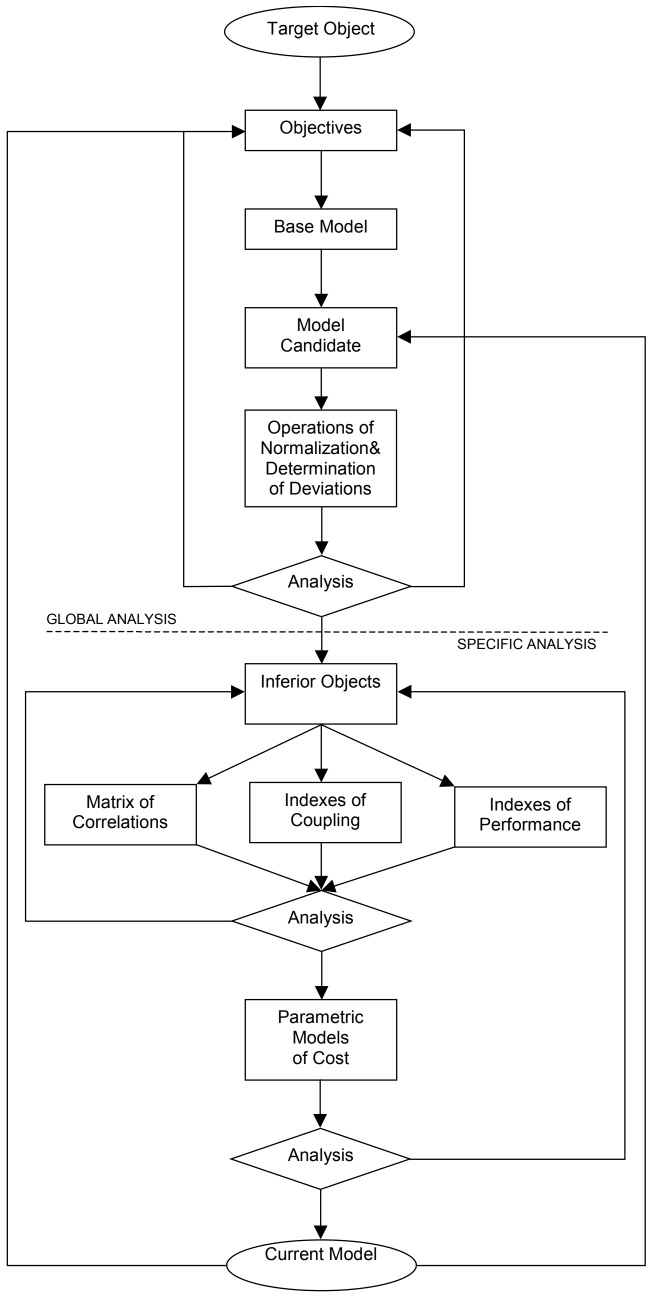

Figure 2- Conceptual flow graph of the method presented.

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Guidelines for Reverse Engineering Process Modeling of Technical Systems

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Abstract. In spite of the process of conception generation being essential to promote product innovation, it has not been effectively carried out by designers, due to the abstract nature of this activity. In order facilitate this process, Reverse Engineering (RE) has been suggested as a way to formalize the processes of identifying, purchasing and modeling design information in terms of functions and solution principles, in a continuous and systematic way. This paper presents a literature review of technical systems conception processes and of RE. The results of a technical visit to a leading RE company, and a preliminary methodological proposal for RE process modeling for technical systems, are also reported. This proposal is intended to support the concept generation process of technical systems. Finally, guidelines are proposed for the final version of the methodology.

Keywords. Conceptual design, Reverse engineering, Innovation, Product development, Function analysis

1 Overview

In methodological terms, Brazilian companies have made little effort to promote innovation, in a systematic way [7]. This indicates the need to provide better support to companies, in terms of the obtention of information and an understanding of their products and technologies.

Many authors consider the process of conception generation as essential to innovation, because it uncouples the design problem from the known solutions by an abstraction process. This leads to more possibilities for innovation. In spite of its importance, this process is not effectively carried out by designers. Partially, this happens due to the abstract nature of its activities – mainly in the functional modeling – and the difficulty to manipulate generically valid functions (basic operations) to represent the product.

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In this process, standardized functions are suggested to guide the designers in the product functional structuring process, together with the "solution principles catalogues", related to the basic operations. This promotes mechanisms to make the product conception and its innovations easier [2, 8, 13, 14].

Thus, it is recognized that there is a need for methods and tools related to the process of analysis and synthesis of functions. These favor the addition of innovations to the product function tree, by the insertion, combination and removal of standardized functions. Thus, Reverse Engineering (RE) is suggested, as a way to model the processes of identifying, purchasing and modeling design information – functions and solution principles – in a continuous and systematic way.

This paper presents a literature review of Technical Systems (TS) conception processes and of RE. The results of a technical visit to a leading RE company, and a preliminary methodological proposal of RE process modeling for TS, are also reported. Finally, guidelines are proposed for the final version of the methodology.

2 Literature Review

2.1 Conception Process of Technical Systems

In the conceptual design phase, the TS conceptions are developed through the activities: functional modeling, solution principles and product conceptions generation. The main functional modeling approaches are: functional deployment [13]; axiom-based synthesis [18] and the function-means tree [17].

When the function structure of the TS is defined, the process of generation of solution principles starts, where the functions are usually listed in a morphological matrix. Solution principles are proposed for each function and, after that, the solution principles are combined, generating the product conceptions.

The conception process demands a significant capacity of abstraction and an accurate definition of the functions. In order to support the acquisition of this information the use of RE is proposed, as shown in the next section.

2.2 Reverse Engineering for Technical Systems Design

From some definitions [4, 5, 12], RE can be understood as a "process of information getting and analysis from existent systems, in order to optimize systems being developed." It is intended to understand how a TS works from RE analysis, not a copy of technical solutions. In this context, methodologies have been suggested to formalize a part of, or the entire, RE process for TS [11, 12, 16].

Methods and tools were suggested by [15] to develop the TS function tree through the functions analysis. Three methods are highlighted: FAST (Function Analysis System Technique), SOP (Subtract and Operate Procedure) and Force Flow. Another approach to functions analysis was proposed by [6], where physical principles and functions of a system are identified, through an abstraction process.

According to [12], one important process of RE is the Product Teardown (technical disassembly). The TS is disassembled in order to estimate costs, identify materials and manufacturing processes, estimate technology trends, forecast the TS specifications, etc. This is presented in the next section.

2.3 Product Teardown

A teardown process of competitors TS is carried out by many companies, focusing on RE. Their goal is to verify the market technologies and to find technologies to optimize the system [9]. However, this process is commonly informal, aiming at the solution of specific problems. They consider neither the reasons why the concepts were introduced into the TS, nor the functions and solution principles.

However, the teardown must be formal and consider the entire TS, in its normal conditions of use (as purchased). After that, the TS should be disassembled, to analyze each subsystem and component, in order to identify the inter-relationships among them, their functions and solution principles. This favors the identification of the functional structure of the TS being analyzed, and its solution principles.

In order to carry out the teardown, several methodologies have been suggested. In [12] the practical procedure was emphasized but not the functional modeling; in [1] the identification of the TS functions is clear and logical. In the latter study the TS is disassembled and the Bill of Materials is defined. Then, the TS mechanisms and structure are analyzed, where the functions are identified, considering the levels of global, partial and elemental functions tree. The mechanisms used to satisfy the functions and the force flow diagram, are also defined.

2.4 Support Methods Related to Reverse Engineering

An important method related to RE is Value Analysis (VA) [2], because it identifies important attributes of the TS, which are to be priorized in the analysis and redesign. The AHP (Analytic Hierarchy Process) method [3] can also be used to analyze the attribute value of the TS.

In order to identify the connections between the physical components or processes of a TS, Interface Diagrams can be used [15]. The nodes of the diagram are the TS components, and the lines connect the nodes and show the interfaces. The functionality of each component is deduced by observing the physical interfaces among the components.

Beyond these approaches, the assembly analysis methods are presented, according to the DFA (Design for Assembly) approach [15]. Three of them are: the AEM method (Hitachi Co.), Boothroyd-Dewhurst method and Lucas method.

In a general way, even though the literature proposes formal methods to implement the RE in TS, they are not integrated into a methodology. They also do not consider specific mechanisms to facilitate the identification of functions and solution principles, both important to the conception process. In order to understand better the RE process, the next section presents the main results of a technical visit, carried out in a leading RE company, in the automotive sector.

3 Technical Visit to a RE Leading Company

The selected company is an automotive assembler, of a multinational group. The European head office designs the new vehicles, and the Brazilian unit (visited) makes complementary studies and technical adaptations for the Brazilian market.

One information source that helps in the planning and implementing of technical adaptations and redesigns is the RE process. Its analysis is carried out by professionals from the engineering and quality sectors. One very important sector for the RE process is the teardown, where the analyzed vehicles are disassembled. Figure 1 presents a synthesis of their RE process.

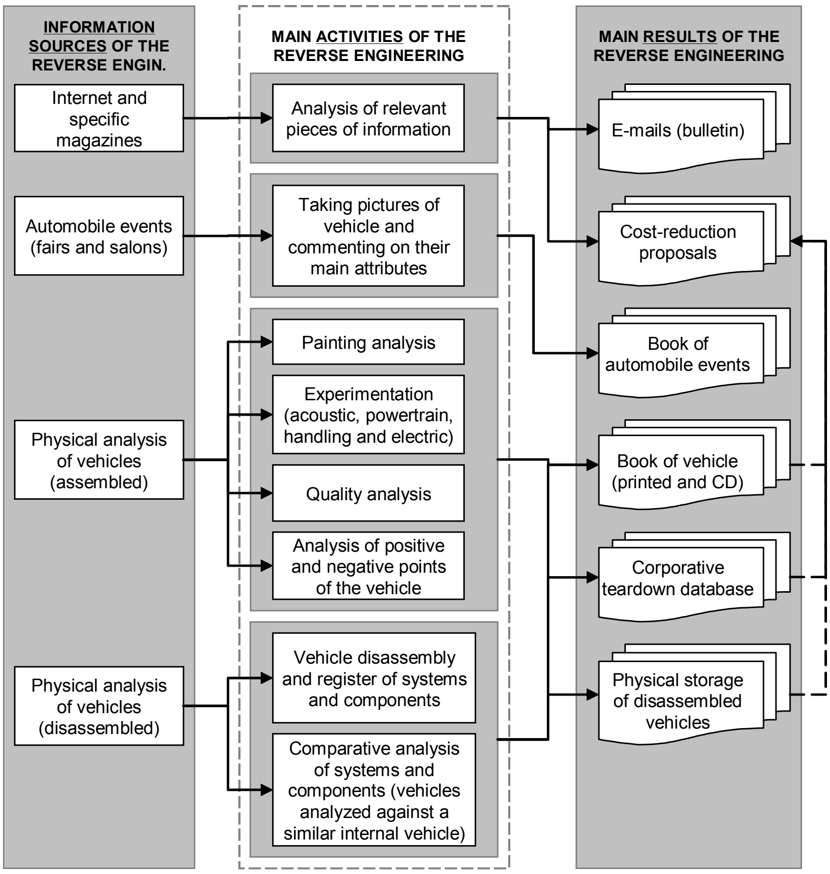


Figure 1. General view of the reverse engineering process of the visited company [10]

The left side of Figure 1 presents the main information sources of the RE process in the RE company. The RE activities are essentially related to information analysis from the Internet, events, tests of assembled vehicle (as purchased) and analysis of the disassembled vehicle (teardown).

From the sources and activities, the results of the RE process are generated (right side of Figure 1). One important publication is the book of the vehicle, which is a report with all the results of the entire RE process, and this information is inserted into the corporative teardown database. The main information of the RE process is introduced into the cost-reduction ideas database of the company, in order to optimize the design and redesign of the company's vehicles.

In spite of the visited company having a formal and well understood procedure of RE – which is not seen in most Brazilian companies – the vehicle functions are not considered in the TS study. The functions should support the planning of new versions, because the designers can find new ways to satisfy the functions, increasing the innovation possibilities.

4 Proposal of the Reverse Engineering Process Modeling

The modeling of the RE process of Technical Systems (TS) aims, among other aspects, to obtain, represent and make available information about functions and solution principles, which can be used to support the TS innovation (Figure 2).

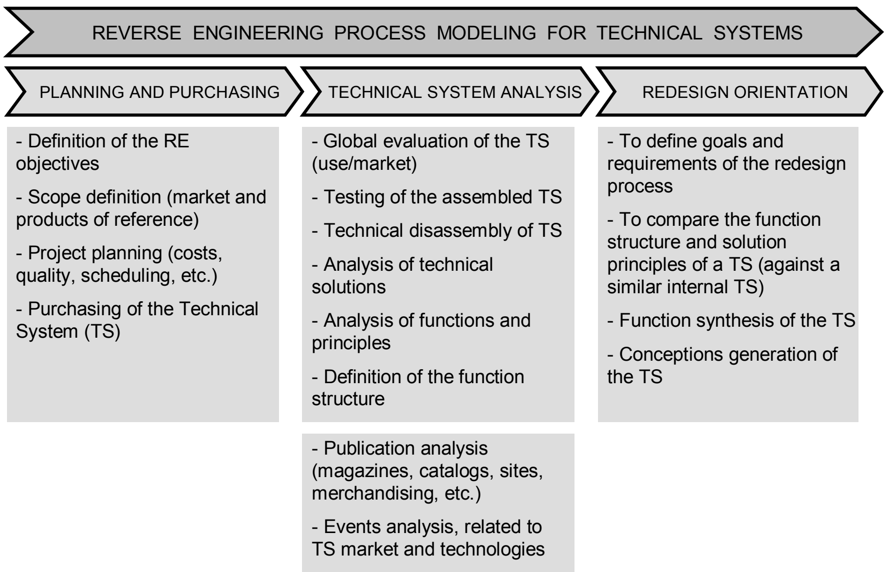


Figure 2. Preliminar modeling of the RE process for technical systems [10]

The RE model (Figure 2) is composed of three macro-phases: planning and purchasing, technical system analysis, and redesign orientation. It seems to be similar to the automotive model (Figure 1), but only here the TS functions are considered, in order to identify opportunities of innovations since its function structure. It is the main original contribution of our methodology.

The goal of the Planning and Purchasing phase is to plan the activities of the RE process, and to orientate the designers to purchase the right TS to be analyzed. The main results of this phase are the project plan of the RE process and the TS purchasing. The Technical System Analysis phase aims at the analysis of the purchased TS, in order to obtain information which can be used in future designs and redesigns. The main results are: a list of components and materials, TS description and information about technical performance.

Another differential result of this research, is the proposition of means to identify the TS function structure, with their respective solution principles. These means are based on the methods of section 2.2 (FAST, SOP, Force Flow and the [6] approach), and the support methods for the RE process (section 2.4 – value analysis, AHP method, interface analysis, etc.).

For example, in [6], a TS is analyzed from its technical drawing, highlighting its mechanisms and principles. After that, the main functions carried out for the TS are identified, as well the energy, material and signal flows. Then, the main functions of the TS are represented in a block diagram, in a systematic process of abstraction, from the real system to its functions.

From the identification of the functions of the TS under analysis, alternatives for the function structures can be suggested. The designers can innovate in the insertion, combination and removal of functions, as well as in the proposal of alternatives for the solution principles for each TS function. In this phase, parallel activities of publications (books, magazines, websites, etc.) and events analysis are also considered, both being related to the market and technologies of the company.

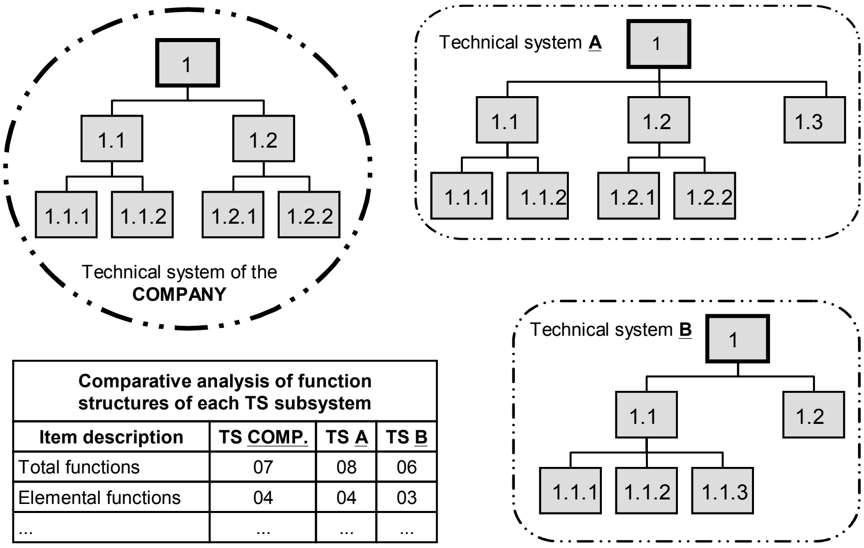
Finally, in the Redesign Orientation phase, the goals and requirements of the TS redesign are defined, indicating which subsystems should be optimized. Then, orientations and means are proposed to compare the TS function structures, against its similar competitors, guiding the function synthesis process (Figure 3).

The objective of such comparison is to visualize the function structures of the TS, seen as a reference for the TS redesign. The function structure of the TS must be deployed in subsystems, where each subsystem can be analyzed (internal against competitors similar), considering: its total of functions; how they are connected (ways of interaction); the sequence of operations/processes of the TS, represented by the functions; flows of energy, material and signal among the functions; etc. From this, the RE team can optimize the function structure to be considered in the design. Adequate methodological approaches were not identified for this application and will be developed in this research study.

The optimized function structure is inserted into the morphological matrix for the generation of new conceptions. The main results of this phase are: the redesign of goals, a comparative analysis of the function structures, the optimized function structure of the TS and the attributes of the new versions of the TS conceptions.

In order to support the suggested RE activities, a database is to be developed, which will be based on the "design catalogues" approach and consider the information structure of the TS functions. Since this research is now in a preliminary stage, the methodology and the database need some guidelines, in terms of RE process modeling, as seen in the next section.

However, this methodology is been developed. For this reason, practical results in companies still have not obtained, but they will be done until this year's end.



Comparative analysis of function structures of each TS subsystem			
Item description	**TS COMP.**	**TS A**	**TS B**
Total functions	07	08	06
Elemental functions	04	04	03
...	...	...	...

Figure 3. Comparison of the function structures of technical systems

5 Guidelines for the Reverse Engineering Model

Firstly, processes of functional modeling will be studied in order to define the information structure needed to describe the TS functions, considering the function deployment levels (global, partial and elemental) and the right technical language. A method for TS function analysis will then be implemented, to help designers to identify and describe the functions and solution principles of the physical objects, considering such a structure of information.

It is also to be developed a method for the comparative analysis of TS function structures, considering the functions of each subsystem, the interaction among functions, types of flows, types of transformations, etc. The innovation opportunities in the TS redesign will then be identified by insertion, combination (and modularization), or removal of TS functions.

In computational terms, the database structure will permit the comparison of similar functions, as well the registration of functions and solution principles from many areas. Information from other areas – mechanical, electrical, optical, bionic (analogy with nature), and others – allows the insertion of functions and solution principles into the TS to satisfy the design needs. However, the structure of the description of function – mentioned above – must be used in order to permit the effective insertion of such information into the design.

6 Final Considerations

In this paper, the importance of RE process formalizing was highlighted, in order to allow the identification of TS functions and solution principles. A comparative analysis between the technical systems studied and an internal TS can then be carried out, favouring an improvement in the TS.

By utilizing the RE process as a source of knowledge for innovations in TS, companies can develop TS solutions in a faster way and with less uncertainties, in relation to a project without comparison parameters. This requires less validation effort regarding the concepts and technologies implemented in the TS solutions.

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Designing a ground support equipment for sattelite subsystem based on a product development reference model

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Abstract. This work presents an application of a reference model for product development: a ground support equipment for an environmental monitoring imager. MUX-EGSE is a product designed on demand to INPE (Brasilian National Institute of Spatial Researches). It is an equipment of electronic tests of a camera which will equip the CBERS3&4 satellite. This reference model was adapted to manage the development of this product, which is quite diferent from the products commercialized in other lines of the researched company.

Keywords. New product development, mechatronic reference model, aerospace industry, ground support equipment.

1 Introduction

In [11] is defined AIT: activities of assembly, integration and tests of an artificial satellite to be launched in the Earth's orbit. It corresponds to a set of procedures and the execution of logically inter-related events with the purpose of reaching a high level of reliability and robustness in the satellite performance. The multispectral imager (MUX) of CBERS3&4 satellite, which is being developed in a Brazilian company, ought to be submitted to a set of acceptance, calibration and functional tests in its design and AIT phases. Hence, it demands a specific electronic system which makes viable the satellite interface and the execution of this complex analysis. This system is called MUX-EGSE – ground support equipment of MUX subsystem.

For the design of this equipment it was necessary a process model of product development that comprehended the best practices in a mechatronic design context. The inexistence of such a model was observed in [1], that works in this gap and

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developed the mechatronic reference model (MRM). MRM is also utilized in other products commercialized by this company.

2 Reference models in New Product Development

This section presents some NPD reference models as chronologically available in the literature.

In [10] is presented the total design model. The author makes differences between total and partial design. He argues that Universities have taught partial design and this practice has created some troubles in company environments. [10] describes NPD as a phased process in which product specifications are continually refined. [9] develop a systematic approach to product design. They present design steps organized by phases too. Each phase is carrying out throughout a problem solving method. At the final, phase outputs are compared with a requirement list.

In [2], NPD is discussed as a map of information assets. Their proposal is a phased structure in which some deliverables are identified. The authors focused in performance measures that allow managers to look at results of development effort. [13] illustrate NPD as a development funnel. Authors stated in the beginning of NPD there are so many opportunities and along the time this number decrease because many ideas are realized to be unviable. At the end only few opportunities are transformed in new products.

In [3], NPD is studied as a process that needs to be performed in concurrency with the technology stream. He states that phases need to be monitored and controlled by check points and describes mandatory activities in NPD projects. A simultaneous engineering background is clear in [3] proposal when he describes the organization by which a new product must be designed. Author relies strongly in product development teams at several organizational levels. [12] rely in activity description and form utilization to present how to develop a new product. Authors identify different roles to each organizational unit in accord to the company organizational structure. For example, a functional manager has different functions if the company structure is functional or projectized.

In [8], NPD is studied to build a knowledge creating theory. All information generated by a new product is classified as a explicit knowledge and the company role is to allow knowledge conversions, especially from tacit to explicit. Some organizational structure and skills are more appropriated to enable conversions. [4] started to call NPD as a stage-gate process. He shows that is necessary to manage NPD to balance different kinds of development efforts. The author models the decision making process in NPD. He describes two situations in which important decisions are made to prioritize projects and allocate resources: gates performed inside each project and portfolio reviews performed by product line as a whole.

In [6] is built a design for six sigma proposal. Authors integrate several of previous approaches into a consistent framework. The main structure of their reference model is a stage-gate process. Each phase is detailedly described to allow activity scheduling and tracking. Another core concept in [6] is critical parameter design. Authors state product requirements must be prioritized and when a product concept is generated it is necessary to identify critical parameters of the product.

To each parameter a critical functional response in technological solutions to monitor it must be chosen. Tolerances must be designed to build capability indexes to each critical response.

In [5] is proposed the capability maturity model integration (CMMI). CMMI consists of best practices organized in process areas that address the development and maintenance of products and services covering the product life cycle from conception through delivery and maintenance. It is a new form of understanding product development, since other authors traditionally describe this process as a stage-gate intercalation, as above described. In CMMI NPD must be evaluated according to a maturity (or capability) level scale and a targeted profile should be used to improve it.

3 Mechatronic reference model

The reference model, used to develop new product in the company, utilizes a framework that represents NPD as a phased process.

The model reflects best practices in mechatronic product development, and a mechatronic reference model (MRM) has been dubbed because, from the technical standpoint, it involves products that integrate electronics, mechanics and software.

Figure 1 gives an overall view of the process of the proposed reference model. The phases of the MRM are defined as a function of the results they generate. Results are documents and represent the concept of “information of value” discussed by [2].

The phases of the MRM can be described as follows:

- Strategy: definition of the strategic objectives to be pursued in each product line (PL);
- Portfolio: definition of the portfolio of each PL;
- Specifications: definition of the specifications of each product;
- Project Planning: definition of the project plan for each product;
- Conception: definition of the main components and solution principles for the main functions of the mechatronic product;
- Technical planning: detailing of the project plan based on the previous defined conception;
- Technical design: technical solutions for the main functions of the product;
- Optimization: detailing and testing of solutions for the product’s secondary functions and analyses required to increase the product’s robustness and reliability;
- Homologation: homologation (approval) of the product’s manufacturing and assembly process;
- Validation: product validation and certification;
- Launch: launching of the product in the market;
- Monitoring: monitoring of the results attained with the product and management of the modifications made in the initial production configuration.

Each phase is separated by a decision point and four different types of gates were developed. The gates, illustrated by ( ),represent moments but the decisions are made for a given set of products. In the strategy phase, the set comprises all the products of the company, while in the portfolio phase, all the products belong to a given PL.

Gates ( ) are business-oriented decisions made on the basis of design performance indicators. These gates ( ) are technical decisions made through peer review meetings, and a gate ( ) represents the closing of a given development project after ramp-up of the product.

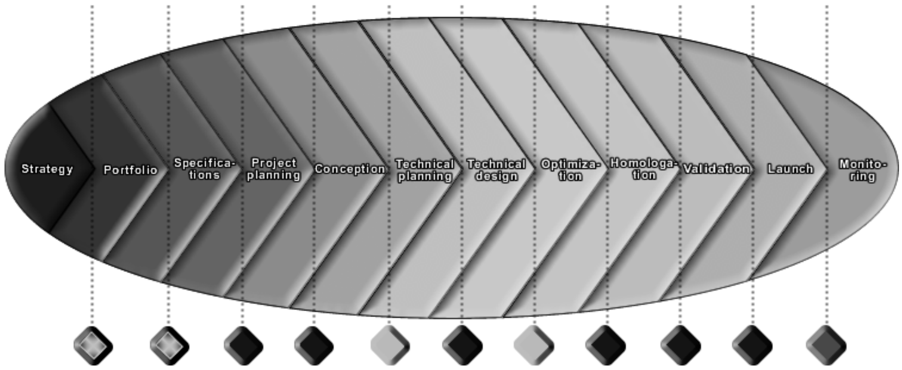

Figure 1. Phases and decisions of the MRM

4 Development of a ground support equipment

The application of the MRM started in the specification phase because strategy and portfolio phases are related to business decisions. In the aerospace industry the specification phase of a new product project is performed by contractor. The company role is to understand functional, constructional and safety requirements and to deploy design specifications in a verification matrix associating the proper types of verification (analysis, similarity, inspection or test).

In the project planning phase the product architecture suggested by contractor was written as a work breakdown structure (WBS). Some designers were allocated to each element of WBS and a schedule was built to comply with contractor milestones. This schedule was used to develop equipment conception. In this phase the ground support equipment was the larger risk of the project as a whole because its timetable was shorter than other project parts and its complexity was almost so larger than the main equipment.

In the conception phase, the main technologies, components and facilities of the project were chosen. As demanded by the requirements, the electronic system should be composed by two racks with industrial computers that automate the control of all equipments and the tests to be executed. Real and virtual measurement instruments were chosen and an own electronic system based in boards settled in slots of a main board was developed to process hundreds of telemetries, telecomands, video, high-frequency and other necessary signals between MUX-EGSE and MUX subsystem.

Before technical planning phase all technologies were known. A product tree was structured (Figura 2) and a detailed schedule was built and refreshed every month.

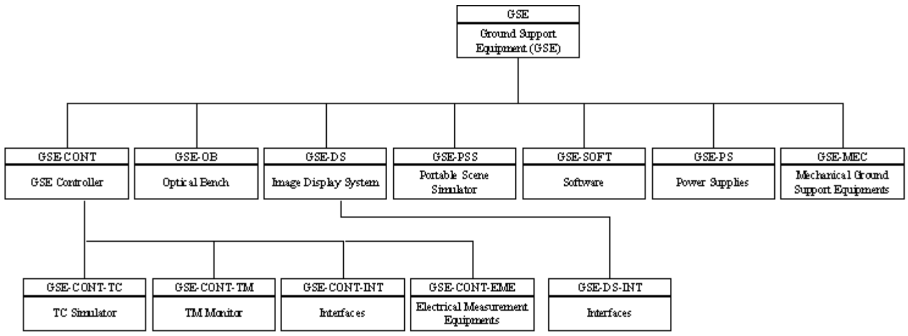

Figura 2. Product tree

The product architecture and interfaces were detailed consisting in:

- GSE-LAN interface: integrated local network with D-Link router that utilizes Gigabit Ethernet, Fast Ethernet (IEEE 802.3) and Wi-Fi (IEEE 802.11) standards to communicate among the controller rack, the images exhibition rack, printer and remote client computers.
- High speed I/O interface: acquisition PCI board of high speed low voltage differential signaling (LVDS information can be found in [7]) of National Instruments which receives the image data from the MUX camera.
- TM/TC simulator: PCI boards of analog and digital data I/O with developed circuits to multiplex, demultiplex, conditionate and distribute signals simulating the MUX interface with the on-board data handling (OBDH) subsystem of the satellite.
- Energy source supply interface: Agilent's source supply controlled by GPIB with developed circuits to distribution, in-rush current measurements, power switching and closed loop to supply precision simulating the interface of electrical power source supply (EPSS) subsystem of the satellite.
- Measurement electrical equipments: virtual instrumentation PCI boards that emulate multimeter, scope, logic analyzer and waveform generator for electronic tests.
- Optical equipments control: equipments acquired of specialized companies (Omega, Labsphere, Newport) controlled by interfaces RS232, GPIB and Ethernet: temperature and pressure sensors, radiometric light source, filter wheel, precision motorized motion controllers and integrating sphere.

Critical parameters were identified in form to allow the team to search functional responses to manage them. In the project the following aspects were understood as critical:

- Real time camera images acquisition;
- High precision jitter signal measurements;
- Client remote computers system access;

Software requirements were identified using structured analysis. LabVIEW platform was chosen to the software development. It makes simple the implementation of communication routines between virtual or real measurement instruments and computers. Hence, the processing activities of telemetries, telecomands and image data decode were the only ones which demanded more work. Figure 3 presents a data flow diagram for the EGSE controller software.

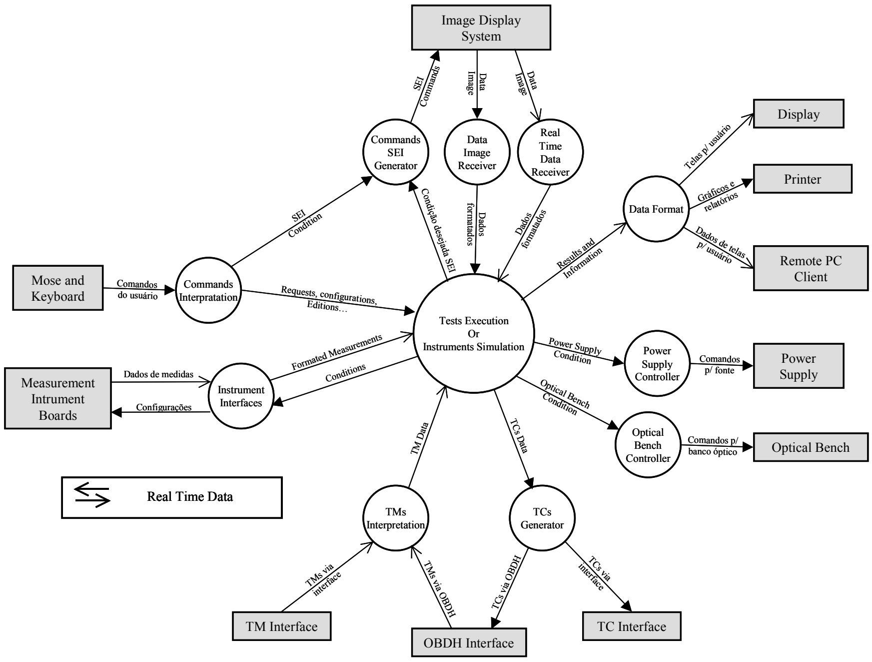

Figure 3. Data flow diagram for the EGSE controller software

In the technical design phase the reference model predicts some concurrent activities as illustrated in Figure 4.

The basic engineering of the product was basically the development and fabrication of mechanical parts to support the equipments.

The communication and control system was developed interconnecting all necessary connections as required by specification and setting all instruments controlled by Ethernet, GPIB or RS232 with proper options as in the router, in the software and in the operational system of EGSE controller.

For electronic design, the components were chosen considering already used ones in other company projects or the main manufacturers such as Texas Instruments, Analog Devices, among others. Circuit simulations, electrical schemes, lay-outs and gerber were developed using Altium Designer platform. After the boards were designed, they were manufactured, assembled, tested, revised and re-manufactured achieving theirs second fully operational version. For tracing purposes lots of documents had to be generated to each developed board: electrical scheme, lay-out, gerber, assembly map, assembly list, assembly checklist, assembly fluxogram, test procedures, inspection checklist, inspection procedures and test report.

Software develoment was divided in low and high level. In the first one, all communication among system components routines were designed and in the second one, using these routines, all necessary programs were designed to run all MUX subsystem tests automatically, such as grounding and bounding, signal clock jitter, optical alignment, temperature control, among many others.

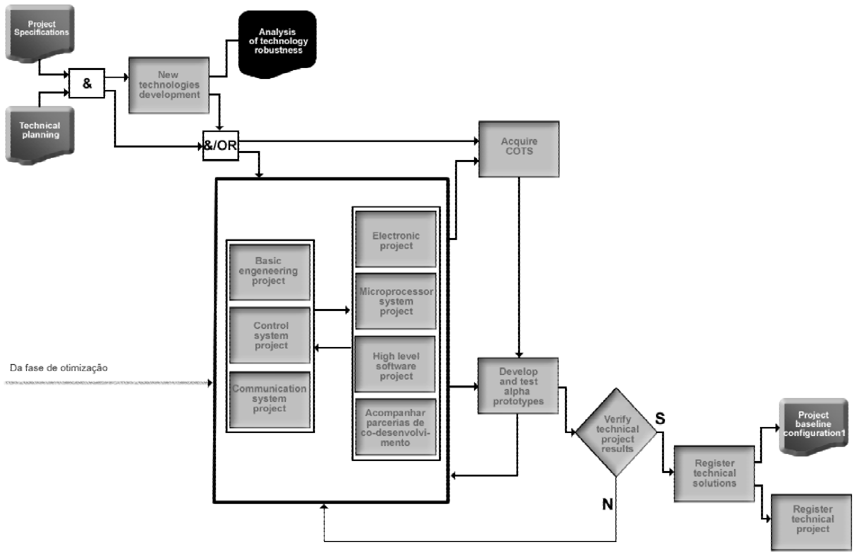

Figure 4. Technical design fase

The phases of optimization, homologation, validation, launch and monitoring were not yet implemented because the engineering model of satellite camera is still being developed, then optimization phase could not be finished. Figure 5 presents some photos of the built system: controller rack, part of its electronics and image acquisition test screen.

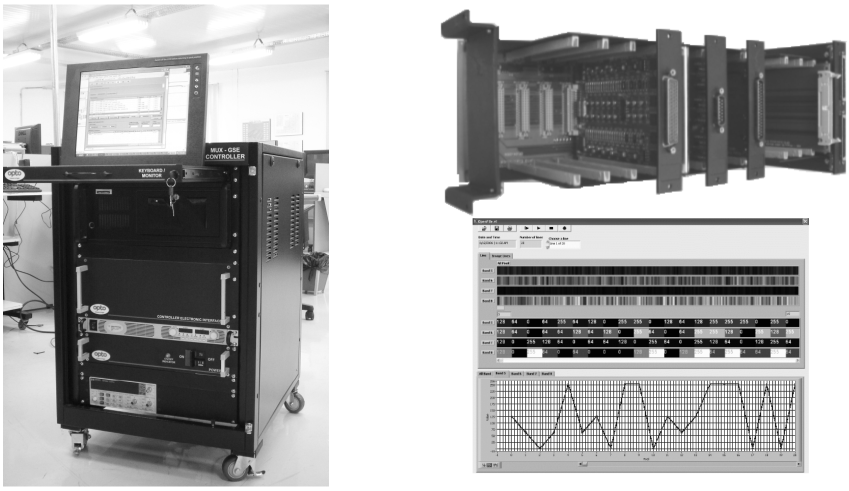

Figure 5. EGSE controller rack, electronic boards and image acquisition test screen

5 Final considerations

This work presents a well suceeded adaptation of MRM, a development reference model. Althought it has been designed to consumer goods, its guidelines emphasize the concept of phases that helped designers in the consistent development of an equipment for aerospace industry and in the generation of its documents. By practice viewpoint, the results obtained so far are totally satisfactory, since the developed electronic ground support equipment for CBERS multispectral camera is able to test all the satellite subsystem requirements, fulfilling all specifications.

These results show the qualities of the MRM's structured framework, which provides a clear understanding of design status and guides the designers through the best practices observeds in academic researches and companies approaches.

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Impacts of Standardization Process in the Brazilian Space Sector: a Case Study of a R&D Institute

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Abstract: The main focus of this paper is to evaluate the impact of standardization process in a R&D Institute of the Brazilian space sector. The research has tried to identify the several organizational changes associated to the implementation of NBR 15100:2004 (a specific standard for quality management systems for the aerospace sector) that have been implemented since the middle of 2005, in one of the institutes in charge of research and development in the space sector. In order to identify those changes, researchers that are participating directly in the NBR 15100 implementation were interviewed. The results of research have demonstrated a major impact on organizational, relationship and human resources.

Keywords: Standardization, NBR 15100, space sector, concurrent engineering.

1 Introduction

The Brazilian State, under coordination of Brazilian Space Agency (AEB), has been participating in the national and international space context in several projects, such as: partnership in the construction of satellites (CBERS), participation in the International Space Station (ISS), microgravity programs and others. The Brazilian participation in the microgravity projects is fomented through the project, production and launching of sounding rockets, accomplished nationally. Besides sounding rockets, the Program of National Space Activities (PNAE) has as objective to project, develop and manufacture in the Brazilian industry the Satellite Launch Vehicles (VLS). In 2003, during the assembling process of VLS-03 at the launch tower, located at Alcântara Launch Center (CLA), an accident happened impacting in many losses. As result of the accident report, were established actions, and one of them was the implementation of a quality management system standard, edited by Brazilian Association of Technical Standards (ABNT) in 2004, in the institute of R&D in charge of VLS project. The standardization adopted was the NBR 15100 (Quality Systems, Aerospace Model for assurance of quality in the project, development, production, installation and services) [1].

Therefore, this paper has as objective to evaluate associated impacts with the adoption of standardization in the Institute of R&D. The paper is organized in five

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items, initially a brief historical of the quality system standardization in the aerospace sector is described and the NBR 15100:2004 characteristics. In the next item the applied research methodology is explained and the obtained results are described and analyzed. Finally, the conclusions are described.

2 The Standardization in the Aerospace Sector and the NBR 15100

In the middle of the 90's, the aerospace industry recognized that the international standard ISO 9001 did not assist the minimum requirements of its sector. Most of 1st level organizations, in the supply chain of the sector, were increasing additional requirements to ISO 9001, when they asked them for their suppliers.

In this context, the authorities of aerospace companies in the United States, Europe and Asia organized the International Aerospace Quality Group (IAQG) with the intention of minimizing the complexity of international integration process of aerospace components, sub-systems and systems. In 1999, the IAQG, together with the Aerospace Technical Committee of ISO [2], organized the first international standard for aerospace supply chain, denominated SAE 9100 [3]. It was based on the ISO 9000 plus aerospace requirements. So, the IAQG and ISO established the basic conditions for the alignment of requirements in the aerospace supply chain and the specific demands of production [4].

Following the international perspective, the aerospace sector in Brazil created the CB-08 (Brazilian Committee of Aeronautics and Space), with the objective of standardize the sector regarding materials, components, equipments, project, production, evaluations, maintenance of aircrafts, subsystems, aerospace infrastructure and space vehicles. Therefore, the CB-08 worked out, in 2004, a standard technically equivalent to SAE AS 9100, registered at ABNT as NBR 15100:2004 (Quality System - Aerospace - Model for assurance of quality in project, development, production, installation and associated services). It was ratified by IAQG and were established the most favorable conditions for the insertion of Brazilian aerospace production in the international chain.

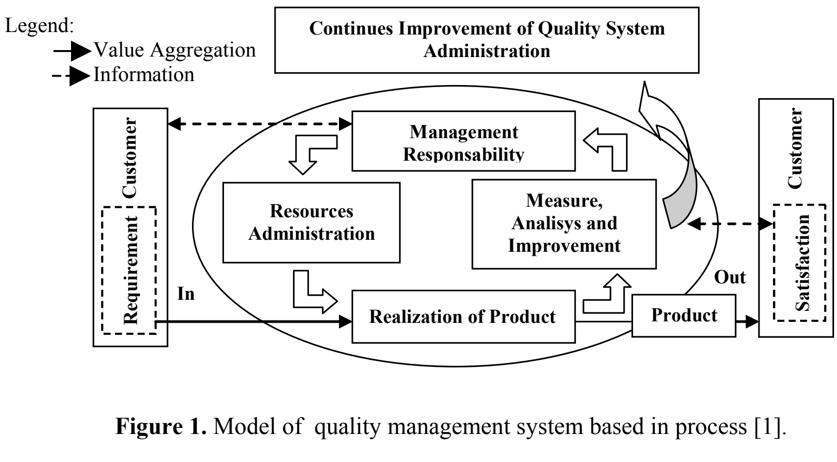

Figure 1. Model of quality management system based in process [1].

The fig. 1 above describes the model of quality management system of NBR 15100 based in a continuous improvement process [1]. The process begins by the identification of the customer's needs and the evaluation of the service capacity, considering the references of product and/or service compliances. Afterwards, those needs are translated in technical requirements that guarantee the product effectiveness, observed the aerospace regulatory restrictions. Then, the established configuration is documented, as well as the resources used for the production process, operation and maintenance of the product. The production is controlled by monitoring devices, to analyze the process conformity levels with the product requirements, and identify opportunities for preventive actions and improvements.

The main characteristic of NBR 15100, is the continuous improvement of quality management system, through the use of quality policy, quality objectives, audit results, data analysis, corrective and preventive actions and critical analysis of administration system. In that sense, the organization has to show evidences of the commitment with the development and implementation of quality management system as well as with the continuous improvement process, such as: to communicate to the organization the importance in assists the customer's requirements, to attend the governmental regulations, and to supply the necessary resources. It is important to mention that SAE AS 9100 and NBR 15100, are characterized as consensus standards, in other words, both of them are of voluntary adhesion, and do not substitute the regulatory requirements adopted by the aerospace production. In Brazil, for instance, they are subject to the Brazilian Regulations of Aerospace Quality (RBQA), whose objective is to assure, through requirements and procedures, that the demands of product contracts and conformities are assisted.

3 Research Methodology

According to Eisenhardt [5], case studies can include a single or multiple cases, as well as they are driven in several analysis levels. Our research was characterized as a single case study, trying to deepen in the selected case, through the study of a governmental Institute of R&D related to the Brazilian space sector [6].

In order to elaborate a questionnaire for the interviews, was utilized a model developed by Nadle, Gestein and Shaw [7], and the relationship network perspective [8]. In this model, the variables that have influence in the results are classified as external, when they can not be controlled directly by the organizations, and as internal variables, such as: the technology, the human resources, and the organizational structure and work organization. Modifications in the internal variables, that represent the organizational basic elements, can be considered decisive for changing the process and the way that the tasks are accomplished [4].

In the research, were analyzed the following areas of impact:

- Organizational Impacts - aspects regarding communication process (responsibility, content and diffusion), authority (hierarchical structures, command and control) and the tasks (formalization); and

- Technological Impacts - aspects regarding infrastructure (machines, equipments and instruments) and process information (communication protocols and hardware infrastructure and software); and
- Human Resources Impacts - aspects regarding labour volume (direct and indirect) and the competences (qualification profile, knowledge and requested attitudes); and
- Relationship Profile Impacts - aspects regarding internal interactions (volume and characteristics) and external interactions (volume and characteristics) [8].

The research questionnaire was applied in interviews with researchers that participated in the institute routines, before and after the accident, as well as, are participating directly of the NBR 15100 implementation process. It is considered before the accident, dates previous to August, 2003, and after the period from July, 2005 to December, 2006. It was used as research strategy some affirmative phrases and the interviewees evaluated the approval or disapproval degree, according to the Likert scale, in levels that varied from 1 to 5 (I disagree absolutely, I disagree, I do not agree and nor disagree, I agree and I agree absolutely) [9].

4 Description and Result Analysis

According to the results obtained in the interviews, below follows the graphic related to organizational and technological impacts.

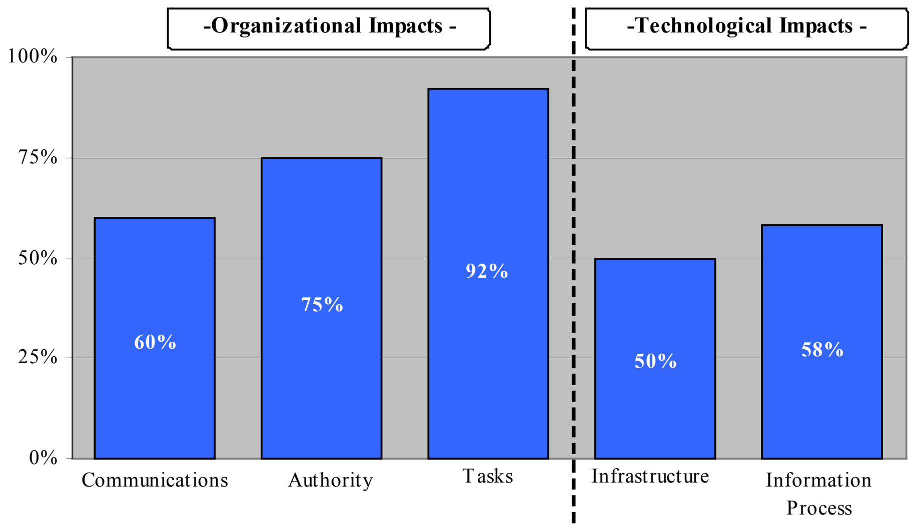

Figure 2. Organizational and Technological Impacts

It is important to emphasize that the affirmative phrases of the questionnaire were evaluating if the impact was relevant, in other words, an affirmative answered "not agree or not disagree" represented, in the majority of the answers, a positive impact but not so relevant to be considered as "agree or agree absolutely" by the interviewees. So, the interviewees mentioned that there was a better communication inside the organization, specifically regarding quality objectives.

The communication process was improved with more representatives of quality and assistants in the divisions and facilitating the diffusion of the NBR 15100 requirements. The interviewees affirmed that relevant modifications happened to provide larger authority, but without significant changes in the hierarchical structure. Finally, regarding tasks, were detected changes, mainly in the type of formalization, demanded for accomplishing the new quality standards.

Regarding technological issues, in the infrastructure of machines, equipments, and software / hardware were identified impacts, but still lack to complement them.

Below, follows the graphic of the impacts in human resources and the internal and external interactions.

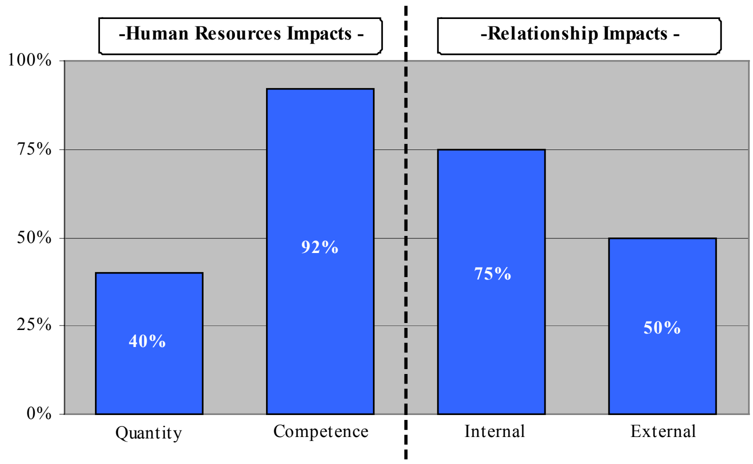

Figure 3. Human Resources and Relationship Impacts

Because of the NBR 15100 implementation more researchers had begun to participate in the activities of quality. On the researcher's profile competence occurred changes because of new quality activities demanded by the standard requirements. Those answers are ratified by the increase in the number of hours performed on quality training, such as: course of internal auditors, quality management systems and standardization.

Internally the quality representatives and their assistants interact more intensely, through weekly meetings to discuss subjects related to the standard implementation. This socialization process promoted a larger change of tacit and explicit knowledge among the participants, facilitating the implementation process in the Institute's divisions. Finally, in external interactions, it was observed that the standardization is beginning to confirm its importance in partnerships of the Institute with other organizations.

Also, according to the NBR 15100, item 7.3.1 – Planning of Project and Development -, the organization has to manage the interfaces among different groups involved in project, and development to assure the communication effectiveness and clarify the designations of responsibilities, and all of it have to happen during all stages of the project life cycle, in order to attend the requirements related to the product. This affirmative is similar to concurrent engineering definition. As Loureiro [10] defines “Concurrent engineering is a systematic approach of simultaneous and integrated projects of products and its related process, manufacturing, and staff. This approach intends to prompt developers to consider, in the early project stages, all elements of product life cycle, from conception up to discharge, including quality, cost, term, and user requirements.”

5 Conclusions and Final Considerations

The paper tried to identify and analyze the impacts caused by the implementation process of NBR 15100, in a governmental Institute of R&D, in the Brazilian space sector.

The methodology applied was a single case study. It was effective, because it has given us an opportunity to deep in the researched subjects. Besides that, the researchers have been implementing the quality standard and, also, were working at the Institute by the time that the accident happened. All of these have provided us a valuable source of data.

The most important impacts observed were related to the organizational, relationship and human resources. In the organizational impact, tasks and authority, demonstrate that the process of quality management system is permeating on several process in the Institute. The NBR 15100 implementation is emphasizing the importance of quality function in the professional profile of each researcher, independently if his/her original work is in quality or not. Also, it is important to mention the impact regarding internal relationship promoting the researcher works as a team since the beginning of the project life cycle. So, a standardization process has demonstrated a direct impact in the attitude of the researcher changing from an individual work to teamwork. Indirectly the standardization is creating an environmental situation facilitating a concurrent engineering approach.

In order to generalize the results for other institutions, new researches are suggested in organizations that have been going through by a quality standardization process. Finally, despite NBR 15100 implementation, has begun no more than 18 months, it was possible to observe the beginning of a cultural change in the functional quality vision, in other words, from a departmental quality to a (yet embryonic) Total Quality Vision.

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Proposal of an Efficiency Index for Supporting System Configuration Design

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Abstract. Demands for various miniature mechanical parts and products such as mobile phones, medical devices and so on, will increase more and more. Contrarily, manufacturing systems for those devices are becoming larger and more complicated. AIST developed the first prototype of a machineable microfactory which consisted of miniature machine tools and robots in 1999 as a countermeasure for the situation. An expected advantage of the microfactory was that the microfactory can reduce environmental impact and costs of miniature mechanical fabrication. However, the effect of the microfactory in reducing environmental impact and costs, or enhancing system efficiency have not been quantified. So, an appropriate index to evaluate microfactories by considering environmental impacts, costs and system throughput, simultaneously, is necessary. In the paper, the authors propose an evaluation index, based on the required time for each process, machine cost, operator's cost and environmental impact, using the microfactory as an example. The calculation shows that the proposed efficiency index is useful in evaluating the system configuration.

Keywords. Microfactory, System configuration, Environmental impact, Throughput

1 Introduction

"Microfactory" was a concept of a future manufacturing system, which was proposed in the Japanese national R&D project named "Micro Machine Project [1]". The original concept of the microfactory was "a super-miniature factory consists of micro machines and capable of producing miniature products anytime and anywhere". In 1999, AIST developed the first prototype of a microfactory that consists of miniature machine tools for parts fabrication and miniature manipulators for parts transfer and assembly. (Figure 1) The microfactory was able to perform a series of fabrication and assembly on a small desktop [2,3]. The result of the test production led us to conclude that the microfactory had considerable capability of micro mechanical fabrication. Some other microfactories [4-6] have been proposed and "microfactory" has become a rather common concept. An expected advantage of the microfactory was that the microfactory would reduce environmental impact and costs of miniature mechanical fabrication, especially for "diverse-types-and-small-quantity production". Since the smallness of the machines enables flexible layout changes, it can control the increase of the costs when the product designs have been modified. And, by replacing conventional manufacturing systems to microfactories, electrical power can be reduced. However, since there have been no effort to evaluate effect of microfactories quantitatively, abovementioned advantages are still uncertified. In recent world where "green manufacturing" is strongly required, environmental aspect of microfactories should be examined. The purpose of this research is to propose a simple efficiency index for a microfactory-like system to support its system configuration design.

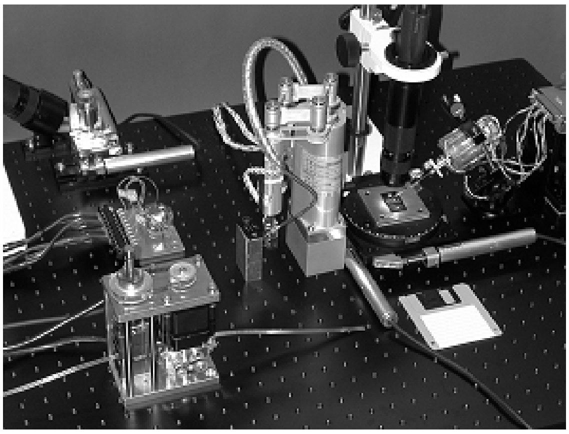

Figure 1. Microfactory

2 Overview of the Microfactory

The microfactory shown in Figure 1 consisted of five miniature machines. The five components were a lathe, a milling machine and a press machine for parts fabrication, and a transfer arm and a micro-hand for assembly. Every component is well-designed and extremely smaller than the corresponding conventional item. To show the capability of the microfactory as a manufacturing system, test production was executed. The test product was a miniature ball bearing, which was 900 microns in diameter, and consisted of 4 kinds of parts. The parts and the test product is shown in Figure 2. All the parts except steel balls were fabricated using the miniature machine tools, and assembled using the manipulators. As the result of the fabrication, the microfactory was capable to assemble the test product. Therefore, it can be said that the microfactory has possibility as a future manufacturing system to produce many varieties of extremely miniature machine parts. However, it still has some problems, such as the low throughput or the difficulty of the fixture of the product. To improve the throughput, an appropriate system configuration should be considered. To fabricate the miniature ball bearing shown in Figure 2, manufacturing process in Figure 3 was applied. Every part starts from the material shown in the left side, passes through some sub-processes shown in the block and reaches the assembly processes written in the right side. From the figure it is easily imaginable that the assembly processes are very time-consuming, because the manufacturing processes should be done sequentially under a microscope using the micro-hand. Table 1 indicates the average process time of the corresponding processes in Figure 3, after operators have been skilled enough. Number of operators required for each process is also shown in the table.

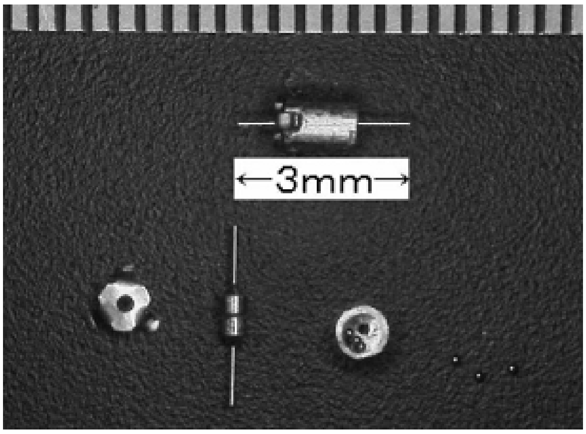

Figure 2. Miniature ball bearing

According to Figure 3 and Table 1, it is evident that the assembly operations will be the bottlenecks for the throughput. Machine and labor costs are also important for manufacturing. Table 2 shows the rough estimation for the cost of the machines

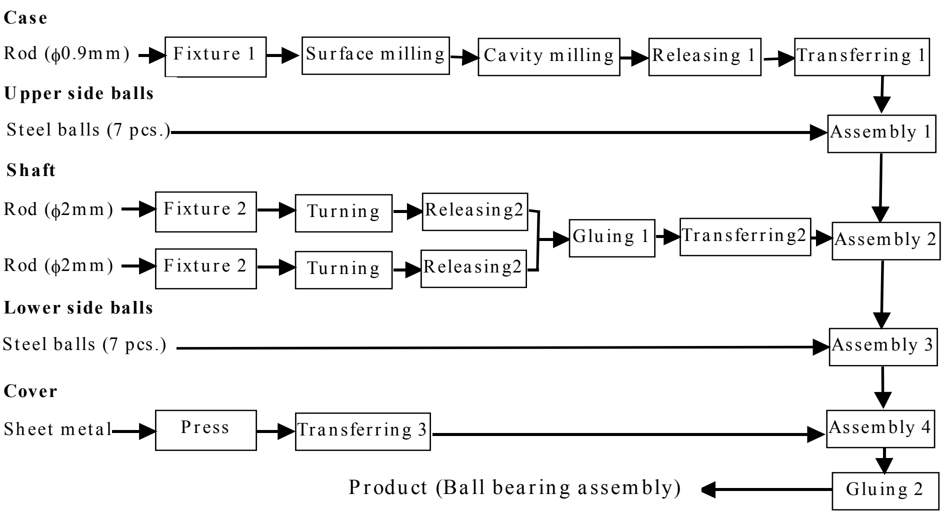

Figure 3. Manufacturing process of the test product

Table 1. Process time and number of operators for each process per unit

Sub Process	Process time in seconds	Number of operator
Fixture 1	10 sec.	1
Fixture 2	5 sec.	1
Surface &cavity milling	3 min.	1
Turning	2 min.	1
Press	0.2 sec.	0
Releasing 1	10 sec.	1
Releasing 2	5 sec.	1
Transferring 1	1 sec.	0
Transferring 2	1 sec.	0
Transferring 3	1 sec.	0
Assembly 1-4 (total)	48 min.	1
Gluing 1	1 min.	1
Gluing 2	2 min.	1

used in the microfactory. And also the energy consumption of each machine is an important factor to consider system efficiencies. Table 3 shows the average power consumption of the machines during the operation.

Table 2. Machine costs

Machine	Milling	Turning	Press	Arm	Hand
Cost in million yen	0.7	1.2	2.0	3.0	5.0

Table 3. Energy consumption

Machine	Milling	Turning	Press	Arm	Hand
Average power in Kw	0.25	0.3	0.05	0.2	0.4

3 Proposal of a System Efficiency Index

Hereby, the paper tries to define an index to evaluate the efficiency of manufacturing process. In an existing research [7], there was a proposal of an index to evaluate total performance of products by considering product values, costs and environmental impacts, through product life cycle. Functionality per cost is often used to evaluate product performance in quality engineering field. And functionality per environmental impact, so-called eco-efficiency [8,9] is also a common index in recent design for environment [10], for evaluating another aspect of product performance. However, these existing evaluation indexes cannot evaluate the environmental and economical aspects simultaneously. Because the design engineers and manufacturers have long histories of serious effort to reduce cost of manufacturing, they might not accept an index without evaluating cost and functionality. The proposed index is the simplest combination of “eco-efficiency” and “functionality per cost”. To evaluate the efficiencies of manufacturing systems, the same idea can be applied. Efficiency index defined by Equation (1) is used in the following sections.

$$Ef = \frac{F}{\sqrt{C}\sqrt{E}} \tag{1}$$

Ef: system efficiency index, *F*: system functionality,
C: cost of the system (yen/hour), *E*: environmental impact (kg-$CO2$/hour)

Instead of the total performance of a product defined in the original index, "*Ef*" which is an index to express system efficiencies is introduced. "*F*" is the sum total of the value of the various products created within a certain time. But, since the target product is not changed in this case, "*F*" can be simply represented by the system throughput. By defining the throughput by number of products assembled in an hour, the efficiency index for the microfactory can be calculated. "*C*" can be calculated by a sum total of machine costs, labor costs and electricity cost during the corresponding time. Labor cost is assumed to be 5.0 (million yen) per person per year. For "*E*", many indexes have been proposed to estimate it. In the microfactory, since it isn't necessary to consider special waste, equivalent CO_2 emission will be a good index to estimate environmental impact. So, "*E*" can be expressed by the sum of $CO2$ emission cased by electricity shown in table 3 and machine material. (1kWh =0.38kg-CO_2)

4 Efficiency Analysis of the Microfactory

Analysis of the manufacturing process mentioned in the former section showed that the assembly processes performed by "micro-hand" is critical both for throughput and environmental impact. When the number of components or operators is not limited to be 1, a simple strategy to enhance system efficiency will be to increase the number of the "hands". According to table 1, total process time of assembly and gluing (gluing is also executed by micro-hands) will be 51 min. So, when the system has one operator for machining and one for assembly, number of the product produced in an hour is 60/51=1.18. And when the number of hands and assembly operators is *i*, throughput will be 1.18*i*. By assuming the annual operation time of the system is 1600 hours, the efficiency is calculated by Equation (2). When the number of the "hand" is more than 6 and the system has only one machining operator, the turning process becomes the bottleneck and the efficiency index can be calculated by Equation (3). This value is lower than that of the case in which there are 5 hands and one machining operator. By adding one more machining operator to the system, again the bottleneck will be the assembly process. When the system has *i* hands, *j* machining operators, *k* lathes and *l* milling machines, the system efficiency is expressed by Equation (4). Figure4 shows the behavior of the system efficiency calculated by these equations.

$$Ef = \frac{1.18i}{\sqrt{(6.9+10i+5)\times 10^6/1600}\sqrt{(0.8+0.4i)\times 0.38}} \quad (1 \le i \le 5) \tag{2}$$

$$Ef = \frac{6.4i}{\sqrt{(6.9+10i+5)\times 10^6/1600}\sqrt{(0.8+0.4i)\times 0.38}} \quad (6 \le i) \tag{3}$$

$$Ef = \frac{1.18i}{\sqrt{(5+10i+5j+1.2k+0.7l)\times 10^6/1600}\sqrt{(0.25+0.4i+0.3k+0.25l)\times 0.38}} \tag{4}$$

i: number of hands and assembly operators, j: number of machining operators, k: number of lathes, l: number of milling machines

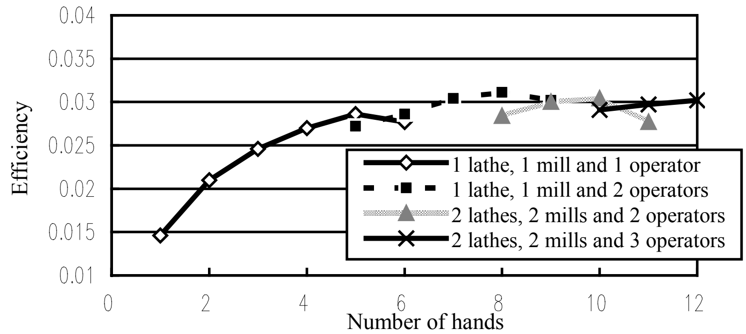

Figure 4. Behavior of the efficiency index

In the figure, since press and transferring processes are not significant for the overall throughput, the figure shows the behavior of the efficiency indicator according to the change of the number of hands, lathes and mills. ("Operators" means number of operators for machining processes.) According to Figure 4, it can be said that there are some local maximums. The result suggested some simple strategies. For example when the system had a lathe, 2 machining operators and 6 hands, the efficiency was higher than that of the case having 1 lathe and 5 hands. The results showed that having 6 hands and one machining operators won't be efficient. Usually, the configuration of the system is mainly determined by the required throughput. But the calculation indicates that covering the shortage of the throughput by extending the operation time of the factory will be a better solution in the aspect of green manufacturing.

5 Comparison with a Conventional Factory

Focusing on "diverse-types-and-small-quantity production" of micro mechanical products, the final goal of this research is to prove that a microfactory-like system is more suitable than a large mass production manufacturing system. When frequent layout change of the system is necessary, high flexibility may cover low throughput. The paper tried to compare system efficiency of the microfactory with that of a conventional mass production line. A rough estimation says the maximum throughput of a typical manufacturing system of miniature ball bearing is about 100 thousand units per month. By assuming the system runs 20 days a month and 8 hours a day, it is equivalent to 625 units per hour. Initial cost of the system is about 200 million yen and the power consumption is estimated to be about 200kw. Considering the environmental impact of machine material, die-set and electricity, the efficiency can be calculated. Figure 6 shows the rough estimation of the efficiency of the mass production system, corresponding to lifetime length of the system, and average demand.

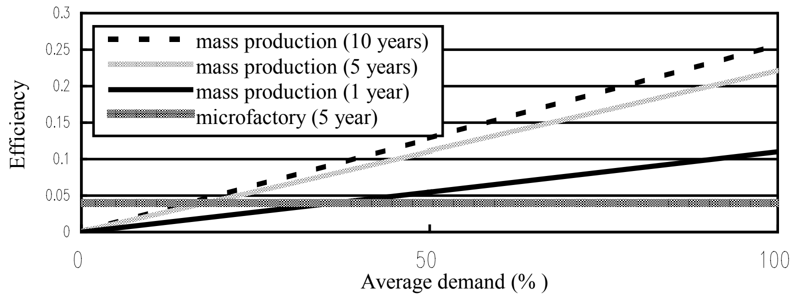

Figure 5. Efficiency of a mass production system

The figure indicates that the microfactory is rather efficient when the demand is low and the lifetime of the system is relatively short. When the system lifetime is 5 years, the efficiency of the microfactory in its suitable configuration is about 0.04. So, when the average demand is lower than 20% of the maximum throughput, the microfactory is more efficient than the mass production system. Although more precise comparison is necessary, it can be said that "microfactory" has a good possibility for diverse-types-and-small-quantity production of miniature mechanical products.

6 Conclusion and future work

A simple index to evaluate the system efficiency of a microfactory-like system was proposed by considering system throughput, machine costs, labor cost, and CO_2 emission caused by machine material and electricity. As the results of the analysis of the test production process of the microfactory, it was able to show that the system had some suitable configurations. By using the evaluation result, it was possible to design the system configuration of microfactory-like systems.

The result was compared with a rough estimation of the efficiency of a conventional manufacturing system of ball bearing. The comparison indicated that the efficiency index of the microfactory was lower than that of a mass production line. However, when the lifetime of the system is relatively short and the demand is low, efficiency of the microfactory can be higher than that of a mass production line. The fact shows although “microfactory” is not a suitable system for mass production, it will be a good solution for “diverse-types-and-small-quantity production”.

As the future work, more precise comparisons with mass production systems are required in order to prove the effectiveness of microfactory-like system. In addition, modification of efficiency index to consider frequent change of demand and product design may become necessary to estimate the feature of microfactory-like systems.

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Reaching readiness in technological change through the application of capability maturity models principals

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Abstract. New technology introduction generally implies a change management plan as the adoption of advance technical capabilities comports information, cooperation and coordination restructuring. When planning for potential organizational developments the application of integrated design principals facilitates structure modelling. It enables to capitalize the perceived recommendations and constraints by the individuals impacted by change. Organizational structure design is considered as integrated product design where concurrent engineering principals are applied. The different professions concerned by process redesign, collaborate to its definition so as to ensure interoperability. This methodology allows considering the implied stakeholders at different level of the process and the needed resources to ensure readiness for a given technological change. As indicated by O.Poveda [9] even if the objective of this kind of methodology is clear, it remains complex to operate. The main difficulties are to translate the recommendations and constraints captured at the specifications phase to elaborate an optimal organizational structure supporting the new processes. In order to face these hurdles we propose a potential change maturity model so as to tackle the technical, social and strategic factors linked to organizational performance.

Keywords. Change management, Organizational development, Concurent engineering, Readiness for change, Change maturity models.

1 Managing change as a constant

Organizational change is often considered as a constant in contemporary firms. As Stated by A. Rondeau [10], there are multiple change sources linked to external environmental pressure such as worldwide competition, technological innovations and new norms and standards F.Pichault [8]. Enterprises are searching for methods and tools allowing productivity and innovation capability improvements. The productive system evolutions generate considerable functional transformations. ICT's developments contribute circumstantially to job transformation. These technologies accelerate some evolutions by replacing hierarchical systems by

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network structures. The effects are that business actors have more operational autonomy and decisional power including an increase in transversal activities and collective data management. This kind of organization can be considered as complex. In fact the system is composed of multiple subsystems incorporating different professional corps cooperating to design and run the activity. It results to the fact that no unique profession can manage the global system as it is interconnected. Changing the organizational structure in this context is critical; a restructure of the collective activities must be operated while keeping day to day performance. Classical change management models describe transformation levels and steps that have to be reached to adopt new operational modes. In those models we cannot estimate the necessary capabilities that are needed by structured organizational agents to operate under a new mode. In order to measure the change capabilities we propose a combination of three evaluation models measuring information, cooperation and coordination transformation. The presented model which is developed in a European project provides a framework allowing project management teams to assess the organizational maturity to integrate new practices under structural or technological change.

2 Maturity and readiness for change

Maturity for change is defined here as workforce capability to operate effectively in transformed processes. In other words this methodology is addressed to tackle organization al readiness to fulfil business objectives through technological and structural improvements. As defined by Armenakis et al [1] readiness for organizational change is linked to the beliefs, attitudes and intentions of individuals regarding the organization's capacity to successfully undertake change. Our goal is to investigate the change capacity and specifically change capabilities. The proposed model integrates a set of evaluations structured in three main steps defined as maturity levels. The first level "Change Impact Mapping" is the step where departments, organizational actors and the relevant impacted core competencies are identified. The second level "As Is & To Be State Comparison", introduces evaluations characterising variables such as Cooperation, Coordination and Information form. These assessments allow capturing to which extent current work practices will evolve. The third level "Transformation Costs" provides an evaluation of the needed resources and support to simulate and introduce new work process. The innovative feature of this model is to integrate technical and human capability for organizational development. Few researches have been done both considering human and technological dimensions and activity performance. This paper does not answer to all organization al change problematic; nevertheless it brings a practical resource in process design.

3 SMMART European Project

SMMART (System for Mobile Maintenance Accessible in real Time) in an integrated European project programmed on a three year period launched on November 2005. The consortium integrates 24 industrial and research actors investigating RFID embedded system development in the transport industry. Executed under the Framework Programme 6, the project is sponsored by the European Community. Aiming at enhancing the European leadership in the worldwide MRO (Maintenance Repair and Overhaul) sector, the project main objective is to provide usage and maintenance monitoring system technologically based on smart tags network. The tags will be designed to operate and communicate wirelessly in harsh environment such as vehicles propulsion unit. This network will enable the capture of usage and maintenance data through critical parts life cycle and secure end to end visibility of industrial and logistical supply chain. The application of this system would imply establishing new normative referential for the MRO stakeholders such as manufacturers, operators and regulation bodies and insurance companies. The general strategic stakes for the transport industry in investing in such research and development project is to decrease maintenance time in order to maximise operation time, to improve traceability of maintenance operations and operational safety. The introduction of these technological developments will include considering the needed re-engineering of technical and human capabilities. Business process change will be necessary and the presented potential change maturity model is established as a support tool to ensure the SMMART technology deployment in industry.

4 Potential change maturity model

The term capability applied to organizations refers to the skills within a business structure that are relevant to managing a planned activity. The most suitable literal meaning taken from Oxford advance learners' dictionary 2004 for the term maturity is "fully grow or developed, having achieved one's full potential". We understand Capability Maturity Models as a method which allows a certain level of performance achievement prediction. One of the well known groups of Capability maturity model has been developed by the SEI (Software Engineering Institute) of the Carnegie-Mellon University. Theses models derive from Watts Humphreys original works, who introduced in the 1980's a model to improve software process development. Referring to CMMI Product Team [2] definition, maturity is perceived as "the extent to which an organization has explicitly and consistently deployed processes that are documented, managed, controlled and continually improved". There is a close relationship between capability and maturity they are both link to the quality improvement concept. Process maturity was born in the total quality management movement, where the application of statistical process control (SPC) techniques showed that improving the maturity of any technical process leads to two things: a reduction in the variability inherent in the process, and an improvement in the mean of performance of the process related to the capability [6]. Thus quality improvement consists in making process stable and enabling statistical control so as to maximize capability. A process can be said to be mature as it pass trough the stage from unstable to stable and then enjoying improved capability Cooke-Davies [3]. The CMM's that are available today cover project management processes, technical delivery processes for products and software development and organizational maturity. Among theses applications of CMM our objective is to inquire about change management capability and maturity. Change management is commonly incorporated in project management and generally defined as being a constant in project based organizations. Our main objective is to describe through a change management perspective how to determine the prerequisites to acquire a capability to incorporate a designed change. Considering change management within its theoretical or experimental literature, we observe few investigations on the readiness for change Lillian T. Eby et al. [6]. It is meant about readiness the extent to which an organization is capable to incorporate new business process and mastering them. The aim of the tool is to measure to which extent activity is going to be transformed. Structural and technological transformation due to process change can occur on different levels. Skills, knowledge and practices have to de readapted to react to the constant change. To resume introducing new technical process implies the consolidation of two factors. The former is ensuring the technical capacity to support the process and the latter is ensuring the capability of the impacted unit or profession to deliver a constant process. Mastering the potential change maturity is critical to accesses the organizational ability to monitor the service levels and ensure compliance with newly design corporate procedures and processes.

4.1 Impact Mapping

It is the first step where the impacts of the programmed change is characterised on the organizational activity. Through interviews the impacted processes and core competencies are determined. Core competencies as defined by Hammel et al [5] are those capabilities that are critical to a business, it embodies an organization's collective learning, the know how of coordinating diverse production skills and integrating multiple technologies. When the impacted core competencies are revealed, the link can be made to identify the teams and the individual competencies impacted. This step is crucial to fix the As Is state; it fixes the body of organizational knowledge and competencies that is concern by the change. The impacted process analysis reveals the related capability that is supported by the knowledge, skills and abilities employed by organizational actors to achieve the process goals and objectives. This level allows identifying "who" the organizational roles and functions and "what" competencies or tools, impacted [4]. The next figure illustrates an example of how organizational impacts are determined. Impacts on the general business workflow and the related processes or sub processes are identified. It allows considering the concerned teams or individuals. The last phase is to define the impacted factors which can be used to evaluate the needed recourses for change.

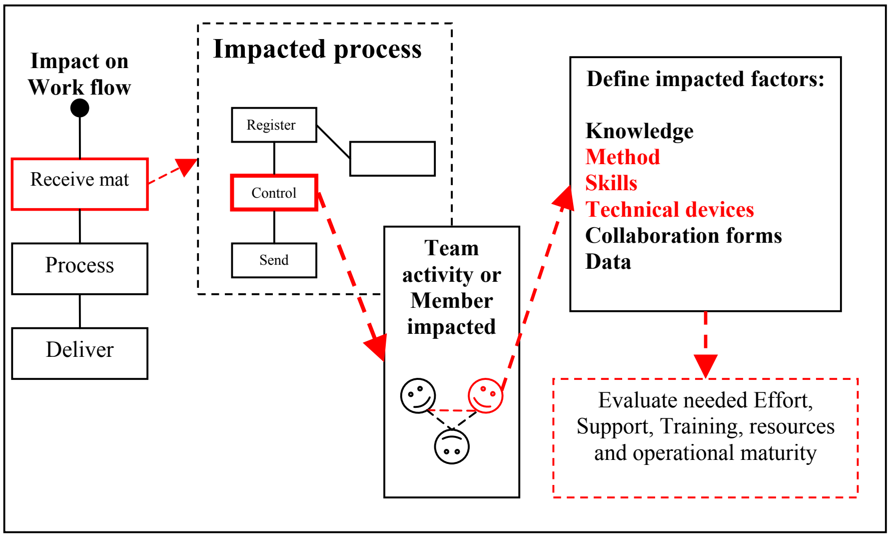

Figure 1. Impact Mapping

4.2 As Is V/S To Be

When the As-Is situation is set the To-Be one is designed considering all the impacted stakeholders in the various concerned processes. The Minel's [7] Cooperative Evaluation Scale (CES) is applied to characterise the level of collaboration between 2 professions involved in a same activity. Useldinger's [11] model defining as a six point Likert scale different levels of information is readapted to express the level of information change in an activity. Our investigation consists in the mapping of collaborating professions in the spotted impacted activities. We first carry an "As-Is" collaboration situation, to evaluate the level of cooperation before the change. Characterising the degree of cooperation allows defining targets related to change implementation. That is, when considering 2 professional corps collaborating, to determine if the same cooperative level is to be kept after change implementation or if it needs to be optimised. The Minel's CES considers 6 levels of collaboration, described by the level of knowledge shared by two interacting actors. The levels are as follows: 0 stands for no knowledge shared, 1 for common vocabulary, 2. Knowledge of concepts, 3. Knowledge of methods, 4. Master of domain, and 5 for expert of domain. Empirical studies show that in order to attain collaboration between two different professions, the level 3 of the CES is required to share a common vision of how to integrate the constrains of the other in ones own goals. Above this level, actors' specialised skills affect the cooperation. Under this level, cooperation is not efficient and can be improved. When the result of the "As Is" cooperation state is figured out, it has to be linked to the evaluation of the information changing state.

This is carried out by using Useldinger's model where six level of information are defined as follows: Signal, data, information, knowledge, Skills and know-how.

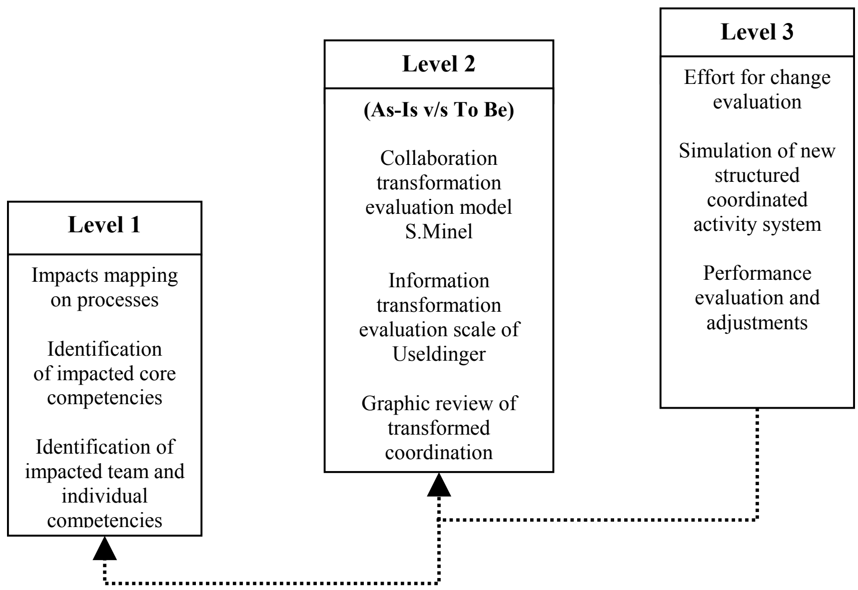

Figure 2. Potential Change Capability Maturity Model (O.Zéphir 2006)

The model is similar to a 6 point Likert scale characterising (under a hierarchy) the different levels of information throughout different formalized schemes. The collaborating actors have to define in common the level of information changing in their activities. Defining that, allows evaluating to what extent the activity is changing, from the form of data or structure to competencies and know-how. Having those information collaborating actors are able to redefine their common activities, and also to state the needed resources, effort and support they need to collaborate under a new operating scheme. A similar evaluation is applied to evaluate coordination evolution from the As-Is to the To-Be situation there is no particular method applied here, but and indication on each described collaboration activity.

4.3 Effort for change evaluation

This last step is design to indicate for each transformed activity spotted in the level two, the necessary human and technical resources to deliver a constant process. Once the extent to which activity is being transformed is fixed, as referred in CMM models, simulations are programmed to evaluate the needed documentation, management and control to reach continuous process improvement through readjustments. The prerequisite skills, knowledge, practices and tools to ensure compliance with the corporate procedures and process are fixed at this level. We estimate that readiness for change is reached when technical and human capability is estimated in relation to a define service level with improvement possibilities. Readiness means here the organizational capacity to incorporate new business processes and mastering there possible evolution.

5. Future developments

The presented Potential change maturity model is still in its development state. The first two levels are being actually tested and fine tuned through the SMMART European project. Theses first steps are crucial to determine the impacts of a new technology and the needed capabilities to support it. Change readiness definition relies circumstantially on the impacts definition. Applying capability maturity models principals to model the proposed method provides an efficient and practical framework to estimate the change project progression. Our next issue is to elaborate a strong simulation method so as provide reliable human capability evaluation. We still have to set the adequate method base on empirical researches analysis and strong theory evaluation. Our main focus trough this article was to present a practical model enabling the evaluation of the need capabilities in terms of human and technical capital for new technology introduction. Our investigations aim at conciliating human and technical factors for optimal process design.

Acknowledgement:

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The System Verification Breakdown Method

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Abstract. High integrated and complex systems are more and more scattered and common in people lives. Even without the exact feeling of this means, they hope for the best product. This desire implicate in system manufactures improve knowledgement and create solutions with more advanced technologies to satisfy consumers expectations. Verification have been done at the end of process development, but it have resulted in difficulties to manufacturers because is very expansive and hard to implement any required modifications at this point of development process. Thus, many manufactures have started verification process at begin of development, decreasing erroneous implementations. This paper is intended to show an intuitive method possible to apply in any cases, using block diagrams, that assists generate test cases procedures, since when development starts, making relationship among system interfaces, subsystems and functions, enabling tests traceability and tests coverage analysis. In cases where manufacturer develops same kind of products, the block diagram will be easily reused to a new one, including or removing systems, subsystems and functions, adapting it to new features and project requirements. The propose is starting developments doing the things right earlier as possible.

Keywords. Verification, System, Interfaces, Block Diagram, Reuse and Test Coverage.

1 Introduction

The verification and validation activities have been generated a lot of discussions where is applicable validation or verification. It is possible find many ways to understand and define these activities, even that they should executed together without clear and explicit separation in terms of time and stages of development. Many documents consider that validation is based in non implemented hardware and software while verification is based in a target implementation of hardware and software components. In spite of divergences about the best definition to validation and verification, there is a common

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consensus that validation means “Do the right things” and verification means “Do the things right”. Thus, both issues are supplementary during process to ensure the correctness products development and, at this paper, the term verification will be considered here disregarding stages of development.

2 Motivation

This work is motivated by the last modifications occurred in development process of high integrated and complex products forcing developers improve their knowledge about technologies, process and methods to speed up the development and ensure that the new products will be accepted by market and consumers will be satisfied.

The intention of this paper is propose a method to start verification even without formal requirements have been written. When a development is defined, developers have, at least, a minimal knowledgement of the system under construction, thus it enables the start of verification process, once that it is possible create a block diagram with systems and breakdown it in a small parts. This method allows and helps many levels of verification, traceability of tests and coverage. A brief example will be done later.

3 The System Verification Breakdown Method

The verification activities, usually, were executed from the middle to end of product development, when implementation in the target was started. It have caused a lot of difficulties because problems of erroneous creation and implementation of elements and components that when integrated in target were figured out and at this time is very complex and expansive any required modification to fix this mistakes.

Thinking in avoid this kind of problems, manufactures, using the new facilities allowed by grow up of computer sciences, starting modeling requirements and testing it to ensure that the desired functionalities were created and implemented. Only after test all, or at least, a major part of testable requirements, the hardware and software implementation is ready to be initiated. This model tests are proving a good initiative in order to reduce later problems finding. Developers, just after write requirements, were able to generate models and starting tests.

Unfortunatelly, the process to write requirements is not a short process and it is made during many stages of development, it causes changes due requirements correction and creation. Then it implicates in generate models with risk of hard modification after requirements revision or even create a new one. Due a divergences in accept verification while modeled systems and difficulties to create these models due a requirements modifications, a considerable number of problems are figured out in implementation in target phases.

If verification starts even no formal requirements have written it will help developers to create requirements more reliable and correct. It could make easy the identification of integration problems even if the systems and their interfaces are not detailed and totally defined.

Using blocks diagrams to depict systems is an easy way to visualize whole integrated system because they are more readable and intuitively understandable than formal languages. With the complete view of the system and its interfaces is possible investigate details not so simple to think when writing a requirement. Using a symbolic way to represent ideas about system could be simplier than use words, spoken or written. This way to analize system is valid and applicable also to subsystems, elements, components, functionalities among others. In any moment is demonstrated the intention of change formal requirements by non-formal languages, it is only expected to aid developers to have a complete visualization of the systems.

Usually a developer creates each system separately establishing interfaces between systems only by requirements, but it could not be well understand by parts causing problems later during integration. This example is only one case, but misunderstand could be generated inside of own workgroup, where subsystems do not agree with them interfaces. A device defined by one part of the system or subsystem could not met all features requested by other or a post requirements elaboration changes could not be transmited completely or clearly.

With this method is possible make integration of parts and start a process to develop a complete verification analyzes from system to components and functionalities (top down verification) or from components and functionalities to system (bottom up verification). The system verification responsible could use this method to perform analyses around the correction of system functions (top down) in normal or abnormal conditions. The components verification responsible could start the verification from componens and devices level (bottom up). Both, system verification responsible and components verification responsible are able to use the same block diagram breakdown, it only depends of fidelity and detail of block diagram breakdown.

Other advantage is to facilitate the coverage of tests. Usually is generated a verification matrix to ensure that all requirements are verified. The verification matrix is used to make cross between each requirement with each verification modalities and during the initial stages of developments and based in written requirements that can change. Here is easy to split systems in subsystem or in minor parts and analyze each separate parts as well as integrations and interfaces. Each minor part verified could be linked with its interfaces to start other verification and so on, covering wide parts of system. This way is possible cover, at least an enormous number of tests cases.

The system traceability is accomplished when each block diagram carry all of important signals to next block level becoming easier the paths to follow signals and verify correct links among blocks (systems, subsystems, components, etc.).

Nowadays the reuse of tools, developments, process, methods are very commented, but the reuse is not so easy to achieve once that, there are improvements and different objectives from development to development. Other feature this method is to reuse the block diagram, making modifications that are not so hard to implement. It only needs remove or add blocks and rearrange interfaces, inputs and outputs. It is very normal that a product have very closed features with other, for instance, in automotive development an automobile could have automatic transmission while other manual transmission, thus, the changes should be done in transmission diagram blocks where one receive car speed as input to shift gear while another wait for driver command among others signals.

Basically, method is based in imagine how create a system and its main features and interfaces and inputs/outputs. Following this, to start creating a low level of system and linking interfaces. Continue breaking systems in subsystems and putting interfaces and related signals. Repeating this until the system is totally broken and covered. Next an example to demonstrate the idea to understand better it, as described above, sometimes visual depict is more readable and intuitive. This method consider that who develops it have a minimal knowledement of the system.

4 A Electric Wheel Chair Example

To this first work with this method was chosen an electronic wheel chair as example. This is an interesting system, once that it has structural, electrical, electronical and mechanical subsystems. The basic features of electric wheel chair are:

- The Electric Wheel Chair shall move without a human pusher.
- The Electric Wheel Chair shall have a control to command chair by the desired way

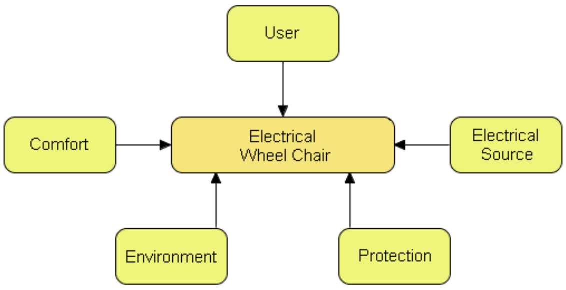

Figure 1 - Electric Wheel Chair Interfaces

It can be understood that these two basic features are requirements to start project. Based in these is possible start thinking in interfaces and necessities that system will require to satisfy them. After keep in mind the basic requirements, starts the phase where detailed requirements are written. But like we are intended to show that no requirements are necessary to start the assembly of this block diagram breakdown we will start drawing blocks.

First of all, it is necessary understand which are the main interfaces of electric wheel chair and them insert in an initial block its interfaces, like **Figure 1**.

After gathering all possible interfaces, in major view, break system in known technologies or parts and insert those interfaces internal and external. In this case was chosen break in technologies electrical system, mechanical system and structural assemblies (**Figure 2**).

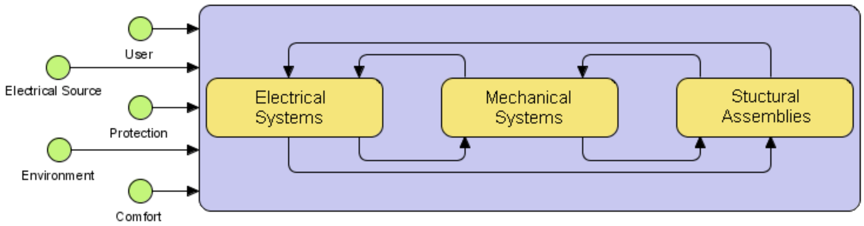

Figure 2 - System Major Breakdown View

Start to splitting technologies in separated blocks to make easier the connections of interfaces, but always thinking systematically and shall never forget other systems and technologies interfaces.

It is possible to visualize in **Figure 3** that main interfaces and relationships among systems are kept allowing analyze connections and ensure that all parameters and signals were inserted.

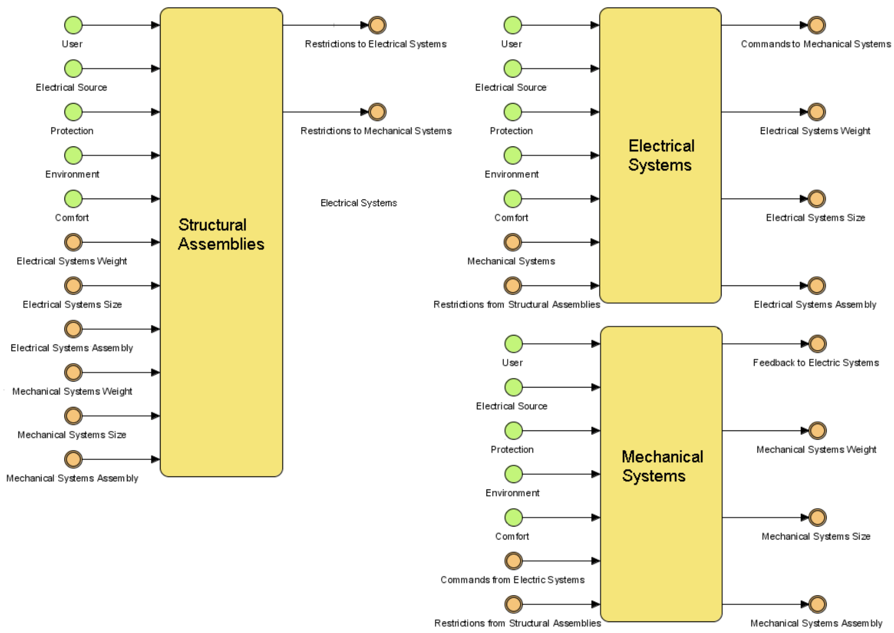

Figure 3 - Detailed Technologies View

To simplify this paper was chosen detail only blocks to electrical systems. As below, **Figure 4** depicts in more details electrical systems that were broken in electrical sources, electrical commands and torque system. At this step is possible insert in each subsystem their respective inputs and outputs parameters. An example is that all subsystems have a kind of protection, but comfort is a not necessary characteristic to battery, but necessary to other three subsystems.

In order to demonstrate reuse, it will be created new requirements to modify system and show how this method could be reused. These requirements are proposed, for instance, to create a higher level of product with more functionality and comfort. Consider next requirements:

- The Electric Wheel Chair shall have a control to recline back and feet to increase comfort of user.

- The Electric Wheel Chair shall have a protection to no wheel motion available when it is reclined. Rationale: this requirement is necessary to avoid collision and damage to user and equipment when user is reclined and his visibility has no long range.

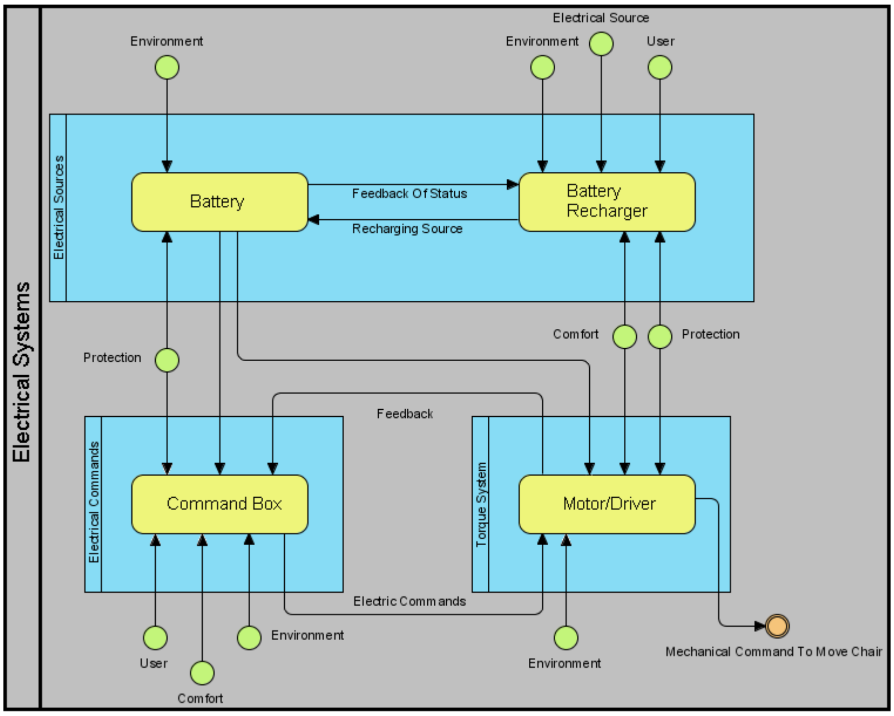

Figure 4 - Electrical Subsystems Relationships

The new implementation could be done inserting a new box with a motor to recline back and feet like **Figure 5**. Note that there signals that are going from existent boxes (command box and battery) to new one and vice-versa.

This example is stopping at this point, but following the present idea it could be detailed even no requirements written, for instance, command box could be break in two functions, move chair or recline. Example of modification could be adding physical system like motors that could be break in motors and clutch and so on.

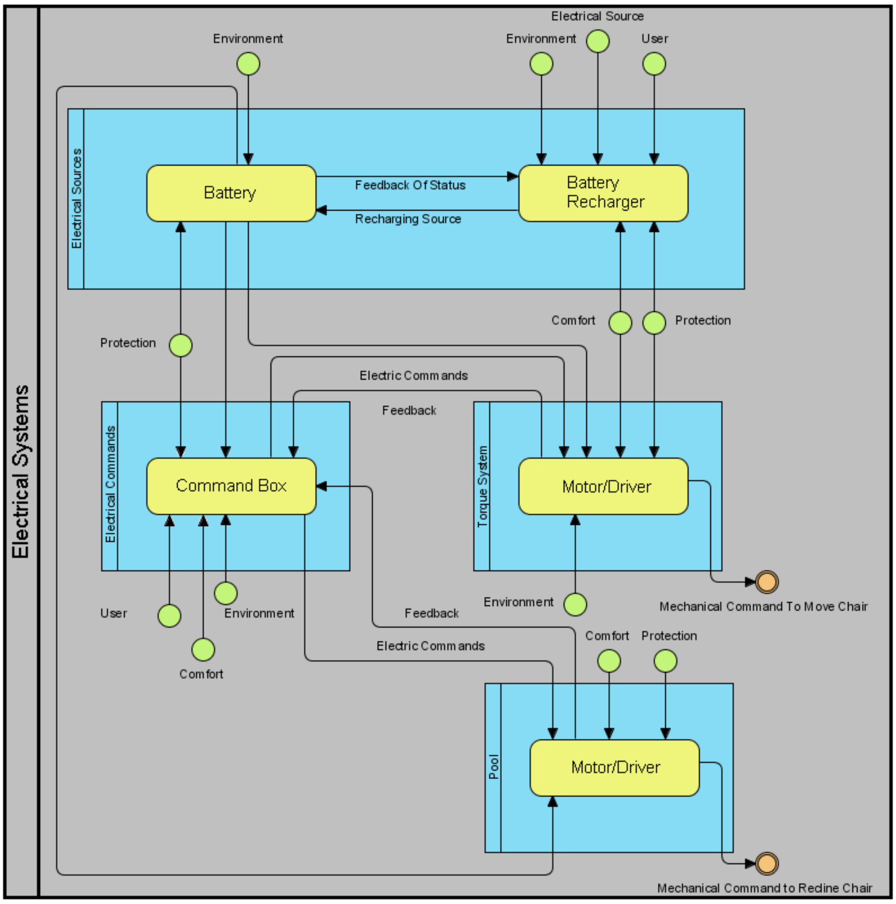

Figure 5 - Electrical Subsystems Relationships With Two Motors

Verification procedures changes due system modifications are common once system is under development and improvements are able to be implemented, but there is a time where requirements and improvements will be frozen. Even after requirements frozen, verification procedures shall suffer modifications, when necessary, to keep them updated. These method applied during development phase, previous system implementation, could assist on generating tests cases giving directions to create procedures more mature, due more detailed knowledge about systems and interfaces and avoiding a great number of tests cases reviews caused by system modifications.

5 Conclusion

While requirements in creation, it is possible increase details of functions subsystems, components, interfaces parameters, etc. When desired details are achieved, other activities could be initiated, the detailed verification procedures. The detailed verification procedures can be created from top to down or bottom to up in this system chain.

Using this method to perform verification, is possible keep control over traceability once that modifications can be easily met in block diagrams and interfaces parameters replaced as necessary. It is possible to analyze the impact over integrated systems in different levels and aid to accept changes. The integration is a good point to exercise in this method once it regards all interfaces with system and external factors.

Other point to highlight is the facility to reuse same block diagram to different improvements in systems only making modifications adding or removing blocks and interfaces.

New improvements in this method shall be implemented to become it more useful than now. Improvements should start by creating software to generate diagrams in order to facilitate to user, creating a user friendly interface to drag blocks and create links.

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Systems Architecting

Hardware and Software: How Can We Establish Concurrency between the Two?

Shuichi Fukuda

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Abstract. Today, most of our products are combinations of hardware and software. we must remember software works on hardware. But the function of hardware is fixed, while that of software is evolving throughout its life cycle.

Hardware is an individual living. Once they are created, they start to degrade. Therefore, maintenance is a very important task with respect to hardware. But hardware functions are fixed so that it is relatively easy because the objective of maintenance is to restore the degraded quality to its original designed level.

Software, however, is a species. Each software, once born, grows in a different way to adapt to the situation. And many new portions are added on. Therefore, decommissioning becomes very difficult for software.

Since most of our products are combinations of hardware and software, we should pay attention to how we should work them together effectively and how we can decommission the system which is composed of both hardware and software.

This paper discusses this issue and suggests the possible solution.

Keywords. Hardware, Fixed function, Individual living, Software, Evolving function, Species, Coordination

1 Introduction

Today, most of our products are combinations of hardware and software. we must remember software works on hardware. But the function of hardware is fixed, while that of software is evolving throughout its life cycle.

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Hardware is an individual living. Once they are created, they start to degrade. Therefore, maintenance is a very important task with respect to hardware. But hardware functions are fixed so that it is relatively easy because the objective of maintenance is to restore the degraded quality to its original designed level.

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Since most of our products are combinations of hardware and software, we should pay attention to how we should work them together effectively and how we can decommission the system which is composed of both hardware and software.

This paper discusses this issue and suggests a possible solution.

2 Hardware: What characterizes it

Hardware is produced with fixed funtions as shown in Figure 1. But once delivered, it will start degrading. The majority of our efforts is to restore its degrading functions to their original level. Thus, maintenance is very important task in hardware.

But hardware is an individual living. The life prediction of hardware is very much like predicting life for each of us. Although it is very difficult to predict its life due to wide variability, it is fundamentally in the same framework as the prediction of our life. In fact, it is well known that hardware failure rates and our death rates exhibit the same bath tub curve.

3 Software: What characterizes it.

Sotware used to be produced in the same way as hardware. In fact, there were companies in Japan who called their software division “Software Factory.”. There were no distinctions between hardware and software at that time.

Software engineers did their best to comply with the design requirements and to deliver software products which satisfy them. But it became soon clear that it is impossible to completely debug and with the increasing diversification, these efforts do not really answer to the needs of customers. Customers would like to have software with more adapatablity and flexibilty than one with fixed functions without any bugs.

Around 1980, knowledge engineering was proposed and what knowledge engineering brought to software sector was quite revolutionary. The most important impact it brought to us is the concept of continual prototyping.

Since then, software development was changed completely. Software engineers started to provide us with a baby software (Beta version) and this baby grows with us. Software was no more “fixed function” product.

But as we come closer to the end of 20^{th} century, around 1990, diversification grew more and more and situations come to change more frequently and widely.

To respond to these changes, software changed once again. It development philosophy was to grow a product. But now it changed from an individual living to a specimen. Many new pieces are coming to be added on so that software products come to "evolve" as species. The discussion based on an indivual living or entity does not hold any more. We have to look at software as "evolving system" or "evolving species".(Figure 2).

Since software is a species, we cannot easily predict its life. It evolves forever.

4 Contradictions between Hardware and Software

As discussed above, there are two major contradictions between hardware and software development. Hardware is produced with fixed functions and it is an individual living, while software evolves with time and it is a species.

Although most of our products are combinations of hardware and software, there are very few discussion on how we can reconcile them and work them together effectively.

This becomes a very important problem when we have to decommission a system which is composed of hardware and software. It must be noted that sometimes the degradation of hardware is "remedied" by software. Therefore, life prediction of a system composed of hardware and software combined becomes increasingly difficult.

Further, we should note that in practical applications, software does not evolve forever. In most cases, hardware on which software runs are replaced with new one and this decommissioning of hardware really defines the life of a combined system.

But currently hardware engineers and software engineers do not work together so well. Rather, they work independently from each other. They need more collaboration to really produce a better combined system. This is the point I should like to emphasize in this paper.

5 What Solutions May be Possible?

Then, what solutions may be possible? We have to remember that hardware is also changing. IC tip technology brought us a big change. Hardware comes to evolve as a system. Too.

Therefore, we have to consider a hardware- and software-combined system as system of systems.

But what is a great advantage of hardware is that it is "a thing in the physical world". With too rapid progress of software, we tend to forget that we are living in a physical world. We sometimes misunderstand that we are completely living in a non-physical world. But where a human lives is a physical world.

Thus the problem of coordinating hardware and software is nothing other than the one how we can coordinate our physical world and our non-physical world.

Our physical world is bounded in many ways. Its space is limited and its resources limited as is well known that our world resources are running out., etc. But our non-physical world is boundless. It can expand to infinity. Thus, the issue is how we can compromise the finite and bounded world and the infinite and unbounded one.

But we are living in a physical world and our life is finite. For example, an organization or a company pursues to proper forever. Survival is their ultimate objective. But the people who work there changes after about 30 years. Generations change.

Then, would it be really worthwhile to develop software that works forever? If the generations change, their ways of thinking or their ways of solving the problem would change. Therefore, it would be far wiser to develop software that works best for this period of time at the maximum. Of course, the situation changes are more frequent so that we have to add on more new pieces to increase adaptability. If the people in an organization changes widely, then it would be time for decommissioning the system. Software is the collection of the brains of these people but if these people are no more with the organization, there will be no more people who can make adequate judgement about the system outcomes.

In fact, people can not understand software with too many add-ons. If they cannot understand it, it is the time for decommissioning.

But what happens if hardware degrades much faster than software. In fact, in most cases, software is thrown away because hardware is replaced. Thus, the problem will be how we can decommission them at the same time. This could be possible if we change our hardware development from the fixed function products to evolving function ones. In short, we will develop hardware as a system. There have been hardware systems. But these systems are composed so to speak in a parallel way. There was no communication between the parts. But we have to change its design so that each part communicates with others to evolve. Some parts could be decommissioned earlier if other parts could take over their functions. Thus, new hardware system works on a complementary basis. Each part or component communicate with other ones so that they can maintain functions as a whole system. The function may not evolve, but it certainly adds adaptability and flexibility to the system. The hardware system survives in changing situations and maintains its original desired functions. Thus, we should change our hardware design to be more system-oriented and adaptive. Hardware elements will serve for the designed purpose as a system to interact with a physical world.

We have to remember again that we are living in a physical world. So if such a hardware system does not work anymore, it is the time to replace the whole software- and hardware-combined system. We can add any adaptability and flexibility as software, but it is within a non-physical world. If we come back to our basics that we are living in a physical world, the system that would not fit anymore with the physical world would lose its meaning. And efforts to evolve software would not be worthwhile.

6 Hardware, Software and Humanware: Integrating Them into One

Hardware and software are contradictory. Hardware is produced with fixed functions and degrades with time. And it is something like an individual living. Software evolves with time and it is something like a species. So how we can work together effectively will pose a big issue because more and more products are produced by combing them.

The problem of decommissioning a hardware- and software-combined system would be the following. If we come back to the basics that we are living in a physical world, then it would be an adequate decision to decommission a system, when a physical part or hardware part of a system would not adapt to the situation anymore. This does not mean the present framework of hardware systems. In the new framework, hardware elements or components will communicate to complement with each other in order to maintain adaptability and flexibility. Software and IC tip technology will help a great deal for this purpose.

It should be noted that in this new framework, software is not just software and works alone. Its very important new role is to help hardware elements communicate with each other to maintain the desired functions as a whole. So in the new framework, the whole system works as shown in Figure 3 by integrating software, hardware and humanware into one. Each subset, i.e., software, hardware and humanware, works for the whole system (intersection) and when the whole system would not adapt to the surrounding environments, we will announce it is the end of life of the whole system.

7 Reference

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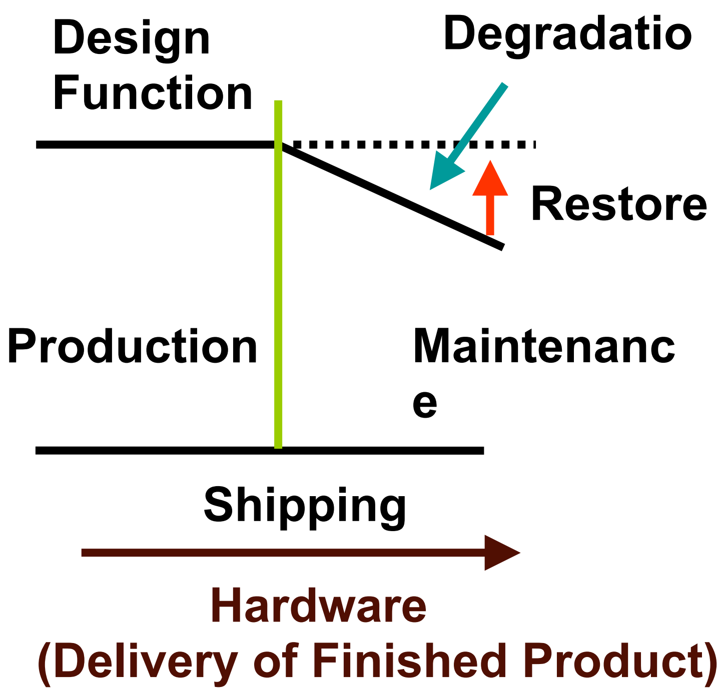

Figure 1 Hardware development

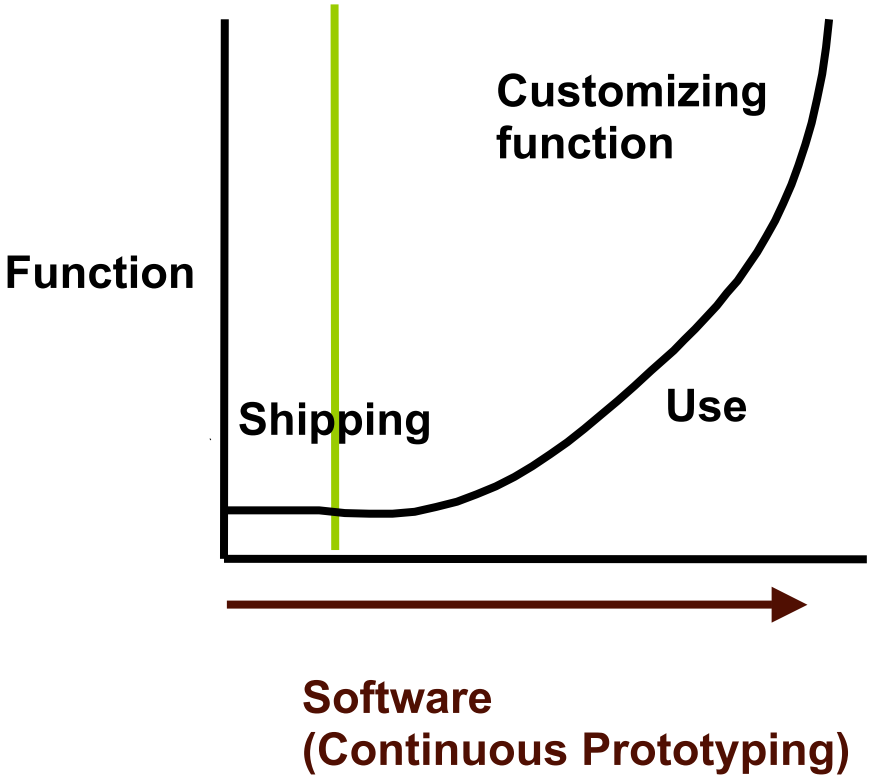

Figure2 Software development

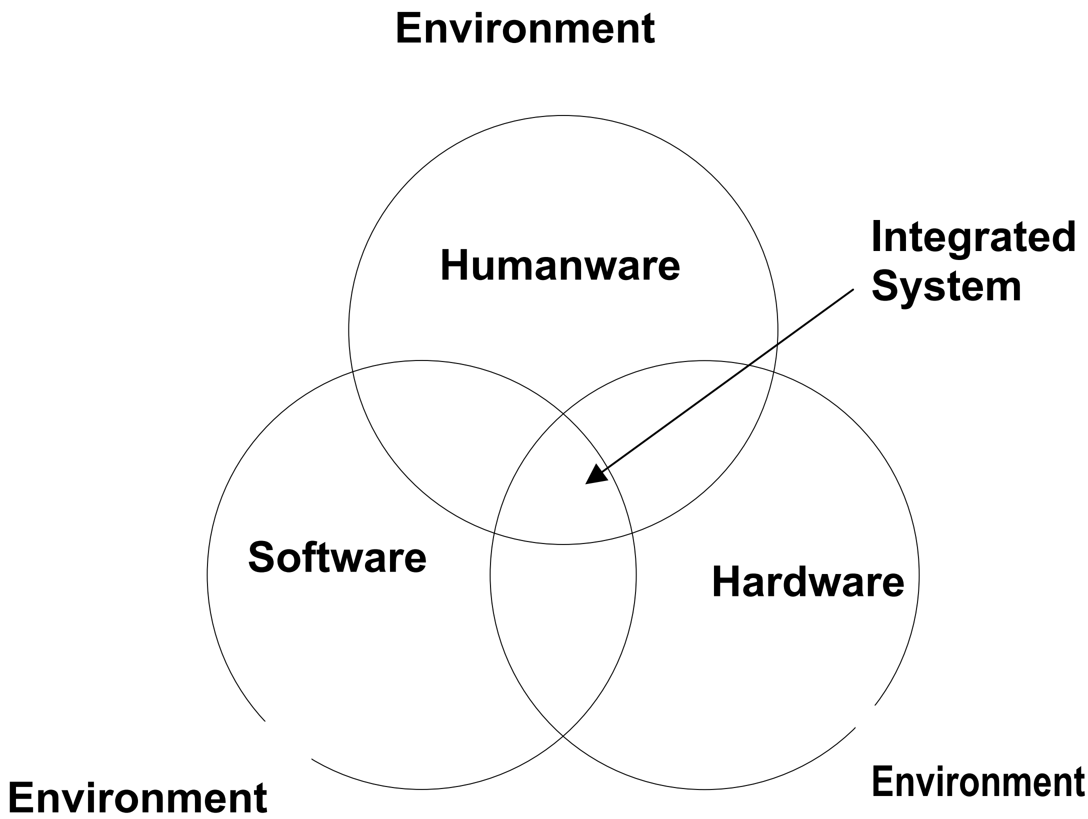

Figure 3 Hardware, software and humanware integrated into one system

A Simulated Annealing Algorithm based on Parallel Cluster for Engineering Layout Design

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Abstract. The layout design problem is a kind of nesting problems that is naturally NP-hard and very difficult to solve. Layout designing of machine is even more difficult because of its nesting items are actually machine parts that have both irregular shapes and complex constraints. A feasible way to solve machine layout problem is to employ ameliorative algorithms, such as simulated annealing algorithm. But these kinds of algorithms are usually CPU-time thirsty, sometime the computing time is unbearable. In this paper, the authors advocate to parallel the simulated annealing algorithm on a multi-computer network (a parallel cluster). We have combined Message Passing Interface (MPI) with Visual C++ to integrate Simulated Annealing Algorithm based on Parallel Cluster and Engineering Layout Design Support System. An engineering example about vehicle dynamical cabin layout design is presented to test validity of the Algorithm. If appropriate temperature piece is chosen and seemly a number of nodes are used, the integration of Simulated Annealing Algorithm based on Parallel Cluster and Engineering Layout Design Support System definitely will improve the efficiency for engineer.

Keywords. Collaboration engineering, Simulated annealing algorithm, Layout, Parallel computing.

1 Instructions

It is difficult to solve the problems of Complex product layout. In order to solve them, there are many conventional algorithms, such as accurate algorithm[1], simulated annealing[2], genetic algorithm[3, 4] and extended pattern search algorithm [5], hybrid algorithm, expert system[6], virtual reality[7] etc. are used for solving this kind of problems. As a kind of heuristic algorithm, simulated annealing algorithm is usually used in engineering layout design. However, because of dozens of existing shortcomings, such as inefficiency, simulated annealing algorithm will spend too much time in solving a layout design question to complex mechanical products. Moreover, a lot of professional knowledge and

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expertise are required in practical layout design. So the availability of simulated annealing algorithm is limited in the field of practical engineering.

A Simulated Annealing Algorithm based on parallel cluster is presented to solve the problem of inefficiency, and combines Message Passing Interface (MPI) with Visual C++ to integrate Simulated Annealing Algorithm based on Parallel Cluster and Engineering Intelligent Layout Design Support System to solve the problem of high requirement of professional knowledge and expertise.

2 Simulated Annealing Algorithm based on Parallel Cluster

Because of randomicity of simulated annealing algorithm, the temperature of simulated annealing algorithm can be divided into small pieces, and each piece can be computed on different node. We will collect results on current stage from every computer, so that we can get the best conclusion after comparing them. Then, the condition of nodes will be adjusted in order to continue with a better point.

The number of nodes is p, the number of temperature pieces is q, the goal function is $f(X)$, the design variables is $X=(x_1,x_2,\cdots,x_n)$, the simulated annealing function is $S(T_b,T_e,X_b)=X_e$, T_b is initial temperature, T_e is final temperature, X_b is initial value of design variables.

The generic steps of Simulated Annealing Algorithm based on Parallel Cluster are like this:

(1) Divide the temperature into small pieces, and get the initial temperature (equation 1) and final temperature (equation 2) of each computing step.

$$T_{bh}(h)=T_0-\left(\frac{T_0-T_1}{q}\right)(h-1) \tag{1}$$

$$T_{eh}(h)=T_b(h)-\left(\frac{T_0-T_1}{q}\right) \tag{2}$$

In this equation, h is the index of current temperature piece ($h=1,2,\cdots,q$). T_{bh} is initial temperature of stage h, T_{eh} is final temperature of stage h, T_0 is initial temperature of all computing process, T_1 is final temperature of all computing process

(2) Do Simulated Annealing Algorithm with the current temperature and value of design variables on every node.

For example, on node m (m is the index of nodes, $m=1,2,\cdots,p$), the process of Simulated Annealing Algorithm computing is $S(T_{bh},T_{eh},X_{bh})=X_{ehm}$, T_{bh} is current initial temperature, T_{eh} is current final temperature, X_{bh} is the current initial value of design variables, X_{ehm} is the current final value of design variables, after Simulated Annealing computing on stage h, and on node m.

(3) Collect results from every node on current stage after Simulated Annealing computing so that we can find the optimum point with comparing the results. The rule of compare is min($f(X_{eh1}), f(X_{eh2}),\cdots, f(X_{ehp})$). The optimum node is k ($k=1,2,\cdots,p$). After that, the best values of design variables are sent to all of

nodes, so that we can keep the situation synchronal on different node. The equation $X_{b(h+1)} = X_{ehk}$ will be set to prepare for next computing.

3 Integration of Simulated Annealing Algorithm based on Parallel Cluster and Engineering Intelligent Layout Design Support System

The modeling and computing complexity of complex product packing is obvious. Its layout solution made by an algorithm is usually not better than the one made by people with rich professional experience. The reason is that the diversity of professional experience and expertise make it more complicated to solve by a single optimal algorithm. So it is important to integrate Simulated Annealing Algorithm based on Parallel Cluster and Engineering Intelligent Layout Design Support System.

3.1 Framework of integrative system

Figure 1 shows the framework of Engineering Intelligent Layout Design Support System.

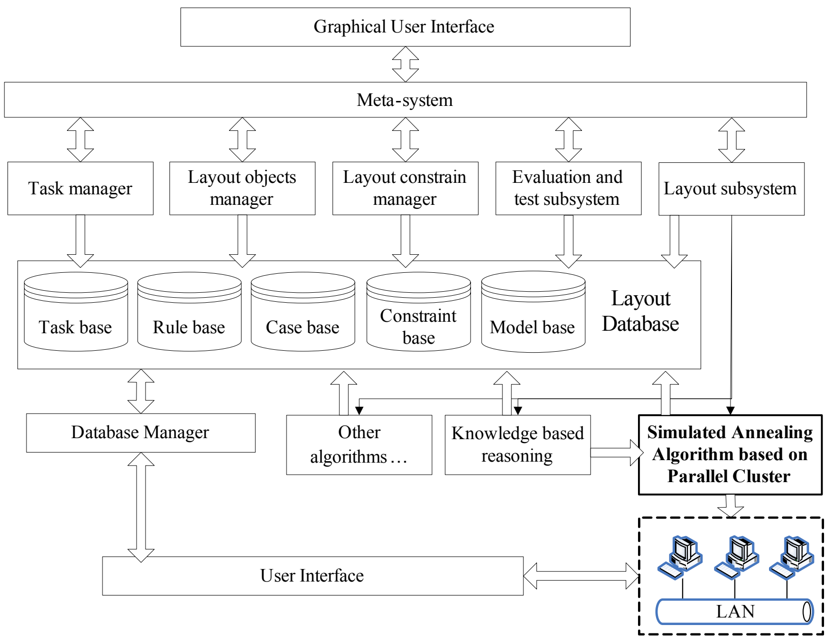

Figure 1. Framework for Engineering Intelligent Layout Design Support System

A whole process of engineering layout design follows this step:

(1) Define a layout task.
(2) Choose layout objects.
(3) Define layout constrains.
(4) Give the primary layout result.
(5) Optimize the layout result.
(6) Evaluate the layout result.

Each step has a subsystem to support, and all of the design resources are kept in the database. Meta-system manages other subsystems, database, knowledge base and graphics base. The Simulated Annealing Algorithm based on Parallel Cluster is a part of the layout algorithm subsystem. It will work with other modules.

3.2 Simulated Annealing Algorithm Subsystem

Figure 2 shows the detail flow chart of Simulated Annealing Algorithm based on Parallel Cluster, and the algorithm works with other modules.

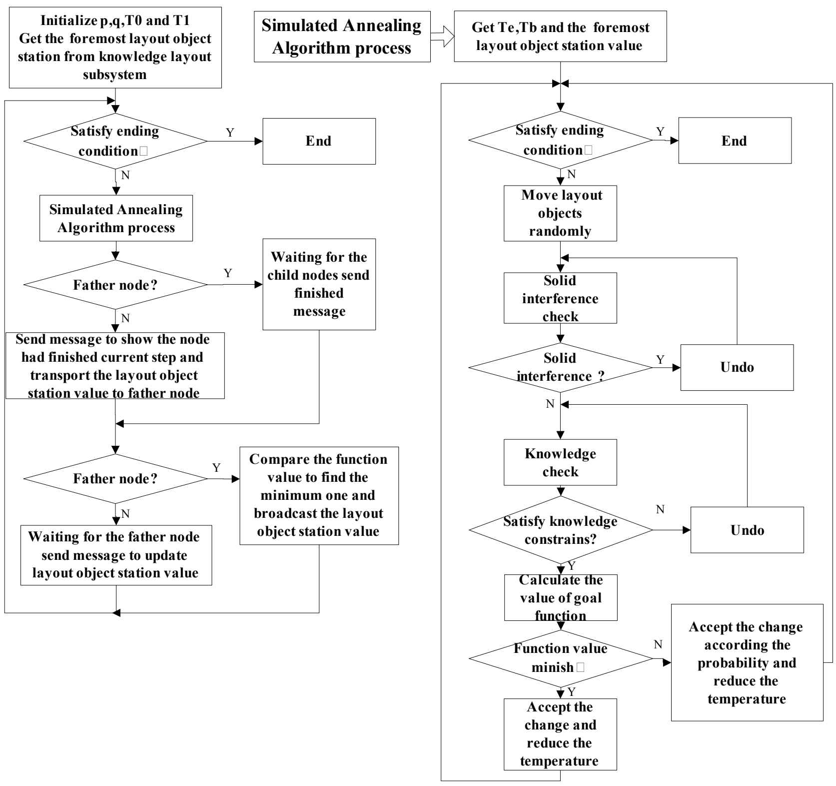

Figure 2. Flow chart of Simulated Annealing Algorithm based on Parallel Cluster

In the process of this solution, the Simulated Annealing Algorithm module cooperates with solid interference check module and layout knowledge check module. The efficiency of parallel computing almost depends on other subsystems.

In the process of computing, the transmission of messages during nodes depends on MPI (Message Passing Interface). MPI library support many methods to translate and broadcast messages. MPI is a kind of message transmission model, which is widely used in the field of parallel computing. MPI is so efficient and easy to be mastered that we use MPI and C++ to integrate the system and the parallel algorithm.

The messages which need to be translated contain design variables information and layout object model information. For high efficiency, simplified objects model is designed to replace the complicated one. Complicated objects are simplified as the combination of cuboids and cylinders, as shown in figure 3. Because of expansibility, XML format is used to express simplified objects model.

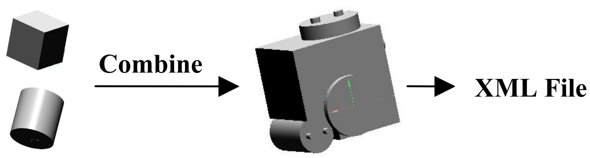

Figure 3 Simplified shape

4 Example

An engineering example about vehicle power cabin layout design is presented to test validity of Simulated Annealing Algorithm based on Parallel Cluster. The knowledge constrains have been defined. The number of layout objects is 15, the number of nodes is 4 ($p = 4$). Table 1 shows the result.

The goal function is minimum volume (m^3).

Hardware: CPU 2.5GHz, RAM 768MB, 100M Ethernet.

Software: OS Windows XP SP2, MPICH-2 1.0.3.

Paper title and headings should be formatted as explained in Table 2.

Table 1. Result of the test

Initial Temperature (T0)	**Final Temperature (T1)**	**Time (q=1)**	**Time (q=4)**	**Volume (q=1)**	**Volume (q=4)**
10	0.01	7’15"	7’21"	4.467346	4.056414
50	0.01	10’45"	11'01"	3.845643	3.164648
128	0.01	12’30"	13'25"	3.513285	2.856683
320	0.01	13’57"	15'15"	3.348564	1.054785
800	0.01	15’20"	17'08"	1.845643	0.697365

The results from table 1 show that because of the message translation time, Simulated Annealing Algorithm based on Parallel Cluster spends more time than single Simulated Annealing Algorithm does. But it can achieve much better target function value. The higher Initial Temperature can get much better result. Figure 4 shows the layout result ($T_0 = 800$, $q = 4$).

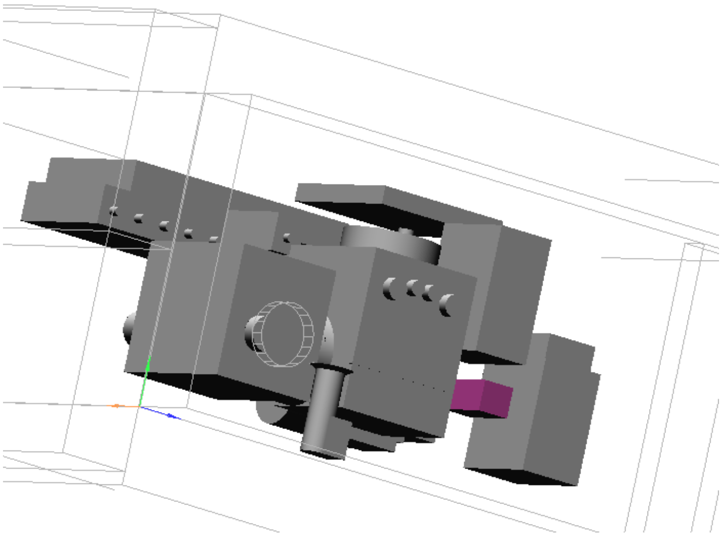

Figure 4 Layout result of the vehicle power cabin

5 Conclusions

The test shows that the Simulated Annealing Algorithm based on Parallel Cluster is useful and efficient. The result and the computing time not only depend on algorithm efficiency, but also relate to the style of layout object model, the condition of network and so on. For complex mechatronic products, it is hard to solve layout problems with a single conventional algorithm. There are a lot of layout knowledge and constrains to influence the process and result of a layout problem. So the algorithms have to cooperate with other intelligent systems and human-computer interactive systems sometimes. The integration of Simulated Annealing Algorithm based on Parallel Cluster and Engineering Intelligent Layout Design Support System is superior to others in this field.

Acknowledgement

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Space Mission Architecture Trade off Based on Stakeholder Value

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Abstract. One the most difficult aspects of system conceptualization process is to recognize, understand and manage the trade-offs in a way that maximizes the success of the product. This is particularly important for space projects. In this way, a major part of the system engineer's role is to provide information that the system manager can use to make the right decisions. This includes identification of alternative architectures and characterization of those elements in a way that helps managers to find out, among the alternatives, a design that provides a better combination of the various technical areas involved in the design. Space mission architecture consists of a broad system concept which is the most fundamental statement of how the mission will be carried out and satisfy the stakeholders. The architecture development process starts with the stakeholder analysis which enables the identification of the decision drivers, then, the requirements are analysed for elaborationg the system concept. Effectiveness parameters such as performance, cost, risk and schedule are the outcomes of the stakeholder analysis which are labelled as decision drivers to be used in a trade off process to improve the managerial mission decisions. Thus, the proposal presented herein provides a means for innovating the mission design process by identifying drivers through stakeholder analysis and use them in a trade off process to obtain the stakeholder satisfaction with effectiveness parameters .

Keywords. Space mission architecture, Trade off, Value, Stakeholders, Decision

1 Introduction

An effective system must provide a particular kind of balance among critical parameters. An ideal solution should meet high performance requirements on a cost effective way in all technological areas. This is a very difficult goal to attain because the success in one area could drive a failure in other.

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Essentially all space projects go through mission evaluation and analysis stages many times; however there are relatively few discussions in the literature that tackles trade off analysis for designing cost effective architectures. [3].

Thus, considering that about 80% of the life cycle cost, performance, risk and schedule of a project are committed by decisions made during design concept exploration; this paper addresses several questions such as: how to improve such decisions? How to evaluate system architecture through cost, performance, risk and schedule by taking into account stakeholder values? How to anticipate such evaluation to the beginning of design process? How establish the connection between stakeholder values with the architecture elements? These questions do reflect the state of art of the design process regarding to concept phase.

An innovative method is proposed in this paper that is intended for investigating the system trade-off space at an early design phase taking into account all these questions stated above.

2 Concept Exploration and Systems Engineering

Project planning for space products is usually structured into sequential phases. The start up of a new phase depends generally on a milestone to be met. Usually, a project is broken down into seven or six phases according to the NASA or ESA approaches, respectively.

The initial design activity performed by "Advanced Projects" teams consists of inventing, creating, concocting and/or devising a broad spectrum of ideas and alternatives for missions where new projects (programs) could be selected from [6]. Typically, this activity consists of loosely structured examinations of new ideas, usually without central control and mostly oriented towards small studies. Its major product is a stream of suggested projects based on needs capabilities, priorities and resources. The team's effort focuses also on analyzing the project space and establishing a mission architecture.

The realization of a system over its life cycle results from a sequence of decisions among several courses of action. If the alternative actions are well differentiated in the effectiveness space, then the system manager can make choices with confidence.

The objective of systems engineering is to derive, develop and verify a life cycle balanced solution that satisfy stakeholders requirements [evolved from 2]. Stakeholders requirements are expressed in terms of performance, cost, schedule, and risk requirements which represents system effectiveness.

Thus, design trade studies become an important part of the systems engineering process. When the starting point of a design trade study is inside one envelope, there are alternatives that reduce costs without decreasing any aspect of effectiveness or increase some aspects of effectiveness without decreasing others and without increasing costs. Then, the system manager's or system engineer's decision is easy. When the alternatives in a design trade study, however, require trading cost for effectiveness, or even one dimension of effectiveness for another at the same cost, the decisions become harder. In this context, risk and schedule behave like a kind of cost [6]. This is a dillema for system engineers.

3 Integrated Mission Architecture Trade off

Systems exist to generate value for their stakeholders. Unfortunately, this ideal is often met only to a limited degree. Usually, the system manager must choose among designs that differ in terms of numerous value attributes. Often, however, the attributes seem to be truly incommensurate; managers must make their decisions in spite of this multiplicity.

At the beginning, trade studies start with an assessment of how well each of the design alternatives meets the system effectiveness (performance, cost, schedule, and risk). The ability to perform these studies is enhanced by the development of system models that relate the decision drivers to those assessments. Figure 1 shows the integrated mission architecture trade off process in simple terms.

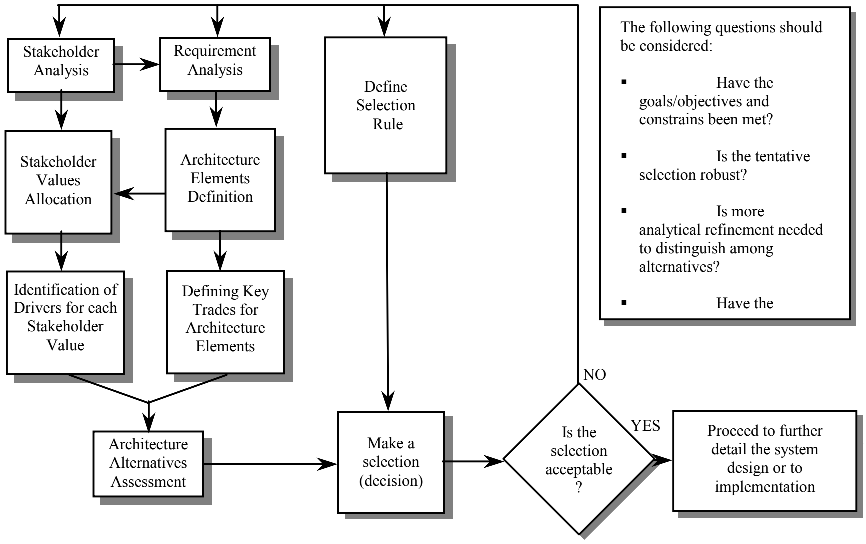


Figure 1. Integrated mission architecture trade off process

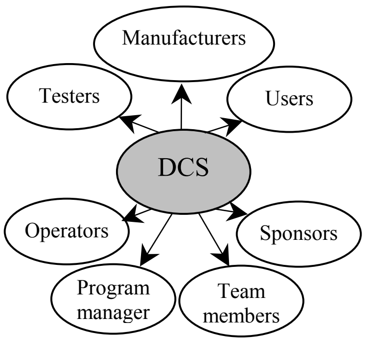
The process begins with the stakeholder analysis where it is defined all interests towards the system to be developed. The requirement analysis can be done in the same feedback loop as stakeholder analysis. Then, architecture elements can be defined and the stakeholder values (defined earlier) allocated to them. This step assures a relationship between stakeholder interests (values) and architecture elements. The definition of key trades for each architecture elements is a creative step where a set of cost effective solutions can be found. The critical point of this approach is to identify the decision driver for each architecture element and stakeholder value. Then, the method establishes a connection between physical solution and the associated aspects that can commit cost, performance, risk and schedule in a project. Comprising all these steps, the evaluation of architecture alternatives can be done, assessing element impact on architecture taking into account decision driver (performance, cost, risk and schedule) identified earlier. A set of alternatives is evaluated and the selection can be done.

A Data Collection System (DCS) mission is introduced herein, as illustrative example, taking into account cost and performance (excluding risk and schedule as effectiveness drivers).

4 Stakeholder and Requirement Analysis

The section outlines a simple stakeholder and requirement analysis approach. Time spent doing these analyses should match project type and complexity.

The first step is to identify project stakeholders. To be classified as a stakeholder, the person or group must have some interest or level of influence that can impact the project [7]. Stakeholder interests must be understood and so are the potential project impacts if a need is not met. Figure 2 depicts an example of this high-level analysis.



Stakeholder (score)	**Interests (value attributes)**	
	Performance	**Cost**
User	Availability (5%)	Maintenance (5%)
Sponsor	Sustainability (10%)	Elements (70%)
Program manager	Responsiveness (3%) …	Development Process (5%)
⋮	(10%)	(10%)
Operators	Operation easiness (10%)	Operation (5%)
Total	100%	100%

Figure 2. Stakeholder context diagram and interests for Data Collection System (DCS)

The second step of the method is to identify the stakeholders' interests and the relative importance for each one. To accomplish this stage, stakeholders should be listed on a table or spreadsheet with their key interests and relative importance in terms of cost, performance, risk and schedule. Special attention must be paid to outline multiple interests, particularly those that are overt and hidden in relation to project objectives. It is important to keep in mind that identifying interests is done with stakeholders' perspective in mind, not your own.

Requirements largely describe aspects of the problem to be solved and constraints on the solution [1]. Requirement analysis reflect sometimes conflicting interests of a given set of system’s stakeholders.

Many authors list sources of stakeholder requirements. Stevens et al. [8] provides a list of sources of users requirements and Pugh [5], a set of additional sources of stakeholder requirements.

Requirements analysis is conducted iteratively with functional analysis to optimize performance requirements for the identified functions, and to verify that the elaboratred solutions can satisfy stakeholder requirements.

The requirements refinement loop assures that technical requirements maps the stakeholder values, assumptions and goals.

5 Architecture Elements Definition, Key Trades Options, and Decision Drivers for each Stakeholder Value

The main objective of the integrated mission architecture trade off process is to integrate stakeholder analysis with architecture concept definition. This is carried out using decision drivers associated with architecture elements and stakeholder values, as shown in Table 1.

Table 1. Relationships among architecture elements options, stakeholder value attributes and cost, performance drivers associated with (DCS)

Architecture Elements and Key trades options		Stakeholder value attributes (interests)	Decision drivers
Mission	Space processing x ground processing	Maintenance price	Processing (cost)
		Operation price	Mission operators (cost)
		Availability	Time of transmit (performance) Message size (performance)
	Level of autonomy	Maintenance price	Infrastructure (cost)
		Operation price	Control operators (cost) N° of control stations (cost)
		Operation easiness	N of manoeuvres (performance)
Orbit / Constellation	Number of spacecrafts and orbit plans	Maintenance price	Infrastructure (cost)
		Operation price	Control operators (cost)
		Elements price (+1)	N° of spacecrafts (cost) N° of ground stations (cost) N° of control stations (cost)
		Availability	N° of spacecrafts (cost) Revisit time (performance) Interval of collect (performance) Interval of transmit (performance)
		Operation easiness	N° of spacecrafts (cost) N° of manoeuvres (performance)
		Sustainability	Funding constrains (performance)
Payload	BER / Mass	Element price	Payload mass (cost)
		Develop. process price	N° of employees (cost)
		Availability	Data rate (performance)
⋮		⋮	⋮

The architecture elements definition models a solution to the problem described in the requirements that comes from the stakeholder analysis (Figure 2). The terminology and concepts used to describe architectures differ from those used for the requirements [1]. Architecture deals with elements, which compose the system concept, capture and reflect the key desired properties (effectiveness) of the solution under elaboration. System (decision) drivers are the main mission parameters or characteristics which influence performance, cost, risk or schedule and which the user or designer can control [3].

In the context of requirements, architectural modelling has to satisfy the roles of supporting fast trade-off analyses about requirements' feasibility and stakeholder interests via architectural key elements options.

6 Mission Architecture Alternatives Assessment

Table 2 shows how to transfer the stakeholder analysis (interests and importance from Figure 1) results to the decision drivers (from Table 1). In this way, it is possible to translate the stakeholder preferences through the cost, risk, schedule and performance drivers inside the architecture trade off process.

Table 2. Transfering of stakeholder values importance to decision drivers for DCS

Stakeholder values Fig. 1 (cost)	**Decision drivers from Table 1 (cost)**
Maintenance (10%)	Processing (3%) Infrastructure (7%)
Elements (70%)	N° of spacecrafts (?) N° gr. stations (5%) N° contr. stations (5%) Payload mass (20%) Bus mass (30%) Launch (10%)
Dev. process (5%)	N° of employees (5%)
⋮	
Operation (5%)	Operators (5%)
Total 100%	**Total 100%**

Stakeholder values Fig 1 (performance)	**Decision drivers from Table 1 (performance)**
Sustainability (30%)	Funding constrains (30%)
Availability (40%)	Time of transmit (5%) Message size (5%) Revisit time (10%) Interval of collect (5%) Interval of transmit (5%) Data rate (10%)
⋮	
Oper. easiness (10%)	N° of maneuvers (10%)
Total 100%	**Total 100%**

The evaluation is done through the relationship matrix presented in Figure 3, which is built by using the information from Tables 1 and 2. The matrix relationships are shown at the lines and columns crossing.

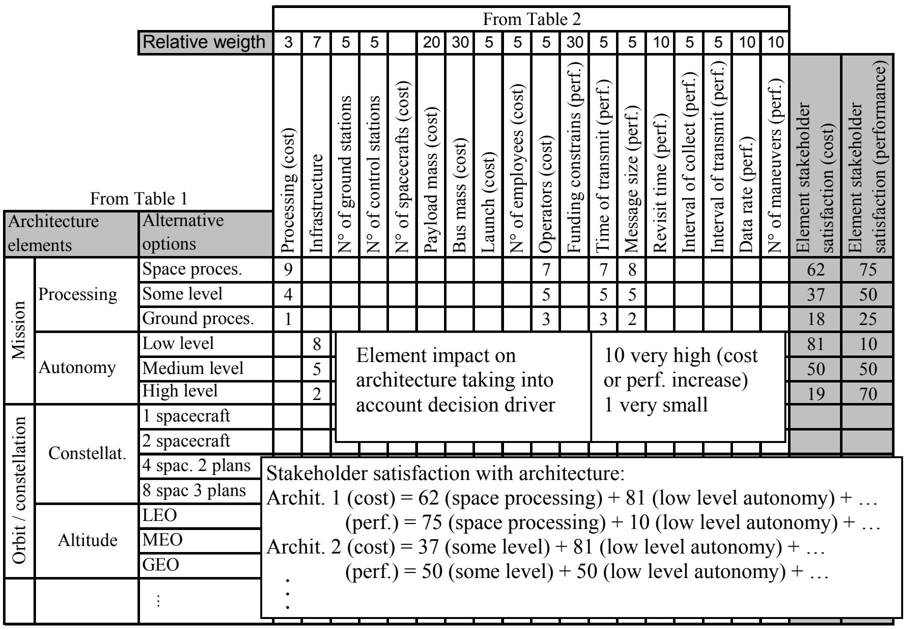


Figure 3. Mission architecture alternatives assessment for DCS

The last two columns are results obtained from the sum of products between relative weight and element impact on architecture taking into account the decision driver relationship established in Table 1. An evaluation of stakeholder satisfaction with architecture effectiveness is obtained trough sum of element results (one option for each architecture element).

The matrix presented in Figure 3 is just illustrative. More studies are necessary to modeling cost, performance, risk and schedule as decision drivers and improve the integrated mission architecture trade off.

7 Selection Rule Definition and Make a Selection

The selection rule criteria for systems differ significantly. In some cases, performance goals may be much more important than all others. Other projects may demand low costs, have an immutable schedule, or require minimization of some kinds of risks [6]. Then, the selection can be made taking into account the considerations as the explained above.

The expected result from the integrated space mission architecture trade off process is to obtain a graph as shown in Figure 4 (DCS case with performance and cost as effectiveness parameters): the bent line represents the envelope of the currently available technology in terms of stakeholder satisfaction with cost and performance. The points above the line cannot be achieved with the current available technology i.e. they represent designs that are not feasible. The points inside the envelope are feasible, but are dominated by designs whose combined cost and performance lie on the envelope. Designs represented by points on the envelope are called stakeholder satisfaction effective (efficient or non-dominated) solutions.

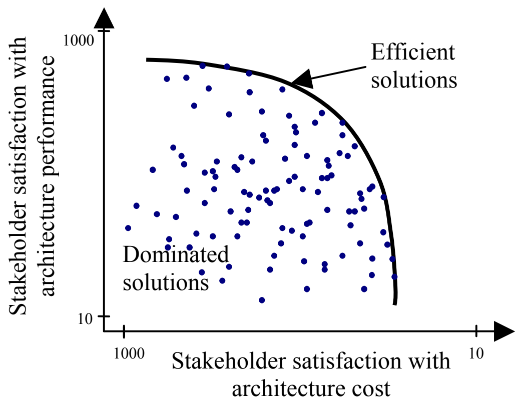


Figure 4. The Pareto frontier obtained from matrix results of Figure 2 (DCS)

Considering cost, performance, risk and schedule drivers, a four dimennsion evaluation is obtained and a efficient region is found by the proposed process.

8 Conclusions

Design methods present product development process in a systemized and organized way; however, the same do not occur with information and activities about the creation and evaluation of design alternatives. There are relatively few discussions about the trade off process in the literature [4].

Defining and using performance, cost, risk and schedule parameters as decision drivers and transfering to them the relative importance of stakeholder interests (values) in a trade off process may promote a new paradigm: a evaluation (through relationship matrix) of the architectutre effectiveness through the value that the stakeholder gives to performance, cost, risk and schedule. In this way, the stakeholder satisfaction with the system effectiveness becomes more important in the management decisions.

Thus proposal presented in this paper provides a means for innovating the mission design process by interconnecting stakeholder needs, requirement analysis, concept exploration and decision drivers in order to capture in trade off process the value given by stakeholders to the architecture performance, cost, risk and schedule. The paper proposes a subtle but closer to reality paradigm shift: trade the importance stakeholders give to performance, cost, risk and schedule attributes rather then those attributes themselves!

9 References

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Product Development Process: Using Real Options for Assessments and to support the Decision-Making at Decision Gates

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Abstract. Enterprises need continuous product development activities to remain competitive in the marketplace. Their product development process (PDP) must manage stakeholders' needs – technical, financial, legal, and environmental aspects, customer requirements, Corporate strategy, etc. -, being a multidisciplinary and strategic issue. An approach to use real option to support the decision-making process at PDP phases in taken. The real option valuation method is often presented as an alternative to the conventional net present value (NPV) approach. It is based on the same principals of financial options: the right to buy or sell financial values (mostly stocks) at a predetermined price, with no obligation to do so. In PDP, a multi-period approach that takes into account the flexibility of, for instance, being able to postpone prototyping and design decisions, waiting for more information about technologies, customer acceptance, funding, etc. In the present article, the state of the art of real options theory is prospected and a model to use the real options in PDP is proposed, so that financial aspects can be properly considered at each project phase of the product development. Conclusion is that such model can provide more robustness to the decisions processes within PDP.

Keywords. Real options theory, product development process, risk, investment decision making under uncertainty

1 Introduction and Problem Definition

Clark and Fujimoto [6] define the activity of product development as the process to transform information from the market into information required to the production of finished goods for commercial purposes. Decisions can no longer be based on trial and error, since the changes occur more quickly than the lessons can be learned [32,33].

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Enterprises need continuous product development activities to remain competitive in the marketplace. Their product development process (PDP) must manage stakeholders' needs – technical, financial, legal, and environmental aspects, customer requirements, Corporate strategy, etc. -, being a multidisciplinary and strategic issue.

In the nowadays-competitive environment, companies must optimize the resources usage to remain in the market game. Therefore, it is critical to study methodologies of product development, establishing connection between concepts of return and risk in decision-making processes with better practices and models to help management to maximize the expected value of the investments in product development. According to Baxter [3], out of ten ideas on new products, three will be developed, 1,3 will be launched in the market and only one will be lucrative. As the same author, the companies need to introduce new products continuously, to prevent competitors from getting part of their market share.

Norton and Kaplan [27] stated that prior to developing a project, one must establish cost-objectives and perform value-engineering analysis, so that a combination of quality, functionality, and price desired by the customers can be incorporated to evaluate the profit feasibility. The present article is intended to study PDP methodologies, mainly return and risk concepts, methodologies, best practices, and working models to maximize the expected return value of the investments in product development.

Several methods have been proposed to value such situation, including decision trees, but the appropriate risk-adjusted discount rate is still virtually indeterminate. The real option valuation method is often presented as an alternative to the conventional net present value (NPV) approach. It is based on the same principals of financial options: the right to buy or sell financial values (mostly stocks) at a predetermined price, with no obligation to do so. Options associated with non-financial investment opportunities are called "real options". In PDP, a multi-period approach that takes into account the flexibility of, for instance, being able to postpone prototyping and design decisions, waiting for more information about technologies, customer acceptance, funding, etc.

2 Background

The present article used the following theoretical references to develop a model for product development: project life cycle, product life cycle, and real options theory.

2.1 Project Life Cycle

Projects, defined as temporary efforts undertaken to create a product or service, have a certain degree of uncertainty. Therefore, organizations have better management control by dividing the project in phases, so that each phase is marked by the conclusion of activities, in a tangible and verifiable form. The set of the phases, which composes a logical sequence, is called project life cycle. Projects must have a well-defined beginning and an end. The end is reached when the objectives of the project will have been reached, or when it becomes clear that the project objectives will not be reached or when its needs no longer exist.

PDPs are usually broken into sequential stages (or phases), so that requirements can be checked against plans to evaluate the process alignment and trends towards the objectives. Checkpoints between phases involve "go/no go" decisions, leading the process towards later management decisions or terminating projects that do not offer good chances of revenue/profits to the company, nor opportunities for a better strategic positioning.

2.2 Product Life Cycle

Many authors studied the product life cycle [3, 18, 21, 31, 42]. Kotler [21] divides it in five periods: development, introduction, growth, maturity and decline. According to author, during the development of the product the company accumulates costs of investments. The period of introduction is characterized by the launch of the product in the market, followed by an increase in sales. After that, the product goes in a period of stability (maturity), and from this point on, sales and profits decline.

2.3 Real Options

In the corporate finance literature, the value of a risky project is calculated by the net present value (NPV) of its cash flows, discounted at a discount rate that reflects the project risk: such method is not able to capture the management flexibility along the decision-making process. The decision-making during the product development requires that the existing options can be evaluated based on expected values earnings and involved risks.

This concept can be calculated by the Capital Asset Pricing Model (CAPM) [10, 15, 34]. Such calculation establishes a discounting factor to be used in the analysis of an investment by its net present value (NPV): the discount tax is increased to compensate the existing risk, beyond the value of the money in the time (which would be the tax free of risk). However, in the PDP, the risk variation has no linear relation with the expected returns: at phases transition, the project evaluation will drive to a decision whether the project goes on (if favorable conditions occur), requires changes (due to consumer needs changes, competition, technological change or a composition of diverse factors), or even be cancelled.

Santos and Pamplona [39] stated that in markets characterized for competitive change, uncertainty and interactions, management has the flexibility to modify the operation strategy to capitalize favorable future chances or to minimize losses. The probability of success in a project usually increases with the reduction of the inherent risk along the time [30]. The deducted cashflow understates projects, therefore it ignores and it does not accommodate the main strategic questions in its analyses: management does not have to accept a NPV calculation, positive or negative, unless an explanation to it exists [24]. Therefore, the CAPM becomes inadequate: some models are used to measure the return and risk in the process of decision making, mainly the Black & Scholes formulae and the binomial model, used in the financial market. However, these methodologies assume a passive involvement of management too [9].

The real options fill this gap: based in contracts of options in the financial market, it becomes a powerful ally in the management process in risk conditions. As stated by Minardi [26] "management flexibility is a possibility, but not obligation to modify a project in different stages of its operational life". Figueiredo Neto, Manfrinato and Crepaldi [9] compiled the existing real options in projects:

- Option to wait: postpone an investment, benefiting by value favorable movements in the project (as increase on product prices), and preventing losses if unfavorable scenarios occur;
- Option to abandon (sell): abandonment of a project when future losses are foreseen and/or selling the project (for example, to another company);
- Option to expand: expand the operation scale of a project previously defined, if foreseen conditions are more favorable than initially analyzed;
- Option to contract: opposite of the expansion option;
- Option to move: changes in conditions (for example, to restart operations), or changes of a product or technology; and
- Composed option: combination of any of the previous ones (called rainbow options).

Diverse applications of real options have been developed: Pinto and Montezano [29] used them to evaluate the project of digital cartographic bases (used for geo-marketing, urban zoning, environmental licensing, etc.); Saito, Schiozer and Castro [36] included management flexibility in the evaluation of reservoirs, while Gustafsson [12] and Gustafsson and Salo [13] focused the studies of real options in management of project portfolio. Santos [40] used real options to measure the potential value of organizational restructure in merges and acquisitions; Brobouski [4] used the real options to analyze forest projects and Martinez [25] analyzed leasing contracts. Many authors studied the use of real options to evaluate R&D prior to production investments [1, 2, 5, 8, 11, 14, 16, 19, 20, 23, 28, 35, 38, 39, 41, 43], while Keizer and Vos [17] describe a method to identify, measure and manage the risks in product development, however the decision-making process has not been analyzed by the authors.

3 Proposed model for decision-making in PDP

Taking a hypothetical PDP, with activities related to the project life cycle and product life cycle within it, resources, parts involved, dates, etc., are to be established in this plan. At same time, a calendarized budget, based on resources usage, dates, etc., can be elaborated (investments during the project phase and operational costs along the product life cycle). In addition, from the cashflow that comes from the budget and revenue expectations, the NPV can be calculated (without management flexibility).

Based on the budget and phases information, it would be possible to create a decision-tree, with all key decision-points along the whole PDP, as represented at Figure 1.

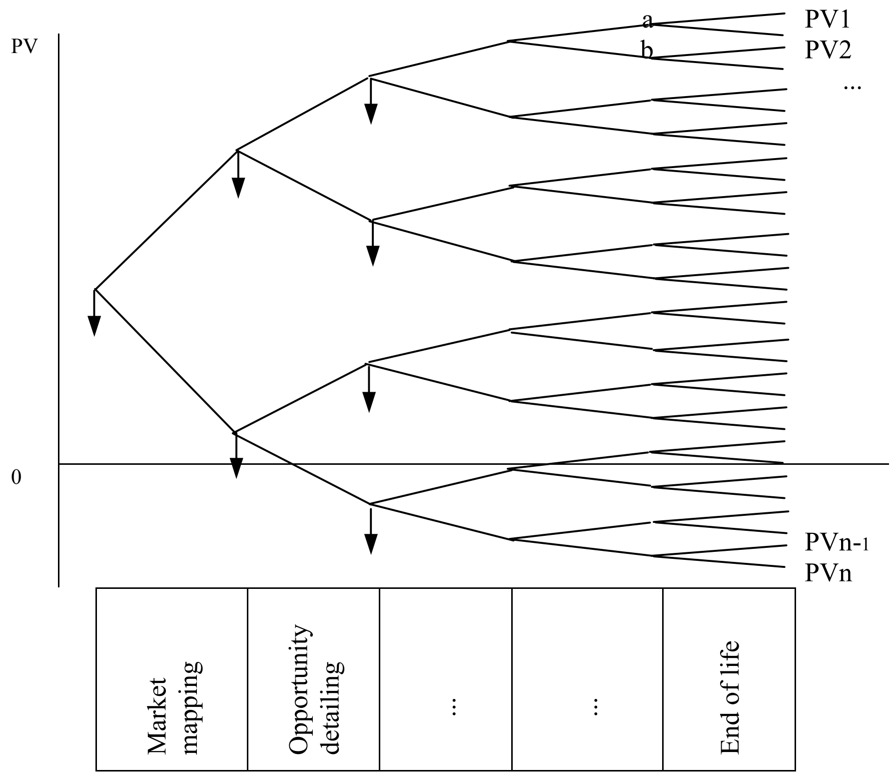

Figure 1. NPV event tree

Then, it is necessary to incorporated it management flexibility - management decisions based in new information that appear - in the tree of events, transforming it into tree of decisions [7]. By doing that, which means, getting rid of alternatives were NPV would be reduced, due to negative values, the adjusted project NPV (adding flexibility benefits) would be calculated.

This calculation - "from right to the left" – along the whole tree, would characterize the consideration the flexibility and management action, supporting the decision-making process since the early phases of the PDP, or at any other phase. The decision on future investments is function of the expected profit when management action is taken and the cost to continue the project [37].

4 Final Considerations

The use of the real options to revision the performance criteria in each of the project phases seems to be an obvious and natural choice. Krishnan and

Bhattacharya [22] approached to such proposal, suggesting a model to evaluate the optimal point to freeze technology through stochastic formulas. Santiago and Bifano [37] described the use of the real options in the development of a laser oftalmoscope, showing as the project can be managed by the estimate of its value and determining the management actions to be taken at each phase revision. However, the authors had only used of the options to continue, improve the technology or to abandon the project in the last phases of the project, while the proposal of the present article is to use real options to evaluate all phases and explore all potential type of options listed by Figueiredo Neto, Manfrinato and Crepaldi [9].

Identified the existing gap, the recommendation to the organizations that develop products is to use real options at each phase of the PDP. To be able to do so, the existence of a structured PDP for the organization becomes a need: such PDP must contain stages (phases) predefined that not only contemplate the phases of the project life cycle, but also the product life cycle.

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A Valuation Technology for Product Development Options Using an Executable Meta-modeling Language

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Abstract. Mistakes or foresight in the earlier phases of product development tend to be amplified over the course of a project. Therefore, having a rigorous approach and supporting tools to identify and filter a development portfolio at the early stages can be highly rewarding. This paper presents an executable specification language, Object-Process Network (OPN), that can be used by system designers to formally represent the development option space, and automate certain model refinement activities at earlier phases of product development. Specifically, an OPN specification model can automatically enumerate a set of alternative development portfolios. OPN also provides an algebraic mechanism to handle the knowledge incompleteness problems at varying phases of planning, so that uncertain properties of different portfolios can be represented and analyzed under algebraic principles.
In addition, it has a recursively defined model transformation operator that can iteratively refine the specification models to simplify or enhance the details of the machine-generated alternatives. A list of successful application cases is presented.

Keywords. OPN, meta-language, Real Options, Algebra of Systems, Model-Driven Software Development

1 Introduction and Motivation

During the earlier stages of product development, limited engineering resources and knowledge incompleteness inevitably introduce a high degree of uncertainty. However, inflexible design decisions made in the earlier phases tend to seal off the future opportunities of the product development project.
Therefore, it is beneficial to employ a design analysis method that can include not one, but a set of possible product development options [1, 4, 5]. Real options is often employed to analyze a set of alternative developmental options. Our paper describes a model-driven analysis method and a supporting tool that extends existing real option analysis methods.

Real options analysis is related, but different from, financial option analysis. When a financial option is purchased, certain rights in the future are contractually protected [7]. Conversely, product development options in the real world usually provide little if any guarantee. For example, the investment in certain technologies may or may not create additional opportunities in the future. Therefore, when modeling real options, the modeling method must deal with this additional level of uncertainty. Furthermore, when comparing between product development alternatives, it is often necessary to preserve the structural and behavioral compositions of the alternative scenarios. Many quantitative option analysis methods assume that the possible behavioral and structural evolutions of the option portfolios of interest can be abstracted into a few statistical measures. To preserve and analyze the structural and behavioral information content in product development options, we utilize modeling principles inspired by Hoare and Cousot [2, 6] to develop a modeldriven method for product development option analysis which can preserve the quantitative, quantitative, and fuzzy aspects of "real" options.

2 A Model-Driven Analysis Method

Model-driven methods are software development techniques that compose the resulting model of a software product recursively using other software models as building blocks. It often employs a special-purpose model manipulation language [3] that manipulates and generates different versions of models.

We adopt a model-driven method to analyze engineering product development options because model-driven methods are effective techniques for combination and comparisons of different options. Competing project plans can also introduce uncertainty because they require comparative analysis before a decision can be made. Therefore, when comparing or composing two or more development options, analysts must first encode options and the respective compositional structures as standard model data types in a modeling manipulation language. Then, analysts may apply model manipulation operations to analyzed the represented options, such as equality or substitution.

Using an executable model-driven language, these analytical operations can be automated to mechanically reason about the logical consistency or other quantitative and qualitative (defined over an un-ordered domain) properties of different options.

2.1 The Modeling Vocabulary

We hereby define three model data types and one operator for the modeldriven method. These data types are: V_{opt}, F, and S. They stand for product development option, payoff function, and product development portfolio respectively. The operator is called D for product development decision. They are defined as follows:

Definition 1 (Product Development Option: V_{opt}**).** *V_{opt} is a data type, in which $v \in V_{opt}$ is a product development option. An option v represents a set of defined possibilities, whose actual values are to be determined under certain or uncertain real world constraints.*

When v defines a finite number of possibilities [7], it can be treated as a discrete variable. When v contains an infinite number of possible values, the option can be modeled as a symbolic variable, whose actual value can be assigned at the point of observation. For example, an aircraft frame material option can be chosen from a finite set, such as {aluminum,wood, steel}. The interest rate of a certain loan can be represented as a continuous variable, symbolized by a variable name v_r, where $v_r > 0$.

Definition 2 (Payoff Function : *F*). *F* is a data type, in which $f \in F$ is an instance of a payoff function. It relates two or more development options. Each *f* determines the payoff values or constrains the allowable value combinations of directly related options, v's.

When all related development options are statically related, the payoff function *f* can be modeled as a conditional probability function, which represents all possible value combinations and associated distribution of these options.
Once any one of these options' values are determined, the payoff function can be used to compute the value distributions for other related options.When two or more options are related temporally, a payoff function can be constructed to take the value of a temporally-causal option and compute the value(s) of the temporally-dependent option(s). For example, $v_{output} = f(v_{input1}, v_{input2}, \ldots)$.
Payoff functions can also be analyzed using algebraic rules to substitute, simplify, or compose into different functions or values.

Definition 3 (Product Development Portfolio : S). *S is a data type, in which $s \in S$ is a portfolio. A portfolio is a collection of v's and f's. It may also be written as a tuple, $s = |\{v_1, \ldots, v_j\}, \{f_1, \ldots, f_k\}|$, where j and k are the number of options and payoff functions respectively.*

A portfolio s is a composition of many product development options. The structure of a portfolio is captured via an associated set of payoff functions that relate these options. Under this definition, a portfolio s can be modeled as a graph containing two domains of elements. One set of elements represent options and the others represent payoff functions. The structures (relationships) between the options and payoff functions can be shown as a bi-partite graph.
A bi-partite graph is a highly expressive formalism. It can be used as the basic syntax for many kinds of computationally complete modeling languages [8].
Based on the computational properties of different s's, we may treat them executable specifications that capture the behavioral and structural properties of different compositions of product development options. One must note that our set-based definition of development option allows the possibility of *recursion*. For

example, when there exists multiple competing product development portfolios, these portfolios make up a set that represents an option instance.

Definition 4 (Product Development Decision : D). *A product development decision* D *is an operator on the* S *domain, or:* $D(s) \in S$.
The operator D is a *model refinement function* over S. It takes one or more instances of *s* as inputs, and produces one or more instances of *s* by assigning option values or specializing the payoff functions in the output s. For example, by choosing to build an aircraft frame using aluminum material, the decision operator D may replace the material option with three choices ({*aluminum,wood, steel*}), into an option with only one choice ({*wood*}).
One should note that D is a meta-operator, whose effects on the domain S is driven by the inputs' information content, also specified using elements in S. For example, the encode, enumerate, and evaluate operations on S (explained further in Section 3.1) can be thought of as specialized versions of D.

2.2 Identify portfolios using fixed-point search

As defined earlier, a design decision D is closed over the domain of portfolios. It modifies the information content of a portfolio by adding or removing a collection of real options or payoff functions. The design process as a whole can be thought of as an iterative procedure that applies design decisions to successive revisions of an initial portfolio. Therefore, the evolutionary history of a product development portfolio, *s*, can be formulated as a fixed point formula:

$$s_{n+1} = D_{n(sn)}$$

Where s_0 is an initial portfolio that is made up of many related development options and associated payoff functions. The term n indicates the sequential index number of decisions made to change the portfolio. The functional operator D_n is the *n*th version of the design decision operator. The design decision operator D may have many versions because at each point a design decision is made, it is mostly likely to have a different effect on its operand since its behavior is partially defined by s_n. One can view this dynamic definition of D as a way to implement *dynamic programming.*
This fixed-point formulation of product design process assumes that all design information can be encoded in the domain of portfolios, S. When a fixed-point in the S domain is found ($s_{n+1} = s_n$), we arrive at a *fixed* or *stabilized* portfolio. This fixed portfolio can be considered for implementation in the real-world. This fixed-point formulation of portfolio refinement reflects the dynamic nature of portfolio refinement in practice.

3 An Executable Modeling Tool

The above-mentioned method requires a modeling tool that enables one to *encode*, *enumerate*, and *evaluate* development portfolios. The rationale of implementing the tool is twofold. First, the above method involves certain tedious model manipulation tasks that must be automated. Second, it should serve as an experimental prototype to determine whether this type of automated model construction tool can be useful in real-world engineering projects. This section briefly describes the functional features and high-level software architecture of a tool, Object-Process Network (OPN). OPN can be characterized as an executable meta-language designed for model manipulation tasks [8, 9].

3.1 Functional Areas

There are three main functional areas of the tool: *encode*, *enumerate*, and *evaluate* models that represent option portfolios. They are three specialized versions of the meta-operator D mentioned earlier. The first functional area is a model editor that enables users to *encode* a portfolio as a collection of development options and a collection of payoff functions. This model editing feature is implemented as a bi-partite graph editor. It allows users to insert and delete options (represented as boxes) and payoff functions (represented as ellipses). A screenshot of the editor is shown in Figure 1. There are specialized editors for development options and payoff functions that allow users to specify allowable values and function definitions for these design primitives. The editor also enables users to insert and remove edges between the boxes and ellipses. Edges are data structures that carry boolean expressions to determine whether certain value combinations are acceptable. Each bi-partite graph diagram shown in Figure 1 represents a development portfolio.

The second functional area is to *enumerate* all the possible variations of the development portfolio. For statically related options, a portfolio can be treated as a Graphical Game model, which can be approximated solved using Bayesian Belief Network algorithms [8]. The enumeration procedure for temporally dependent options is realized via a directed graph enumeration algorithm illustrated in detail in Reference [8]. These algorithms assess the probability distribution of likely sub-portfolios or generate a collection of portfolio variations.

The third functional area is to *evaluate* the properties by human or by machine. During the enumeration process, the algorithm for enumeration also carries out the calculations of payoff functions, yielding additional information about options, or eliminating options that are not compatible. Since each payoff function may assess more than one property, there are usually multiple named properties associated with each portfolio. These named properties can be used as multi-dimensional metrics to compare different portfolios.

3.2 Software Architecture

To support the three functional areas, the codebase is organized into three software packages. They are LanguageKernel, PersistenceServices, and UserInterfaceWidgets. They are all implemented in Java.

LanguageKernel includes four basic data types: Option, Payoff, *Relationship*, and Portfolio. The data type called Relationship implements the constraints specified in the payoff functions (F). A portfolio is implemented as a bi-partite graph. The decision operator, D is implemented as a Java method that merges or deletes certain parts of the bi-partite graph. The graph editing, enumeration, and function evaluation algorithms are all implemented as specialization of the decision operator. These algorithms always return the results in the portfolio data type. This implementation strategy is intentionally designed to mimic the nature of an algebraic system, so that we may inductively reason about the computational results of this software library.

UserInterfaceWidgets is the package that provides the graphical user interface that allows users to visualize and edit portfolios in a number of graphical modes. The user interface of OPN is intentionally designed to allow users visualize that both data content as well as structural properties of development portfolios are being manipulated. Moreover, it shows that portfolio refinement is an iterative procedure that starts from an initial portfolio and unfolds into many generations of alternative portfolios. The generated portfolios are listed in the middle section of the editor and can be individually selected and edited. Each of the portfolios is also associated with a set of properties listed in the lower right corner of the editor window. Users can *decide* between different *portfolio options* as a part of the human-in-the-loop decision procedure.

PersistenceServices is a software package currently implemented to store portfolios as XML files. This package is designed to allow future extensions that utilizes scalable database services when users need to deal with a much larger number of generated portfolios.

4 Applications

This method and its supporting tool, OPN, have been successfully applied to study varying compositional structures of different product development portfolios and assess the interactions between many qualitative and quantitative variables. Due to limitations on article length, the following list briefly summarizes three published applications:

- A study of Moon and Mars exploration architectures for the NASA Vision for Space Exploration [10]. In this study, over a thousand alternative, feasible mission-mode options were generated and compared for human travel to the Moon or Mars.
- A study of developmental options for flight configurations of a particular type of military aircraft [8]. This study demonstrated OPN's ability to reason about the possibility space of physical configurations under incomplete information.
- A study of options for Space Shuttle derived cargo launch vehicles [11]. This study generated and evaluated hundreds of developmental portfolio options for evolving the Space Shuttle's hardware into a new launch vehicle.

OPN helped streamline the exploration of many combinatorial possibilities in different option portfolios. It also supports numeric calculation of payoff values, and the calculations can be postponed or symbolically simplified without sacrificing the integrity of the analysis results.

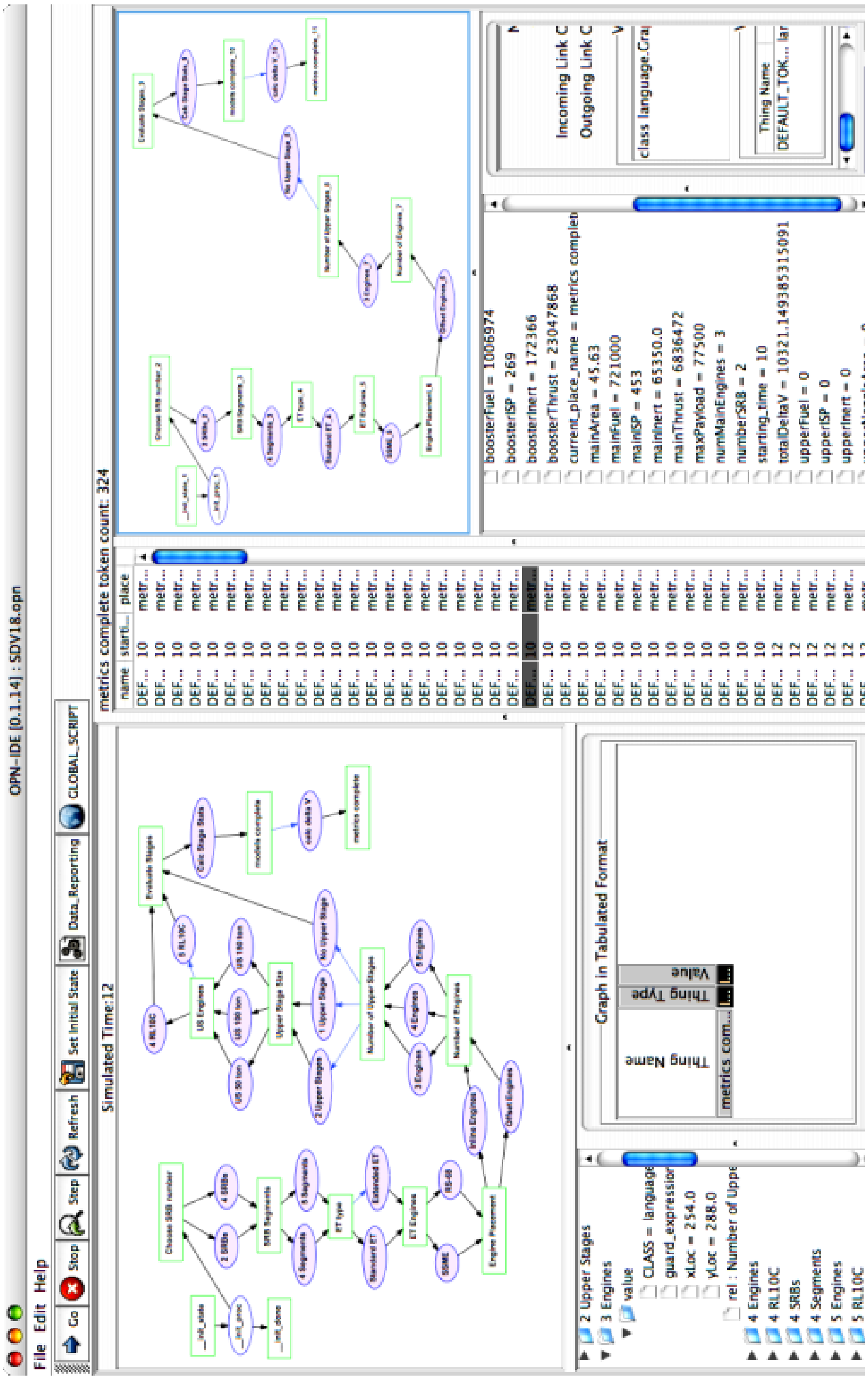

Fig. 1. Screen capture of the OPN tool.

5 Discussion and Conclusion

This model-driven approach allows us to deal with three critical problems in product development option analysis. The are listed as follows:

1. Enable product development planners to represent the state-space of real options as a network of model-driven data elements. Based on modeldriven analysis principles, combinatorially explosive option state-space maybe systematically partitioned into a manageable number of sub-spaces each represented by a sub-network model.
2. Provide an executable language to encode portfolios as executable models, composed of a collection of options and their payoff functions. The models can be executed to enumerate alternative combinatorial scenarios and perform various levels of simulation to assess their strengths and weaknesses.
3. Under incomplete knowledge, portfolios maybe algebraically manipulated [9]. This approach may proceed by applying algebraic rules to infer certain logical properties of the portfolios. In contrast, many quantitative analysis methods often require observational, statistical or stochastic simulation results before formal analysis may proceed.

This model-driven method tackles knowledge incompleteness problems in option analysis using an algebraic approach. It also preserves the structural and behavioral properties of different product development portfolios during the analytical process. The list of rather different applications of this method, indicates that this model-driven analysis framework maybe applied to a broad range of decision-making problems.

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Towards Automatic Systems Architecting

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Abstract. This article intends to shed new light on the system design process. We here suggest the possibility of combining simulation features of an executable meta-language called Object-Process Network (OPN) with the descriptive power of well-known modeling languages such as Object-Process Methodology (OPM), Structured Analysis (SA) or SysML. In the Systems Architecture domain, a great issue one always faces is the great number of options to be considered when designing a system. We must keep in mind that modeling the space of options is actually different from modeling the system of interest. The traditional modeling tools allow us to specify a unique solution, when we should consider the whole set of feasible architectures. On the other hand, OPN is able to help architects to assess all these possible configurations but, as a decision-support tool, it doesn't offer the descriptive power OPM, SA and SysML do.

Keywords. Complex Engineering, meta-language, OPN

1 Introduction

The process of designing complex socio-technical systems often involves tasks such as transferring knowledge across different domains and computing parameters of interest. In addition, the space of options to be considered increases as the system being studied becomes more complex. Experience proved essential the use of architectural reasoning techniques when developing such systems. The concept behind these techniques is that reasonable decisions can be made evaluating relevant parameters to that specific system, often related to cost and time issues. Nonetheless, we have had only tools and techniques able to tackle specific needs. No one could handle the main needs in an integrated approach. That is why Object-Process Network (OPN) [5] turns out to be a unique tool in system architecting. It unifies the processes of decomposing the problem (and thus being able to manage

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complexity), composing (and analyzing the system as a whole) and eventually evaluating possible architectures.

Essentially, this executable meta-language is a decision-support tool that provides a systematic way of using computational tools to reason about decisions during the early stages of system development.

Meanwhile, system modeling frameworks such as Structured Analysis [2], UML [4] and, more recently, SysML [12] stand as a descriptive method that gives us a static view of the system. This means that they do not give us the chance of simulating or computing parameters. Most customers understand structured methods better than others, though. As communication with stakeholders and users is a main reason for modeling a system, having a final model in Structured Analysis turns out to be a great way of presenting the results yielded by OPN. Thus, the great deal about combining descriptive languages with OPN is, given feasible architectures, we can automatically compose meaningful and communicative models.

Not only having a final model in a descriptive language but also defining the options and constraints that bound our problem into one of these models turns decision-makers experience easier, without great difficulties to understand what is being modeled.

The objective of this research is to propose a new approach to conceive complex systems. As the descriptive and communicative language, we have chosen Object-Process Methodology (OPM) [1], because of its ability to specify both structural and behavioral aspects of a system using a small set of symbols. This article is a first step into the ideal "automatic conception of a system". This final objective would allow us to pick up the best architecture once the functions to be performed and constraints have been set up.

The specific goal of this article is to describe what we now call "The New Approach", explaining the transition between a descriptive language into a decision-support tool (OPN), and eventually translating the results of the simulation process back to the original notation. The methodology that gives support to the suggested approach will be carefully explained in Section 3 of this article. In section 2, we give a brief description of the modeling languages considered in this research.

2 The Current Approach

When developing a new system or enhancing an existing one, the common and current approach adopted is to model the problem and its solution into models in various system description languages, among them SysML, Structured Analysis and OPM. Even though Structured Analysis for instance tries to model the problem (its requirements) aside from implementation aspects, it is inevitable tending to a particular architecture for the problem, rather than considering many possible solutions. These "static" languages do not offer simulation or computation features, they are purely visual.

Currently, decision support tools are completely separated from system architecture modelling tools. So when deciding you do not have instruments for a common visual understanding of the system architecture and, on the other hand, when modelling you do not have instruments for deciding which way to move forward with required model detailing.

State of the art is modelling frameworks, on one hand, such as OPN providing a full set of combinatorial options and strong decision support, but needing enhancement on visual modelling detailing and, on the other hand, the ones such as Structured Analysis, SysML and OPM, that provide comprehensive and detailed system models but with no decision support capability. In other words, the decision process and solution architecture modelling are done separately leading, for example, to decisions with less than available systems information or to detailed models that will never be used.

This section provides a brief review on OPN and OPM, once they will be used in the examples in the following sections.

2.1 Object-Process Network

Studies regarding system architects' current modeling process proved essential the development of a tool that could give support to tasks one always faces when developing a system: enumerating the space of possibilities, given constraints that bound the problem; computing all architectures, based of the options assigned in the first task; and, eventually, evaluating all those solutions, leading us to the preferable ones. Prof. Benjamin Koo's research gave birth to Object-Process Network, a meta-language based on a small set of linguistic primitives that unifies these three tasks in systems architecting. A tool [10] based on Java programming language gives support to this meta-language.

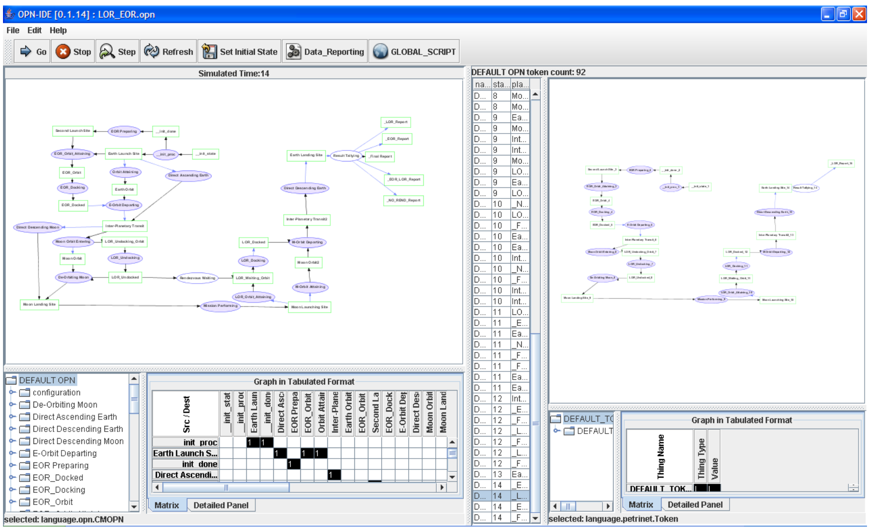

Figure 1. Screen capture of the OPN tool.

An OPN graph is solely composed by processes, objects and links that connect these two entities (only between different types of blocks). A process is defined by functions that modify chosen parameters. Thus, the best architectures can be inferred through analysis of final values of those parameters. Each “thread” in an OPN graph will lead to a different set of “final values”. Figure 1 shows on the right an OPN graph and on the left a possible “path” to be followed. For further information on OPN’s ongoing research, see References: [5,6,7,8].

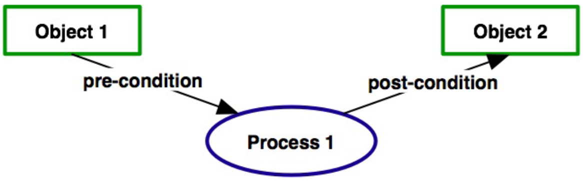

Figure 2. OPN Overview: An object is related to a process through a pre-condition or a post-condition [7]

OPN’s highlight is the capability of helping stakeholders making architectural decisions. Currently, OPN does not offer the possibility of converting a series of suggested decisions into an actual model of the system of interest. Besides that, modelling the space of options directly into an OPN graph may become a difficult task as our system becomes more complex.

2.2 Object-Process Methodology

Model multiplicity due to excess symbols has been pointed out as a serious weakness in Unified Modeling Language (UML). A new approach to design information systems was developed in order to overcome the excess notation problem. Object-Process Network uses three types of entities: object, process (modifies the state of an object) and state. Many types of links are available to define which kind of relation the blocks have with each other. These relationships can be either structural or procedural. The first one expresses persistent, long-term relation; the latter one expresses the behavior of the system. Another OPM feature is that it supports graphical and textual models: Object-Process Diagrams (OPD) presents the system through symbols for objects, processes and links; Object-Process Language (OPL) presents the system through sentences. Object-Process Case Tool (OPCAT) [11] is the software developed to demonstrate the applicability of this methodology.

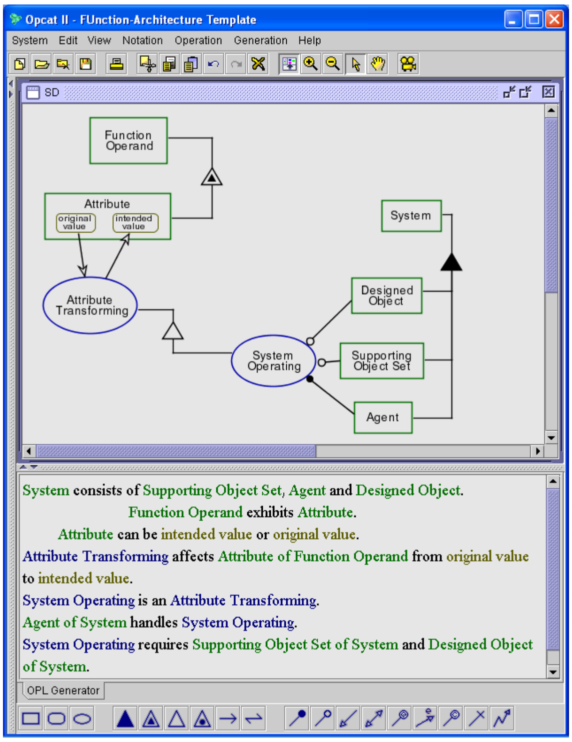

Figure 3. Screen capture of OPCAT [9].

3 The New Approach

The primary objective of this study was to verify the viability of translating a model in traditional modeling tools into an OPN graph. Further studies showed that these languages are not compatible. Actually, OPN has a different purpose than traditional modeling tools. But the association of these two different approaches would lead us to a powerful architecture modelling tool.

Rather then considering a universe of possibilities, currently descriptive languages tend to bias one instance of the system. Nevertheless, each of these languages presents a unique feature. Structured Analysis, for example, allows us to create hierarchy of models that do not depend on their implementations. At each level of abstraction, we could use OPN to help choosing the best architectures to develop. This latter concept can also be applied using OPM as the descriptive language, as we will show with the example to be developed.

All these ideas regarding the union of existing modeling languages gave birth to what we call "The New Approach". Essentially, it means getting the best of OPN and descriptives languages at once. Figure 4 illustrates "The New Approach".

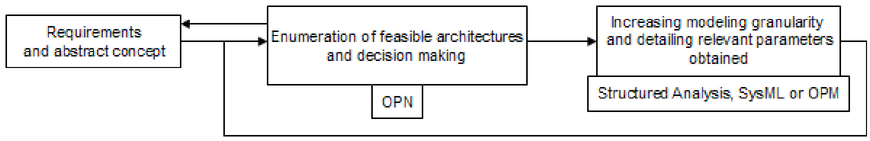

Figure 4. Schema for the proposed approach.

Its first main idea is that we have to define initial and final states related to the system. For example, were we to apply this concept to the Apollo Program the initial state should be "Man on Earth" and the final should be "Man on the Moon". In order not to have infinite possibilities, we have to define the "boundary conditions" of the system. They are the main direct obstacles that hinder the change from an initial to a final state. One may ask: How are we to overcome these "obstacles"? For each of them, a new "subsystem" is designed, allowing these obstacles to be overcome. For an instance, what hinders the man going from Earth to the Moon? The first of the restrictions would be "Distance". For this specific restriction, a given number of subsystems (options) is available.

This process can continue, if for this subsystem to work properly new boundary conditions have to be added. We should stop iterating when the subsystems generated are "minimum blocks", in the sense that there are no more boundary conditions and there is no need to zoom into them. This idea is schematized in figure 5. It is what we will start calling "The General Concept" for The New Approach.

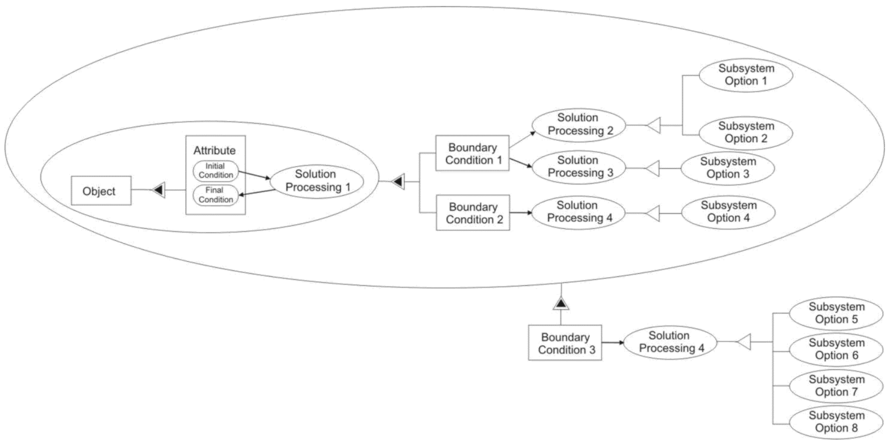

Figure 5. OPM model for The General Concept.

One could argue that the concept here applied does not allow us to make high-level decisions, we would be always obliged to go down into lower levels (generating the “new subsystems”). That’s not true. The problem is that starting to make decisions at top-levels means having fewer parameters to evaluate the architectures. Imagine that we are starting to develop a complex new system, and there are three mainstreams (and completely different) to be followed. Unless this is not a completely new system, we would not have parameters to infer best architectures without going down to lower levels on each of the mainstreams. Simulating at a top level with only macro-parameters could be deceiving. That is why we suggest continuing the iteration process until “minimum subsystems” are modeled. Defining a subsystem as “minimum” is a purely a matter of convenience or availability. For instance, if it is possible to infer parameters that describe this minimum system (for example, from an available database), then there is no need to continue iteration process for it. In other situations, it can be more convenient to develop an entire model for a subsystem and only then it will be possible to describe it in terms of system’s main parameters. Note that Subsystem Option 1 and Subsystem Option 2 are regarded in our model (figure 5) as minimum subsystems.

The essential and first step that will govern the development of the rest of the model is the definition of initial and final states and the conditions related to the central problem. The examples below (figure 6 and figure 7) show familiar systems and the definition of the change of states linked to the macro problem (developed with OPCAT II – Object Process Case tool [11]).

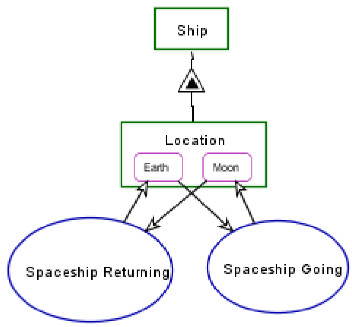

Figure 6. Definition of Change States for the system “Spaceship from Earth to the Moon”.

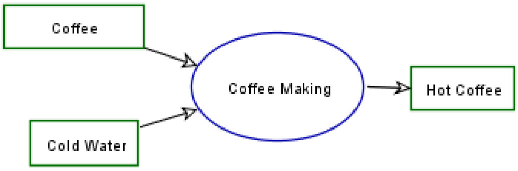

Figure 7. Definition of Change States for the system “Coffee Machine”.

The information presented in The General Concept (figure 5) is not sufficient yet to simulate in OPN. This decision-support tool requires parameters that will be modified by the functions and later evaluated. The next model presents these necessary parameters. They are linked to their respective processes through dashed lines. These parameters are related to a process through functions that describe it.

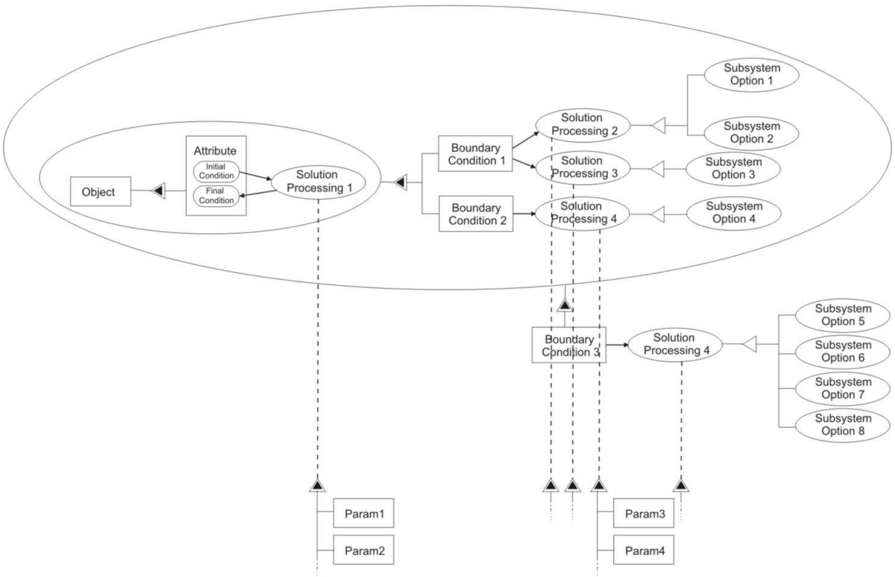

Figure 8. OPM model for The General Concept with parameters to be simulated.

Now that we have options and parameters (related to the options via functions), an OPN model can be created. Based on minimum requirements, the simulation process will eventually point out feasible architectures (figure 9). These requirements could be risk, time, cost etc.

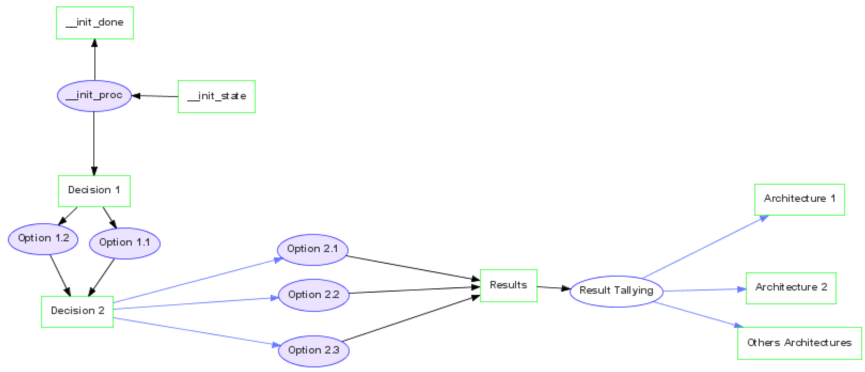

Figure 9. OPN model to be simulated.

The results of the simulation process let us derive a solution for the system to be built (judged to be amongst the best ones).

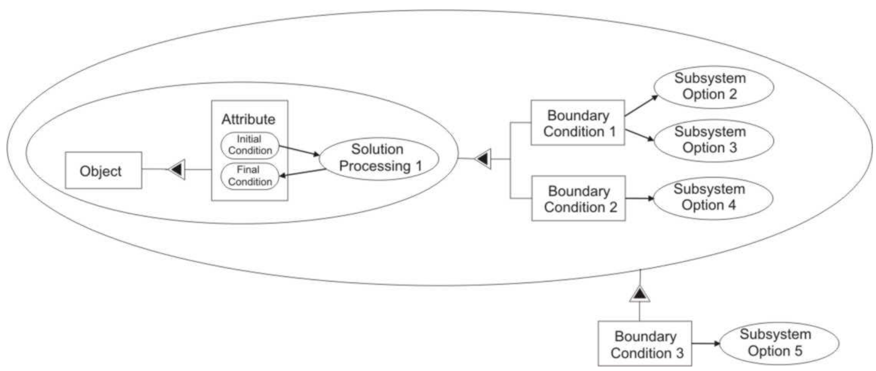

Figure 10. OPM model derived from the simulation process.

4 Study Case - Market of Sodas

The concept behind the suggested methodology was minutely described in the last topic, but no concrete application for a complete system has been presented yet. One could still argue about the unfeasibility of the method to a complex system. "The Market of Sodas Example" is a proof that we can actually develop new systems or improve existing ones adopting this approach. The example to be here presented focuses on logistics issues for the distribution of soda. We will look for best solutions for the problem "Delivering a Soda for a Customer".

The OPM Model in Figure 11 shows the definition of the states and conditions for a market of sodas. Note how the core of the problem (change of states) is attached to boundary conditions such as *Distance*. Following these "restrictions" requires subsystems that "solve" them. This is the first iteration process. The model keeps iterating until "minimum subsystems" are modelled such as *Car*, *Train*, *Airplane*, etc. In the next page, we present the model with parameters to be evaluated (figure 12). New notation has been added to the original set of symbols in OPM. The dashed lines in figure 11 for example, represent the relationships between the subsystems in the actual system, letting us derive an OPM model for the system given the results from OPN (thus, it is essential having all these links signalled).

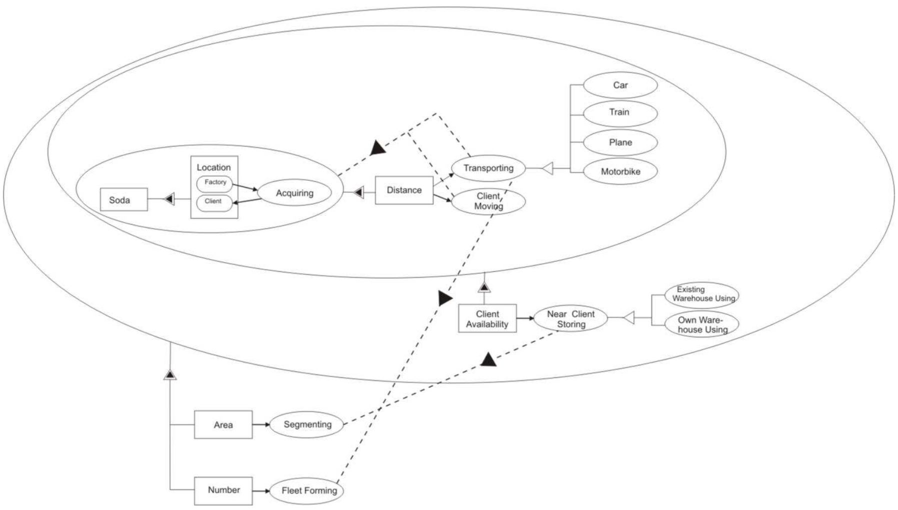

Figure 11. OPM model for logistics of a soda market.

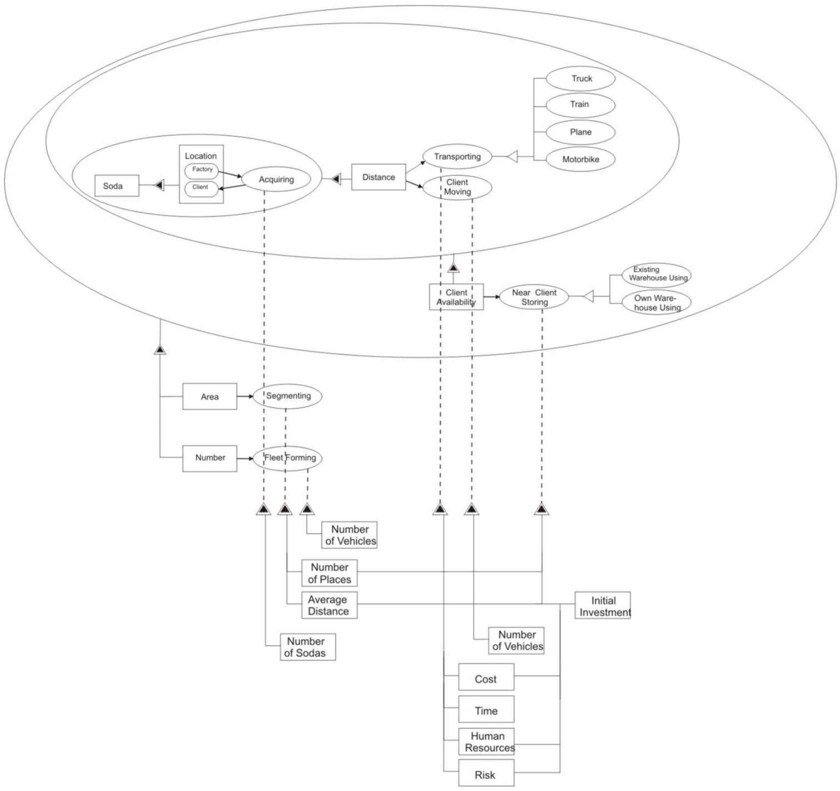

Figure 12. OPM model with parameters (linked to the functions through dashed lines).

Based on the information obtained in the first process, we can now build an OPN model that can enumerate solutions for our problems based on constraints we have defined (Figure 13).

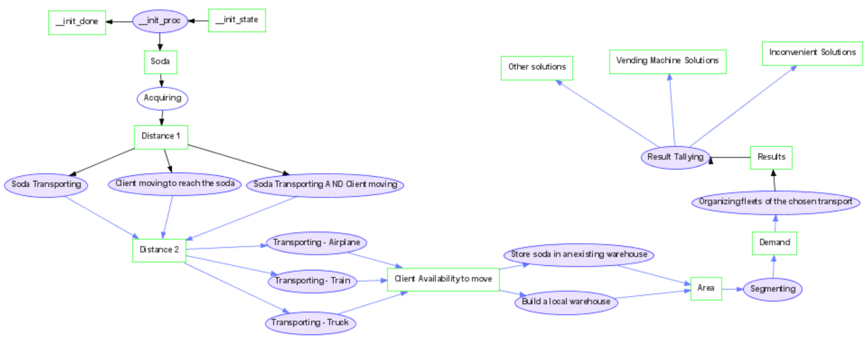

Figure 13. OPN model generated

As stated before, OPN stands as a decision-support tool. Thus, its reasoning features will lead us to a variety of models of the desired system. For our example, after simulating the options of architecture, we can now build instances of systems using OPM. Given a series of decisions made through the simulation process, we can now model them in OPM (figure 14). In figure 8, that would be replacing all the "Solution Processing" processes by the selected "Subsystem Option".

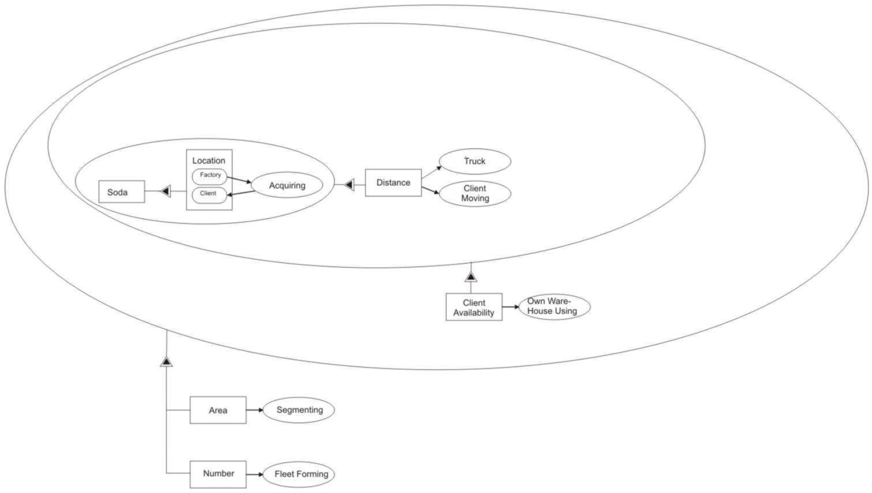

Figure 14. Modeling the decisions using OPM.

The last step of the composition of this system is, based on decisions made, to model the actual system. This can be systematically done erasing all the boundary conditions, their links and not selected options and turning the dashed lines in figure 12 into continuous lines.

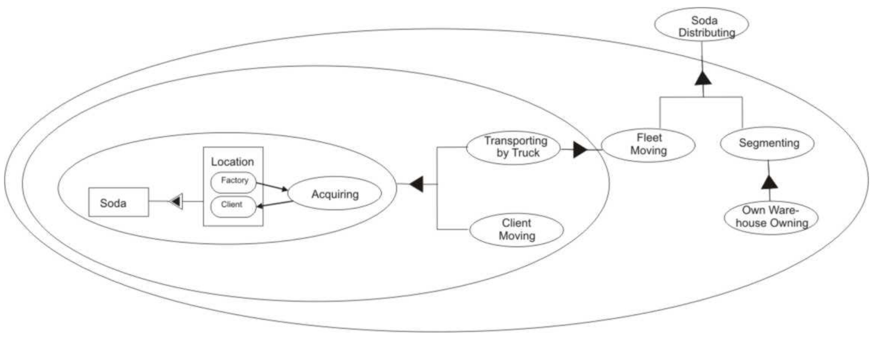

Figure 15. OPM model for the chosen solution/architecture.

5 Further Development

As a next step towards the final goal of mechanizing the conception of systems, further research need to be done. Some questions remain unanswered. How to decide to which extent we should model in order not to spend great effort modeling a solution that will never be developed? When composing and architecture model using different notations for various parts of the model, how to make the overall model make sense? How to integrate different models if they are written with modelling notations at the convenience of the system architect?

6 Conclusions

In this study we presented an innovative approach for complex systems development. The applicability of this new methodology that can automatically generate architectures for a system was shown through the study of the logistics in a soda market. Besides the prospect of mechanizing the conception of systems, this approach would allow us to identify new solutions traditionally discarded by past-experienced based constraints. For an instance, The Apollo Program was constrained in the 60s by time and risk. The solution then was going via Lunar Orbit. New space exploration vision systems are very much constrained by cost. Most cost-effective solutions may point out to a flight directly to Lunar Ground, for example. Certainly, changing initial constraints will change the space of solution options. Using such methodology means that we will not have to start all the decision process over again if constraints change. Further studies are expected in order to answer the current problems with this new approach.

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Software Engineering And Simulation

Implementing integration of quality standards CMMI and ISO 9001 : 2000 for software engineering

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Abstract. In this paper, we present how to integrate several processes using a common reference frame offering various viewpoints. This step is applied to the integration of two standards of quality - ISO 9001: 2000 and CMMI - in order to generate a multivues quality reference frame allowing a certification relative to the two standards. This reference frame takes into account the structure imposed by ISO and the recommendations of CMMI. The implementation of this reference frame is accompanied by the application of the organzational improvement model IDEAL (relative to the implementation of CMMI). This paper is based on the work completed within a software engineering company (SYLIS). Both human and cultural aspects of the company are considered in order to mitigate the problem of acceptability.

Keywords. Quality standards, CMMI, ISO 9001 : 2000, enterprise modeling, business process, reference frame.

1 Introduction

ISO 9001 : 2000 requires that an organization's processes undergo continuous improvement even after ISO 9001 : 2000 certification has been achieved. CMMI provides an organization with a means to accomplish further process improvement. CMMI is a very detailed set of documents that contain many more of the basic concepts for process improvement than can be found in ISO 9001 : 2000. Our paper presents the implementation of these quality standards in a unique reference frame allowing us to obtain certification for both standards.

The remainder of this paper is organized as follows: Section 2 gives a brief explanation of CMMI and ISO 9001 : 2000. Section 3 introduces our proposal of

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integrated model. Section 5 presents the implementation of our model. Finally, section 6 provides our conclusions.

2 State of the art

2.1 CMMI or how to increase the maturity of processes

In the current marketplace, there are maturity models, standards, methodologies, and guidelines that can help an organization improve the way it does business. However, most available improvement approaches focus on a specific part of the business and do not take a systemic approach to the problems that most organizations are facing. For example, there are many maturity models available such as the Software Engineering Institute's (SEI's) Capability Maturity Model for Software (SW-CMM), which focuses on improving software, and the Electronic Industries Alliance's (EIA's) Systems Engineering Capability Model (SECM), which focuses on systems engineering. By focusing on improving one area of a business, these models have unfortunately perpetuated the stovepipes and barriers that exist in organizations.

Capability Maturity Model Integration (CMMI) provides an opportunity to avoid or eliminate these stovepipes and barriers through integrated models that transcend disciplines. CMMI consists of best practices that address product development and maintenance. It addresses practices that cover the product's life cycle from conception through delivery and maintenance. There is an emphasis on both systems engineering and software engineering and the integration necessary to build and maintain the total product [6].

CMMI integrates old models developed in the Nineties. This need for integration appeared in order to make speak the same language and use common processes engineers of multiple disciplines attached to the same project of development: SE (Systems Engineering), SW (SoftWare), SS (Supplier Sourcing) and IPPD (Integrated Product and Process Development).

CMMI regroup 25 "Process Area" (PA). There are two different representations of the CMMI: the staged representation and the continuous representation [1][14].

2.1.1 Staged representation

The Staged Representation focuses improvement on the process capability an organization can expect to attain; however, this expected capability (or ability to function in a mature manner) is contained within maturity levels or stages. There are five maturity levels, as shown in Figure 6 , with each level providing the foundation for further improvements. This representation provides a roadmap for sequencing the implementation of groups of process areas.

2.1.2 Continuous representation

The Continuous Representation has the same basic information as the staged representation, just arranged differently. The continuous representation, as shown in Figure 7, focuses process improvement on actions to be completed within process areas, yet the processes and their actions can span different levels. The continuous representation provides maximum flexibility for focusing on specific process areas according to business goals and objectives [13].

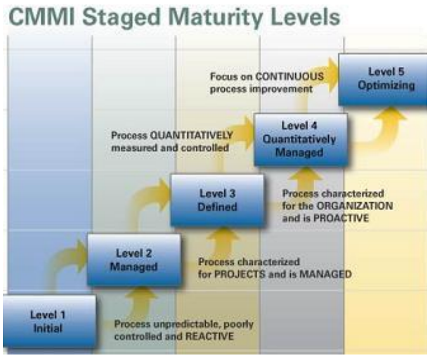

Figure 6 : CMMI Staged Representation

Figure 7 : CMMI Continuous Representation

In our case, we focused on Staged Representation in order to improve all the PAs and not to restrict our work to particular ones.

2.2 ISO 9001 : 2000

ISO 9001 : 2000 is a necessary requirement for a quality management system. It is a part of the ISO 9000 family that consists of ISO 9000 (Fundamentals and Vocabulary) [10][12], ISO 9001 (Requirements) [9], ISO 9004 (Guidelines for Performance Improvements) [11], and ISO 19011 (Guidelines for Quality and Environmental Management Systems Auditing). ISO 9001:2000 is an abstract and is a sparse document that can be applied to any category of business. When it is to be applied to organizations in the software industry, ISO 9001 can be further interpreted by using either ISO 9000-3 or TickIT . To achieve an ISO certification, organizations must be compliant with every clause of ISO 9001 : 2000. Compared with ISO 9001 : 2000, ISO 9004 : 2000 is not a requirements document. Rather, it is a document that provides guidance for further process improvement. ISO 9001 : 2000 and ISO 9004 : 2000 are similar in terms of both the structure and terminology that they use in order to facilitate their application as a consistent pair [9][11] of standards.

3 Proposal of integration model

3.1 Purpose of model integration

All quality models and standards have their advantages and drawbacks. Among the various models, standards and corpus of knowledge, some include all the activities of the company and adopt a breakdown approach like ISO 9000 : 2001, others like CMMI are guides of best pratices and are specific to certain activities of the company and they adopt an ascending approach. On the basis of the two standards that interest us (ISO 9001 : 2000 and CMMI), it would be interesting to combine them or at least to bring them closer in order to see appearing various synergies : to implement a multivues cartography of processes. Such cartography will allow the implementation of the two standards of quality and obtaining relative certifications.

Thus, our objective is to carry out a reference frame which:

- Integrates the recommendations of various quality standards,
- Allows the evaluation of these quality standards,
- Is easily usable by all employees,
- Is easily exploitable in a process improvement approach.

3.2 Model description

Each quality model, standard and corpus of knowledge describes a part of company activities with its own level of precision and specificity. Their scope is different (as shown in Figure 8). So one model can describe non existing activities in the company and forget some existing and implemented activities. So usually a model does not cover integrally enterprise activities. The precision level of the description depends on the model.

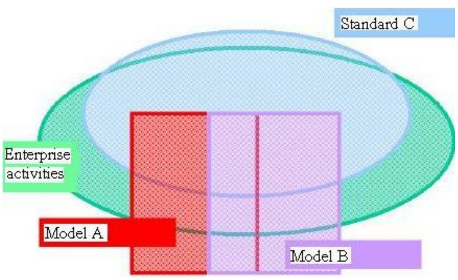

Figure 8 : Models scope compared to enterprise activities.

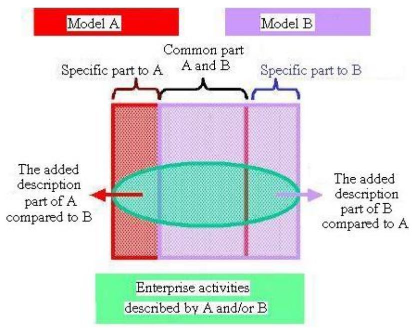

Figure 9 : The common/specific description of enterprise activities.

Generally, we find within two models the description of common and specific activities to each model (as shown in Figure 9). These two descriptions can be implemented or not in enterprise activities.

3.3 The multi-model approach

We propose four steps in our multi-model approach to integrate different quality models:

Step 1 : Models choice

- What are objectives and requirements? Increase customer satisfaction, productivity…
- What are envisaged models? CMMI, ISO 9001 : 2000, ITIL…
- Which the budget? X$...
- What are resources? Young people experimented ones, consultants, significant number…

By answering these questions, we can determine coherence between considered models and enterprise needs and resources. This step permits us to choose the adequate models to implement.

Step 2 : Analysis of models synergy

Once the models are chosen, we compare those standards. This comparison points to both similarities and differences. Fortunately, the synergy between the frameworks can be exploited and the weaknesses of one can be supplemented by the strengths of the others. To analyze models synergy, we implement a mapping between models. This mapping should determine:

- Levels of abstraction between selected models,
- Treated functional sectors,
- For each element of a model, its relation with elements of other models,
- A level of correlation, in order to qualify each relation.

Step 3 : Construction of integrated model

This step will allow us to:

- Resolve all contradictions in the relations between the elements of models,
- Avoid unfolding of work by consolidating the elements with relations of inclusion and identity,
- Maximize the synergy potential by combining complementary elements.

On the basis on this step, we create a theoretical integrated model (as shown in Figure 10) valid for any enterprise wanting to implement two models A and B.

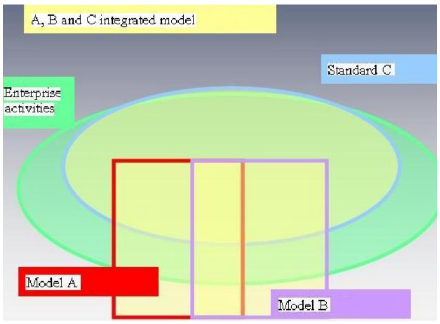

Figure 10 : The integrated model

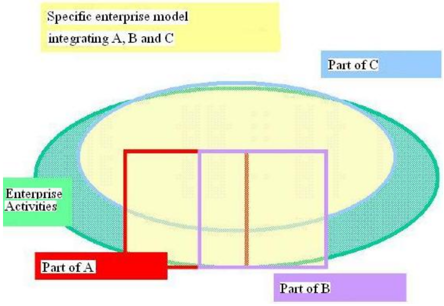

Figure 11 : The specific integrated model

Step 4 : The adaption of the integrated model to the enterprise context

This step will allow us to retain from each model only relevant elements with enterprise activities (as shown in Figure 6) and objectives of quality project and to adapt the theoretical integrated model to human and cultural context of the enterprise.

4 Implementation of the reference frame

4.1 The case study multi-model approach

Figure 12 shows the case study multi-model approach, presented in previous section.

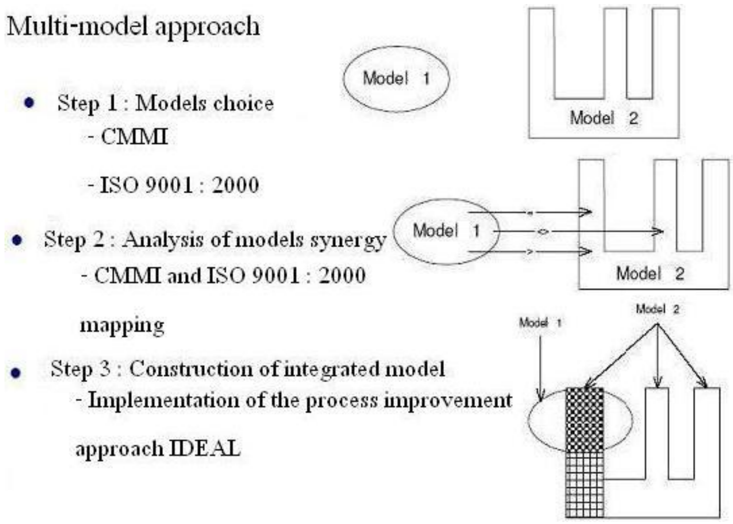

Figure 12 : The case study multi-model approach

4.2 CMMI and ISO 9001 : 2000 mapping

Basing on CMMI and ISO 9001 : 2000 synergy [4] [5], we implement a mapping in order to determine:

- CMMI practices treated par ISO 9001 : 2000 chapters.
- ISO 9001 : 2000 chapters treated par CMMI practices.

4.3 Implementing enterprise quality reference frame

Implementing the specific integrated model

As shown in Figure 13, we implement a cartography of enterprise processes. This cartography shows the enterprise processes and CMMI PAs. It shows also the level of integration of CMMI PAs in or cartography. PAs : DAR, IT, OEI, ISM et RSKM are not treated by ISO 9001 : 2000. All the rest of PAs are localized in our ISO procedures.

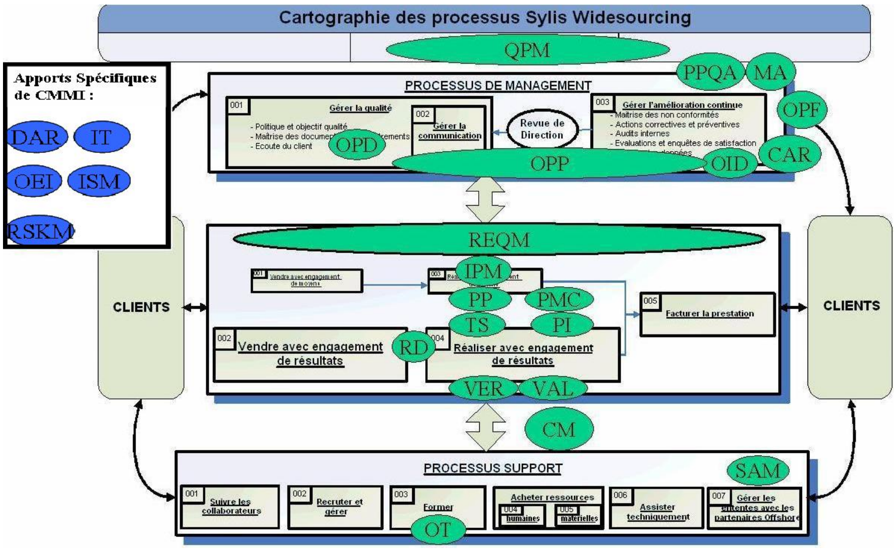

Figure 13 : Enterprise's process cartography including CMMI's PAs basing on ISO 9001 : 2000 representation.

Enterprise processes and quality standards mapping

We implement a mapping between enterprise processes and our quality standards implemented. So for an enterprise process, we can find all CMMI PAs and ISO procedures treated by this process and vice versa.

4.4 The human aspects for acceptance

Since the company has its own methods and ways of work, we feared that the integrated model will not be used. So, we deal with the problem of acceptance. Thus, we began by classifying the personnel of the company in two categories:

- The allies: They approve work and are convinced of the utility and the need on the implementation of such quality reference in the company.
- The recalcitrants: They are a little bit hostile to the implementation of such a model because:
  - Usually, they have their own methods and processes.
  - They are against the use of rigorous methods and processes.

We concentrated our efforts on this second part of the personnel. We chose the strategy of persuasion through presentation to show the advantages of the adopted model compared to classic quality standards and by discussing with them to know which are their waiting and if there are things to modify.

5 Conclusion

To implement CMMI in an ISO 9001 : 2000-certified organization efficiently and effectively, both the common and different parts of the ISO 9001 : 2000 standards and CMMI documents must be identified. ISO 9001:2000 requirements can be mapped to CMMI practices [5]. However, the following limits have been identified in this mapping process:

1. A requirement of ISO 9001 : 2000 can be mapped to many CMMI practices. Conversely, a CMMI practice can be mapped to many ISO 9001 : 2000 requirements. These mappings are useful for comparing these two frameworks, but they may cause confusion during the decision-making process.
2. It is difficult for organizations to understand and apply these mappings during CMMI implementation because they only describe the degree of the correlation between ISO 9001 : 2000 and CMMI without providing any explanation of these mappings.
3. The structure and words that are used by CMMI are not familiar to ISO-certified organizations, which makes it more complicated for an ISO 9001 : 2000-certified organization to implement CMMI.

We are working now on mitigating these limits and the implementation of more than two quality standards on the same reference frame.

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Steps Towards Pervasive Software: Does Software Engineering Need Reengineering?

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Abstract. Nowadays, the definition of service is demanding machines to turn into human beings. In order to work efficiently, machines need to analyze current situations, perceive user needs and provide users with intelligent, automatic and proactive adaptation that responds to current contexts. System performance will be guaranteed only if we add new features to its behavior, such as: self-adaptation, self-organization, self-configuring, self-healing, self-optimizing and self-protecting. These challenging automated processes can produce proactive behavior if software engineers change the engineering logic and use the environment context as a solution instead of thinking about it as an obstacle.

Keywords. Pervasive systems, ubiquitous computing, software engineering, adaptation, context-awareness.

1 Introduction

Due to the revolution of Information Technology, a new computing era is taking place. Many challenges need to be met, especially in a mobile and dynamic environment where users are interacting with different devices, constructing ad hoc networks, while systems should provide them with proactive value-added services.

Pervasive or Ubiquitous Computing was first introduced by Weiser as his vision for the future of computing in the 21st century; where computing elements will disappear from the user's consciousness while functioning homogeneously in the background of his environment [13]. In pervasive computing, users compute and communicate with each others whenever, wherever and however [9].

Pervasive computing merges physical and computational infrastructures in an integrated environment, where different computer devices and sensors are gathered to provide new functionalities, specialized services and boost productivity [15].

While analyzing pervasive computing and studying its progression, it was found that for hardware and computing elements to disappear, software needs to disappear and the spatial and temporal relationships between people and objects (human-machine interaction) has to be well defined in the early design phase in order to cope with the dynamicity of the ubiquitous computing environments [17].

In this section, we have presented different definitions of pervasive computing. Next, in section 2, we'll present the challenges that face these systems. In section 3, we'll present the difficulties of integrating context within content information. In section 4, we'll present some enabling technologies that help the system to adapt with the heterogeneity of its software components. In section 5, we'll present the challenges that meet software engineers while providing different system requirements. Finally, we highlight the importance of changing the adaptively logic and using the environment as a stimulating factor for adaptation.

2 Pervasive Computing Environments

Pervasive information systems are interactive user-centered systems that aim to facilitate user interaction within unfamiliar environments. Facilitating this interaction is highly recommended and comes, in our perspective, through three principal components that should be interacting homogeneously with each others to serve the user. These components are: data, software and hardware, see Fig 1.

Pervasive computing environments should be aware of the context and should be able to capture situational information. Transparent interaction between different components can be provided using different metrics along with run-time, automatic adaptation for both content and context starting from the early stage of requirements analysis and design, till the late testing and execution of the system.

In a previous article [3], we have presented the sub components of pervasive environments and the different challenges that take place during their interaction.

In the ***user -- data*** relatioship, the user full and easy access to information sources. On the other hand, the system should be safe and secure in order to protect the information it contains and should only allow authenticated users to access the system. Therefore, there is a challenge between ensuring system security and accessibility. We highlight the importance of applying multi layered adaptation in order to balance between user requirements and system security constraints.

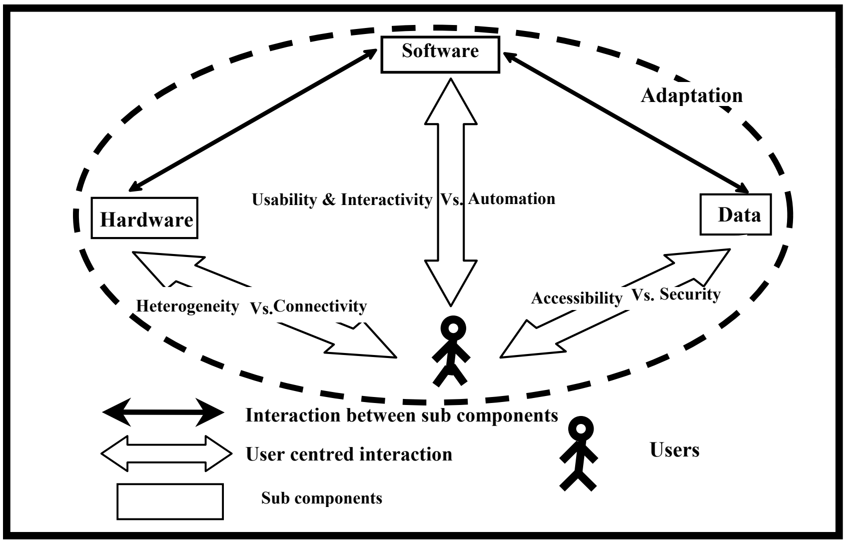

Figure 1. How can adaptation guarantee the homogeneity of pervasive environments

Similar challenges are present in the ***user -- hardware*** relationship, where hardware engineers want to provide users with small-sized, light-weighted, small screened devices that have high storage and processing capacities. At the other side, users need to interact easily with their machines without facing human-machine interaction difficulties that deprive him of smooth and efficient usage.

Finally, the ***user -- software*** relationship is also a confusing one; the user demands for flexible, usable and interactive systems that enable him to control the system behavior and as a result obtain a system that meets his changing needs. However, software engineers tend to provide users with automated services that react towards predicted situations and this way, the system will be guarantying its behavior and its reliability without worrying about user interaction and control.

3 Pervasive Software Engineering: Between Context and Content

As the computer disappears, capturing the context is becoming of high importance. When a user moves around un-trusted environments, the system should model the user in order to provide personalized services that adapts to his needs, interests and characteristics. Mean while, the system should capture environmental context to provide services that turn the surrounding environments into intelligent spaces.

Capturing context is a challenging mission especially from data sources. Data should be integrated and normalized with the aim of facilitating their processing and interpretation to manage context. Context management was introduced as a tool for creating, integrating and administrating context-aware applications [2].

Context can be connected to content using metadata; this process enriches the content and facilitates its interpretation. XML is used to handle the heterogeneity of hardware devices, software components and connection channels. The integration process needs to validate new interaction protocols between service providers and ad hoc connected users in order to achieve interoperable interaction.

3.1 Software Enabling Technologies

Software engineering helps programmers in coordinating between the different parts of pervasive systems. We present some software technologies, standards and reference architectures that facilitate the development of pervasive applications.

3.1.1 Software Components

Software engineers have exploited the fact that pervasive systems could be distributed in different physical locations and introduced software components. A ***component*** is an independently deployable piece of software that resides on a hardware element and provides a service. ***Type-Based Adaptation*** TBA is an automatic adaptation which solves the incompatibility problem between the different components and interfaces [18].

Deploying different software components will facilitate the integration of heterogeneous products. Meanwhile, such integration highlights the importance of middleware technologies that help to provide homogeneous and interoperable environments instead of carrying out complex matching and adaptation processes.

3.1.2 Middleware
The adaptation process in pervasive systems has to deal with its context volatility and unpredictability. Pervasive computing connects many applications together. Matching a lot of software components is not a practical solution but transforming them into generic and powerful middleware would facilitate the integration of these components and would ensure homogeneous communication [5]. A uniform and adaptive middleware technology would ensure interoperability between different services within ad hoc networks.

3.1.3 Programming Models
In order to increase the productivity and interoperability, the implementation of a pervasive application can follow one of two programming models as follows:
1) ***Context - Driven Model*** where several contexts can be defined in advance using description logic. On runtime, the system will explicitly know the behavior that it should follow according to its current state; this model assures the interoperability, extensibility and scalability of the system and is ideal for discovering contradictory system behaviors and to detect conflicts and adapt with multimodal environments.
2) ***Service - Oriented Model*** is an expressive, proactive and procedural model that allows higher programming control levels and employs decision making techniques to provide a service or compose a new service from already existing ones by consulting the history of the service lifecycle [8].

3.1.4 Software Factories
Software Factories [11] produce reusable assets that reduce the overall development time. MDA, ***Model-Driven Architecture***, promotes the use of high abstraction level models which offer an intuitive way to describe the system.

Pervasive systems development is being a challenging mission because of the heterogeneity of used technologies which leaves the developer with a low abstraction level. MDA can be employed in the modeling process in order to cope with heterogeneity and then Software factories can be used to raise the platform's abstraction level by providing a reduced amount of code.

3.1.5 Software Design Patterns
Patterns facilitate systems design by providing solutions to common interaction problems between classes, objects, and communication flows. Patterns offer low-level solutions to specific problems rather than providing high-level and abstract suggestions. Patterns are generative; they help designers to create new solutions by showing actual designs examples. Finally, patterns help designers to solve problems of different structures wheather high-level problems or low-level ones. Patterns are intended to complement guidelines and heuristics [6].

3.1.6 XACML – A Secure Interoperable Standard
The demanding need for security, privacy, authentication and access control has motivated the emergence of a new policy language XACML ***eXtensible Access Control Markup Language***. In order to prevent unauthorized access attempts, XACML provides automated managerial tasks, allows interoperable interactions between several applications with the reuse of access control policies [7].

XACML is a generic language that can be embedded and used in any environment. The power of XACML is due to its ability to support a wide variety of data types, functions and rules that combines the different policies [14].

3.2 Evolutionary Systems with High-Level Requirements

Pervasive computing has introduced new high level system requirements that should be taken in consideration in the design and implementation process.

Interoperability is highly demanded in all the levels of pervasive systems. Software components should be built independently of the context, this way they will be used in different computing environments and applications.

Heterogeneity is a challenge in pervasive environments; mobile users interact with the system using different hardware devices, the context and connectivity become dynamic. Meanwhile, the user also has a dynamically evolving profile. As a result the software should provide services that adapt with different screen resolutions, user-interaction methods, machine power and processing capacities.

Mobility is an important requirement. ***Actual mobility*** is the capability of an autonomous software agent to dynamically transfer its execution towards the nodes where the resources it needs to access are located. Exploiting this form of mobility will save network bandwidth and increase the execution reliability and efficiency. This aspect can be deployed to help embedded software agents to follow mobile users wherever they go. ***Virtual agent mobility*** is the ability to be aware of the multiplicity of networked execution environments[5].

Survivability and ***security*** provide systems with powerful capacities. Survivability is the ability of a system to fulfill its mission on time despite the presence of attacks and failures. Such functioning requires a self-healing infrastructure with improved qualities such as security, reliability, availability and robustness. An application may employ security mechanisms, such as passwords and encryption, yet may still be fragile by failing when a server or network link dies. The literature has presented two kinds of ***survivability*** in the context of software security: ***survival by protection*** (SP) allows security mechanisms like access control and encryption to ensure survivability by protecting applications from malicious attacks. The ***survival by adaptation*** (SA) gives the application the ability to survive by adapting itself to the changing dynamic conditions [5].

Continuity is a very demanding feature in ubiquitous applications especially with the uncertainty and instability of user connectivity while he moves around. The application should have the possibility to pause the user session in the case of sudden disconnection and continue to work later without losing information [4].

In the adaptation context, agility and evolvability become important requirements. ***Agility*** allows managing changes that are timely unpredictable but have predictable characteristics. ***Evolvability*** enables handling changes in the long-term during the life cycle of a system.

Self-organization is the ability of a system to spontaneously increase its organization without the control of the environment or external systems. Self-organizing systems not only regulate or adapt their behavior but also create their own organization. Self-organization applies the concepts of self-learning, expert systems, chaotic theory and fuzzy logic. Self-organization may be also applied in ad hoc networks in order to reach improved and efficient performance, minimize cost and increase reliability and survivability.

Usability, according to human-machine interaction engineers and to interactive system designers, is how easy an interface design is to be understood and used, how unambiguous interactive controls are and how clear its navigational scheme is [9]. This feature is the final objective of pervasive systems.

Next, we'll present a new reflection that aims to ensure the aspired features within pervasive dynamic environments.

4 A Good Reflection: Using Proactivity to Adapt to The Context

Proactive services will introduce context-aware applications that would analyze the capacities of the system and the surrounding dynamic environment then would automatically anticipate some potential features that could be applied and thus provide the user with services that surpass his expectations. The system will employ the surrounding environment resources to ensure better data integration, representation, visualization and processing. See fig 2.

Adaptation should not only provide the best services within the limitations of available resources but should also transform the disadvantages of the mobility into useful features where the surrounding environments will be exploited to ensure proactive unexpected services.

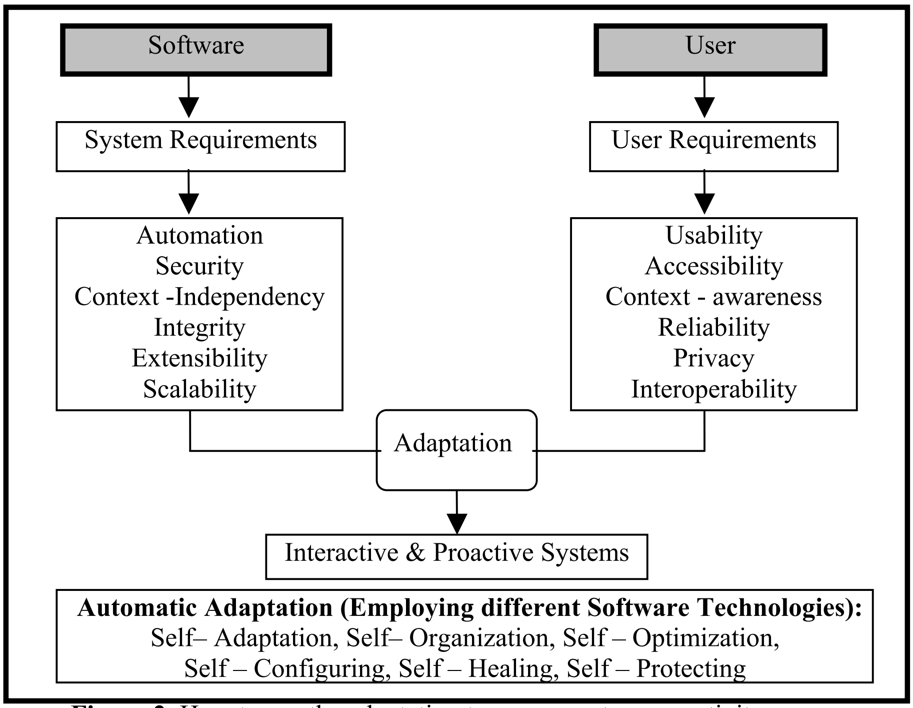

Figure 2. How to use the adaptation to assure system proactivity

Many security parallels should be resolved in order to allow using common resources in data visualization such as; data transfer, hardware accessibility, the presence of other users in the case of visualizing private data, etc.

Atomicity is highly demanded in the pervasive computing environment, but users are being controlled by the application and deprived of obtaining personalized services or interfaces. Therefore, user interaction flexibility is needed. This perspective increases the application availability by a new modeling architecture for user interfaces where the user interface layer is separated from the rest of application. This way application interfaces will support a high level of accessibility to all users and support a high degree of group individualization with more individualized user interaction without the need for specific customization by software developers.

Separating the user interface execution platform and the application logic platform will provide maximum availability of applications to users, especially when these applications are used in small sized devices that don't need have a lot of space or importance for user interfaces. Accessibility to a wider range of users will be ensured since the user interface will be customized according to the users culture, language and it could even follow the user preferences or be compatible with his common user interface objects.

As a step to contextual deployment was to apply technical deployment of user interfaces in different devices, this step aims to achieve real internationalization and user individualization. The complete separation of the user interface from the rest of the application provides a ready made user interface solution for any application based on the Model Based Architecture.

We propose to re-engineer the modelling of pervasive systems by following a hybrid Contextual-Service oriented model. This model will be analyzing the user context and as the context changes the system would carry out a recursive process that aims at searching for the proper proactive adaptation process that might reside already in the service repository or might be composed from different behaviours. As a result, the service will be accomplished in a way that responds to the user (context and needs) and would meet the service provider objectives. A dynamic requirements analysis would provide a successful adaptation process and might affect the structure of the "Software Development Life Cycle" SDLC.

Finally the automatic adaptation that we're looking for means that the service will be fully aware of context information that will be updated as the user moves and as his situation changes. Context information can contain the user location, current connectivity, the different software components (services) that the user is contacting, the hardware devices that he could be interacting with or that are available around him and finally, the most important component is the user who needs to obtain access to the system or just needs a service. To obtain an interactive and a proactive behaviour, we should use a combination of the previously mentioned enabling software technologies that would ensure system ubiquity and transparency.

7 Conclusion

In a pervasive computing environment, everything becomes dynamic and heterogeneous; data, hardware, connectivity and software. The software's mission is and to coordinate between the different system subcomponents in order to satisfy the changing needs, requirements and user context. In this article, we present a new dimension of software adaptation techniques in which we propose using the context to help the system function proactively.

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Question-Answer Means for Collaborative Development of Software Intensive Systems

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Abstract. The key problem of successful development of software intensive system is adequate conceptual interactions of stakeholders at the early stages of designing. Success of development can be increased with using of AI means including means for modeling of reasoning. In this paper a number of question-answer means for conceptual design is suggested. The base of such means is a question-answer method for conceptual decision of a software project task. All question-answer means are organized as workflows “Interactions with Experience” supported conceptual interactions in corporate network.

Keywords. Question-answer model, conceptual decision, software development

1 Introduction

There is a problem of successful designing of the Software Intensive Systems (SIS). The facts of the low success (about 30 %) in this area [2] means that till now developers of SYS have not got very important technological tools. The role of such tools can play the means of Artificial Intelligence, first of all, means supported interaction with Knowledge and Experience, modeling of reasoning, decision-making and problem solving.

The practice of the SIS development shows that the negative influence of the mentioned reasons can be lowered by applying effective question-answer reasoning for interaction with experience (and models of experience) involved in the process of development. As the number of such reasoning, for example, we can mention reasoning in the “inquiry cycle” [5] and “inquiry wheel” [6]. Similar ideas are used in the special question-answer system which supports development of the SIS [8]. In more general context the place and role of reasoning are presented in [1] from , ,. in [7] where reasoning is presented at seven levels of application together with knowledge and in [4] as model-based reasoning.

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Software development activity is usually represented in the form of workflows, each of which connects with a corresponding system of tasks. The part of such workflows provides creation of the SIS conceptual project in the form of the adequate system of conceptual models including both visual diagrams, and documents.

This paper presents the special method of conceptual designing and workflows called “Interaction with experience” that are based on Question-Answer modeling of human reasoning used in design process. The method has received the name “question-answer method for conceptual decision of the project tasks”. In the name of this method the attribute “conceptual” indicates that base actions of decision process are “conceptual actions” of stakeholders, first of all question-answer reasoning used in a design work. Such conceptual actions are needed to build an adequate conceptual representation of the SIS. Method of conceptual decision is realized in corporate environment of the question-answer processor NetWIQA (Net Working In Questions and Answers). Workflows “Interaction with Experience” is developed with orientation on Rational Unified Process [3].

2 Question-Answer Models

Different types of conceptual models are developed for tasks with certain decisions presented during development of a software intensive system and in its results. Such types include, for example, UML-diagrams, Data Flows Diagrams (DFD) and Entity Relation Diagrams (ER-diagrams). Nowadays, the visualized graphic models consisting of components and connectors between them play an important helpful role. Visual models help the stakeholders to include their skills of work with the figurative information to development processes.

Adequacy of the applied conceptual models essentially depends on how they are constructed. Guidelines are often used to support conceptual modeling. But any guideline describes typical scheme of actions and the typical scheme of reasoning applied to the certain subject domain. Such guidelines function properly, but they are not useful for coordination of various conceptual human schemes.

Historically, questions and answers were the basic means to coordinate conceptual schemes of individuals who try to find the mutual understanding in the definite task and work. Such activity is put in a basis of question-answer modeling of the task.

Question-answer model of a task $QA(Z_i)$ is formed and used on a step-by-step process of the conceptual decision of the task. Such decision usually includes “Conception”, ”Architecture” and ”Project” form of SIS representations. Usage of QA-model of any task is aimed at the coordination of human conceptual schemes.

Construction of QA-model is completed when the set of conceptual models $\{M^C{}_k\}$, chosen for sufficient understanding of task Z_i, is created. Usage of QA-model in any state on its life cycle represents the specific kind of modeling named “question-answer modeling”.

Thus, the conceptual decision of task Z_i includes decisions of a set of tasks $\{Z^C{}_k\}$, each of which is aimed at construction of corresponding model from the set

$\{M^C{}_k\}$. Methods and means of QA-modeling represented below are applied not only to the task of SIS design, but also to any "service task?" $Z^C{}_k$.

Question-answer models are the systematized representation of the reasoning used during the decision of the task Z(t) and kept in special QA-database. Any QA-model is a set of interactive objects such as "question", "answer" and "task" with the certain attributes and operations. The structure and content of QA-model are defined according to the following views:

- Logic view, fixing representation of QA(Z(t)) within the frame of logic of questions and answers (visual representation includes a tree of the tasks where each task is presented by corresponding QA-tree).
  - Conceptual view, opening ontology of the task Z(t) and process of its creation.
  - Communicative view, opening question-answer processes as communicative interactions of the stakeholders concerned in conceptual decision of the task Z (t).
  - Activity view, registering "questions" and "answers" as objects of activity.
  1. View from positions of experience, fixing experience involved to the decision process.

Each of the presented views (step by step) is formed and registered in QA-base of the project. The certain set of "concern", models, documents and functions providing construction and usage of views are connected with each view. The logic view is a primary base of all these conceptual units, which are produced by developers with special means of analysis, transformation, representation and visualization (Figure 1).

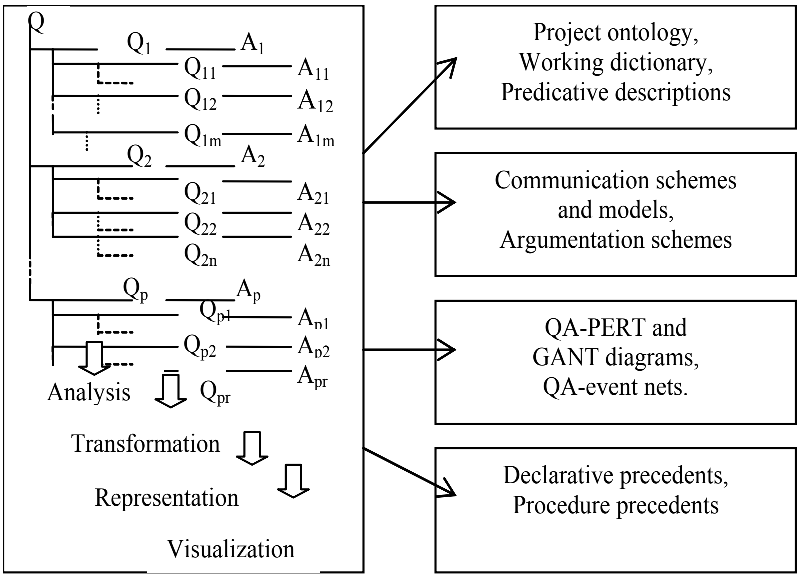

Figure 1.Environment and content of QA-model

Such set of views is used for construction of QA-models of project and service tasks. The general case of QA-model of task Z(t) is defined as an integrated set of "views" on the task, which is realized as a special structure of data registering a logic view, variants of its transformation and representation, including visual representation through results of the analysis.

Let us pass to specifications of QA-models. QA-model QA(Z (t)) of the task Z(t) is created as a system S of dynamic interactive objects QA(Z(t)) = S({XI}), each of which has an unique index name XI definite type X. Names of types (X=..) reflect types of questions and answers. Indexes of names are assigned automatically.

Each object XI(T_i, Sb^1_j , Sb^2_k, t, G_n)} uses the following attributes: T_i - the description of "object"; Sb^1_j - the identifier of the subject responsible for "object"; Sb^2_k - the identifier of the subject (generally the compound subject), concerned in "object"; t - the moment of time in which the current state of "object" has fixed; G_n – the set of other attributes of "object" XI representing it in the base of the project.

3 Essence of QA-Modeling

Question-answer models, as well as any other models, are created "for extraction of answers to the questions enclosed in model". Moreover, the model is a very important form of representation of questions, answers on which are generated while interaction. Questions are fixed in QA-models obviously in the form of "objects-questions" and implicitly in forms of ambiguities used in textual QA-units.

The essence of QA-modeling is an interaction of stakeholders with artifacts of process and its current results and it helps them:

- To enrich model QA(Z(t) by adding its structure by the new question or/and answer.
  - To realize a number of variants of the analysis, interactive (+ collective) inspection and/or validation of state QA(Z(t)) or its fragments, directed on revealing of mistakes and defects of design decisions,and also their conformity to norms and samples.
  - To perform predicative analysis aimed at an establishment of adequacy of model.
  - To use results of the analysis for establishing of understanding and mutual understanding in group of the stakeholders.
  - To extract of requirements and restrictions for the SIS.
  - To manage of changes in the project.

2. To view the results of monitoring states of designing process.

4 QA-Method for Conceptual Decision of the Project Tasks

In most general case application of a method begins with the first step of question-answer modeling initial statement (Figure 2) of a development task $Z^*(t_0)$. In special cases of its application initial statement of a task is included in a task's tree corresponding to the design technology with which it will be used.

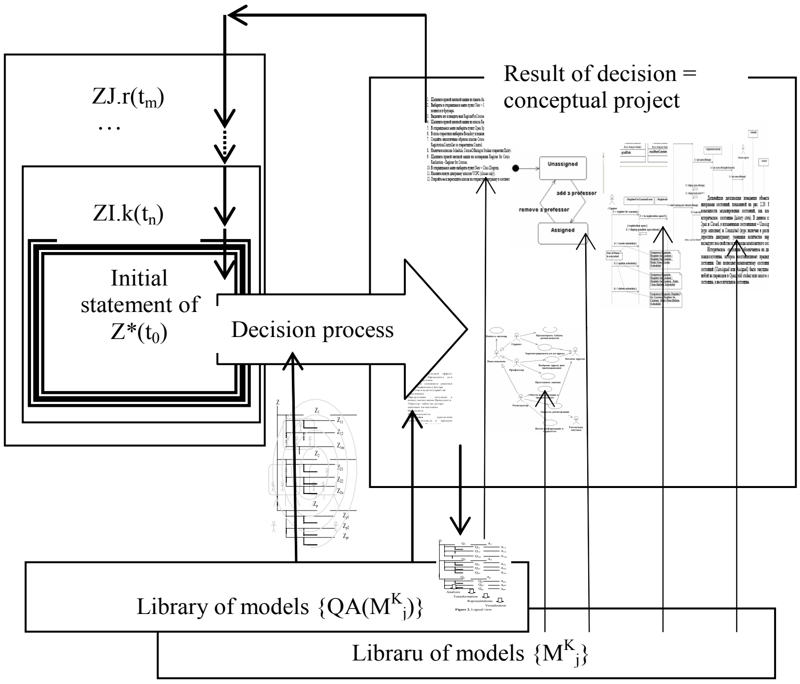

Figure 2. Scheme of method

The essence of a method consists in the following:

- The system of tasks of conceptual designing is formed and solved according to a method of stepwise refinement.
  - The initial state of stepwise refinement is defined with system of normative tasks of "life cycle the SIS" which is included the main project task Z*(t0). The base version of normative tasks corresponds to standard ISO/IEC 12207.
  - Realization of a method begins with the formulation of the main task statement in the form, allowing to start constructing of the prime conceptual models.
  - During detailed elaboration in the system of tasks join not only the project tasks connected with specificity the SIS, but also service tasks, each of

which is aimed at creation of the corresponding conceptual diagram or document.

- For each service task its question-answer model is created on the base of the definite question-answer pattern from the special library.
- During conceptual decision of any task, included in a task tree of the SIS project, additional tasks can be discovered and included to the system of tasks (Figure 3).
- General conceptual decision integrates all conceptual decision of all task included in a task tree of the project.

3. Conceptual decision is estimated as completed decision if its state is enough for successful work at the subsequent development stages of the SIS. The degree of sufficiency is obviously and implicitly checked. Useful changes are added to the more adequate conceptual representation of the SIS.

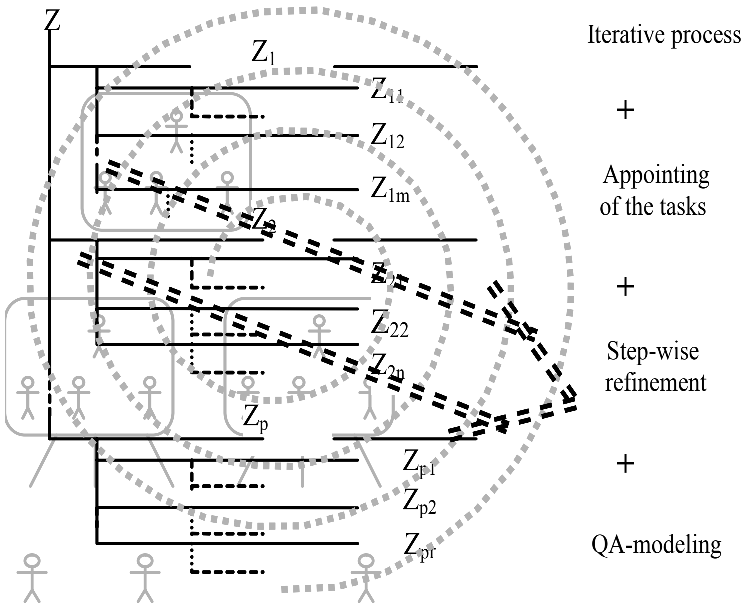

Figure 3. Task's tree of development process

5 Workflows "Interaction with Experience"

The workflows called "Interaction with Experience" is realized as the application of the question-answer processor NetWIQA[8]. QA-processor is an environment for collaborative development of the SIS. It is realized on the base of architectural styles "Client-server", "Repository", "Model-view-controller" and "Translator". All named styles were integrated according to object-oriented and component-oriented paradigms. The base version of QA-processor can be opened for WEB-access of stakeholders from Internet.

Noted application of the QA-processor is developed as the model of Rational Unified Process (RUP) technology providing creation of the conceptual project. For creation of the conceptual project the workflows “Business modelling”, “Requirements”, “Analysis and design” and also three supported workflows are used. The application is aimed at construction of 16 artefacts, including all architectural artefacts of the RUP.

The basic role in realization of a method is carried out a workflow of question-answer reasoning QAR(t). Therefore we shall present a number of details connected with dynamics of this workflow.

At definite time t_i the reasoning QAR(t) goes to QAR(t_i)-state, which has its causal potential that gives the possibility to move the reasoning forward to the next state QAR(t_{i+1}). In this aspect the “history” of previously made work, represented in QAR(t)-codes, influences the next rational step of reasoning. Next steps both for reasoning and for design can be defined by means of question-answer analysis of QAR(t)-codes.

General statement of each project task should be defined before Question-Answer working with this task. Special definition of the task (as its general statement) uses a special pattern to present a task as 3 structured text blocks.

The first reflects the main purpose of a system under design, which is specified by its potential users. Here we begin the work with the basic Use-Case diagram for the task in UML language.

The second defines the main techniques to perform Use-Case diagram for the task. It provides construction of the basic diagram of business -objects of UML.

The third defines technology of implementation of a system under design. Information of this block is applied in conceptual design as context information.

Analysis of a text T_0 of the general statement of a task and its translation to PROLOG-like language are used for extraction of questions to begin and continue QAR.

More detail it is based on step by step registering of questions and answers in accordance with following technique:

- The set of questions $\{Q_i\}$ is taken from the text $\grave{O}_0$ and coded by adequate texts T (Q_i).
  - Actions of item 1 are executed for each text T (Qi, therefore the set of questions $\{Q_{ij}\}$ and their codes $\{T(Q_{ij}\}$ is formed. Actions of item 2 are used to control the correctness of question codes and for the choice of those questions $\{Q_k\}$ which will be used for the next step of detailization from the set Q = $\{Q_i\}\cup\{Q_{ij}\}$. Other questions are recorded for their application in the subsequent steps.
  - Set of answers $\{A_k\}$ and their codes $\{T(A_k\}$ is formed and registered in QA database.
  4. Each text T(A_k is processed as the text $\grave{O}_0$. The cycle 1-4 is repeated until the project comes to the end.

All project tasks $Z^P=\{Z^P{}_r\}$ are derived from process described above. Any task $Z^P{}_r$ is a question qualified by stakeholders as a task-question answer which can be found only through decision process. Any service task $Z^C{}_m$ has its QA-pattern kept in special library. Such pattern helps to build model QA($Z^C{}_s$) for definite conceptual artifact. The work with questions, answers, QAR and conceptual artifacts are executed with the help of technological tasks $Z^T = \{Z^T{}_n\}$ generally described below.

6 Conclusion

This paper presents QA-method for conceptual decision of the SIS project tasks. Method is based on a stepwise refinement and QA-modeling. It can help to build the system of conceptual models which represents the SIS on levels of descriptions presented "Conception", "Architecture" and "Project". Means of method are organized as a set of workflows called "Interaction with Experience", and can be used additionally to the RUP as a model of its workflows. Means of QA-modeling are adjusted to support Conceptual Design of Software Intensive Systems, their documenting, and training of a design team in a closed corporate network. Such means can be open for stakeholders in Internet through the defended WEB-access. Proposed means have confirmed the practical usefulness in development of a number of the SIS, including "Automated system for management of distance education" and "Automated system for planning of cargo transportation".

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Bringing together space systems engineering and software engineering processes based on standards and best practices

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Abstract. The growing complexity of the current space systems results an increasing responsibility for the software embedded in them. This is particularly significant when the systems are employed for space critical missions. Usually the software has rigid real time requirements to fulfil which demands high reliability and a disciplined development process. This paper relates the effort of defining a set of software development processes for the on-board computer flight control software (SOAB), a component of the Brazilian Satellite Launcher (VLS), developed by the Instituto de Aeronautica e Espaco – IAE. To achieve the strict requirements for space missions, the SOAB development team's degree of maturity and technological proficiency had to harmonize with a well defined set of software development processes integrated into the systems engineering. Furthermore, these processes definition had to consider international space systems engineering standards and standards of quality established by IAE. Best practices in software engineering were considered as well.

Keywords. SOAB, software development process, systems engineering, standards

1 Introduction

Engineering in space systems must be a team activity where the various individuals involved are aware of the important relationship between specialties and their roles in the development as an organizational process. Successful accomplishment of engineering objectives requires not only a combination of technical specialties and expertise, but also principles and best practices to harmonize the systems engineering activities and the software development process. This is particularly significant while developing critical systems where the embedded software is required to perform critical functions, mostly in real time. The on-board computer flight control software (SOAB) for the Brazilian Satellite Launcher (VLS) is

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included in this category of critical software. The flight control software takes critical responsibility for the control of the launcher – except for the launcher destruction – from a few minutes preceding the lift-off until the satellite has been deployed into the Earth's orbit. The software is also responsible for the checkout of various launcher systems, including inertial platforms, autopilot chain and sequencing chain. Beside that, each flight has different characteristics and the software has to be prepared to incorporate new issues like a new type of inertial measurement unit. Consequently, this requires well-organized processes of development and maintenance that are directly or indirectly responsible for the specification, acceptance testing, and execution of flight software for the VLS.

On one hand as SOAB is part of the VLS space project, its development process is intrinsically related with systems engineering activities, management and product quality assurance of the organization. On the other hand, the way of developing software has to be consistent with software engineering methodologies. The final outputs of the working process are operational prototypes made available for extended operational validation. The results in terms of technology exploitation experience and novel implemented solutions become an asset for reuse for future space projects.

This paper presents the result of structuring and defining a set of software development processes based on the Brazilian Standard for Quality Management Systems [1] which has been adopted by IAE as a reference for its Quality Management System and also on ESA ECSS Architecture for Space Projects [3, 4, 5], particularly the E-40 family [6,7]. The processes definition also considered the software system life cycle, the development environment, best practices and techniques.

This paper is organized in six sections. Section 1 is the introduction, followed by section 2 that presents the importance of the adoption of space standards. Section 3 presents the relationship between the software development process and the systems engineering process in the organization. Section 4 describes how a set of processes was structured and Section 5 presents the visual representation chosen to symbolize these set of processes. Finally, the conclusion and future prospects are summarized.

2 The role of space standards

During the structuring and definition of the set of processes to be used for the SOAB development, the standard ECSS E-40 Part 1B [6] and the Unified Software Development Process – UP [9] were considered as standard process and framework respectively, due to their specific intended use for software development. They served as a guide in recognized methods for engineering tasks and managing of a software system throughout its life-cycle, addressing the tasks performed by software engineers.

The Brazilian Standard [1], due to its more general role in quality management, was used more as a guide for product quality and it was also a helpful guide to specify the requirements for the deliverable or result, especially in software product acquisition. Furthermore, this standard provided a good orientation for the necessary engineering activities to carry on a system development, while ensuring that the system is properly designed with quality. The guidance of this standard could not only be applied to a new system but also as an incremental enhancement to an existing system. By addressing system requirements, the content of this standard helped to describe an integrated approach to system development.

In order to adopt the Brazilian Standard ABNT NBR 15100, E-40 Part 1B and the Unified Software Development Process [9] in a consistent way, the technical efforts were aimed in:

a) Defining software development processes totally integrated into the systems engineering activities and the space system life cycle that could be implemented in an existent environment, considering the restrictions of the infrastructure and the development team;

b) Defining a methodology of development, associated with techniques, that should take in account not only the environment and the related conditions in which the software system would be deployed, but also functional and performance requirements and quality factors, like usability and safety;

c) Defining processes for requirements, design, codification, testing, delivery, maintenance and acquisition, which are necessary to provide life cycle support for the software system;

d) Establishing a manner to represent the set of processes in such way that they could be easily understood and employed by the development team;

e) Publishing the set of processes in the same development environment (Computer Aided Software Environment - CASE) in order to make them directly accessible by the team in their working environment.

3 Real-time space software and the systems engineering process

Integration of systems and software engineering processes in space systems development activities is an ongoing challenge. The ability to deal with a high level of complexity in a flexible way makes software a critical and growing part of space segments and ground segments products. Software engineering can be found at several parts of space systems, embracing high level system functionality and also basic functions implemented in firmware.

According to Blanchard [2], systems engineering and analysis, when joined with new and emerging technologies may expose unpredicted opportunities for creating new and better systems and products. However, there used to be a lack of integrity between systems engineering and software engineering teams during the SOAB development. This situation had caused several problems for the software development team since the software system specification was usually delivered by the systems engineering team without any participation of the software team in its elaboration. Some decisions were made that would strongly affect the software development and not always in a smooth way. Aware that this situation had to change, a new software development approach was elaborated and adopted by the software team, with the approval of the systems engineering staff and the quality group.

According to this new software development approach and based on [6], the requirement engineering process, in which the software requirements and specifications are defined, has a special role in the software engineering activities considering that these activities are purely intellectual and the outputs are normally documents. Even the code can be taken as a special form of electronic document. At this point resides the importance of adopting the ECSS-E-40 Part 2B [7], which focus is on the requirements for the structure and content of the documentation produced.

The requirement engineering process [6] includes the activity of System Analysis and Architecture, which results in a Software System Specification that is delivered to the software team to be reviewed in the System Requirements Review (SRR). This review has the participation of both teams: systems engineering and software development teams. The consolidation of the Software System Specification generates the requirement baseline, which will serve as a base for the SOAB requirements during all its development.

Subsequently, the software development team will start the requirements engineering analysis activity in which the requirements and specifications of the software are defined. This activity is part of the set of processes mentioned in the next section and usually takes a large and underestimated time in the whole development. Aware of that, the software quality team gives special attention when planning the development schedule. As a result of this activity, a software technical specification is elaborated and reviewed jointly with the systems engineering team in the Preliminary Design Review (PDR). In this review, the systems engineering team will verify if all the requirements with respect to the requirements baseline are captured in the technical specification and if the software architecture is well identified. This is the opportunity to make sure the software will totally fulfil the systems requirements, considering all the environmental definitions and restrictions.

From this point on the software team, based on a set of processes (section 4), will carry on the software development, which includes two more internal formal reviews apart from those reviews made jointly with the system engineering team: Detailed Design Review (DDR) and Critical Design Review (CDR). The CDR is conducted at the end of the design and the completeness of the software validation activities with respect to the technical specification is reviewed and verified.

Once the CDR is realized, the subsequent planned activities are carried out. The accomplishment of these activities will lead the software team to the next formal review, the Qualification Review (QR), which is conducted in cooperation with the systems engineering team. At this point, the system and software engineering processes come together again to verify if the software meets all its specified requirements in the approved requirement baseline, before its integration into the system. The consistency and completeness of all software documentation are also reviewed and verified.

The next formal meeting with both teams is in the Acceptance Review (AR), which aim is to prepare the software to be integrated into the space system, where a summary of tests reports and the software user manual are reviewed. The consistency and completeness of the documentation are verified again. At this point, the system becomes internally validated and it is delivered to the systems engineering team in order to start the Software Acceptance activity.

The Software Acceptance and System Acceptance activities [6], as part of the systems engineering process, will integrate the software into the system and perform all the required operational tests. These tests are executed to guarantee that the software is working correctly and accurately in the system environment as well as with other system components.

4 Structuring a set of software development processes

As part of IAE's Quality Management System implementation [1], it was highly recommended that all of its divisions that develop VLS components should document the manner or method of realizing their products, outlined as operational procedures. However, in order to support the software development approach detailed in the previous section, and to align this approach with international space standards, an organized and documented way of software development should also be set down. To meet both necessities, a set of software development processes were defined in a high level, considering jointly the IAE's Quality Management System recommendations, the ECSS-E-40 family and the established best practices of the Unified Process.

To meet the Brazilian Standard [1] recommendations about the product realization, the operational procedures were written in a level of detail that could be understood by other individuals besides software engineers. However, the software engineering team would need a more detailed description of this set of processes to allow them to work properly and uniformly, employing best practices in a consistent way. The result was a set of software development process, or operational procedures, in which the activities were split up in a more comprehensive and detailed level to be employed by the software engineers. The CASE environment facilities were fundamental to help the graphic representation of this set of processes and their respective sublevels as well.

The first step considered in order to structure the set of software development processes was the tailoring of ECSS-E-40 standards. The result of the tailoring activity was a document, which served as a guide for future on board flight control software development.

Although ECSS-E40 Part 1B covers most of the activities of a software development, there are some other important activities not totally covered by this standard. In this case, the Brazilian Standard [1] and the best practices of the UP served as a complement to base on the processes activities.

There was a leading culture of how to develop software among the members of the software team that reflected the way they had been working for years. This was a big issue to be treated adequately as well. The team's adherence and trust in adopting the set of processes was fundamental for their implantation.

A set of six software development processes was initially defined:

1. Requests Analysis;
2. Software System Development;
3. Software System Delivery;

4. Software System Acquisition;
5. Software System Acceptance;
6. Software System Maintenance.

The Requests Analysis process reflects the way the software team handles all the requests of services and it was mainly based on the organization workflow. These requests may be for a new software system development, maintenance of an existing space software system or for providing some technological assistance (consulting, training, etc.).

The main body of the Software System Development process was strongly based on ECSS-E-40 Part 1B standard. This process was the hardest one to be defined because it reproduces the principal effort of the software group. Besides ECSS-E-40 Part 1B, its definition had to bring together software development methodologies, software life cycle and best practices of software development.

The Software System Delivery process was delineated to complement the Software System Development process and it defines the means the software is delivered to the system engineering team, after being internally validated.

As being a system itself, SOAB or any ground software system segment may have a few of its components or, in some cases, the entire system, acquired from suppliers. Considering that IAE's Quality Management System follows the NBR 15100 recommendations and they are very rigorous regarding how the acquisitions and the suppliers control should be, a Software System Acquisition process was defined to fulfil these recommendations. The Brazilian standard NBR 15100 was adopted since the ECSS-E-40 Part 1B does not give recommendations about the acquisition process, as its primary focus is on software development.

The Software System Acceptance process was outlined to complement the Software System Acquisition process and it details how the software should be received from the supplier by the software team. In this case, besides other issues, the software team has to be aware of the integration tests that have to be executed in order to accept the system properly.

The last listed process is the Software System Maintenance that was identified to fix and maintain the several SOAB configurations to keep them operational for different VLS flights.

It is worth to mention that all the activities represented in this set of processes have another level of detail that was implemented as hyperlinks in the CASE environment, where not only the activity itself is better described via another graphical representation (UML activity diagram), but also the role and responsibilities for each activity

5 A visual representation and integration of the defined process in a CASE tool

Once the set of processes was defined, it was necessary to consider how to implement it and achieve maximum efficiency in following it. A process can be defined and represented as a set of interrelated activities, which transforms inputs into outputs [8]. In order to have an easy and more comprehensive view of the set of processes, they were drawn in a CASE tool (IBM© Rational Suite) using an adaptation of the UML activity diagrams. Each process in the set was represented by one activity diagram, where each activity in a process was mapped into an activity of the UML activity diagram. Activities in the processes were also detailed in another activity diagram, when necessary.

The choice of incorporating the visual representation of the process in the CASE environment helped to bring together the development environment, the process of development itself and the best practices of the Unified Process (UP), allowing to apply the very same techniques to disciplines other than software that also use models, especially systems engineering, promoting more integration among them.

The CASE environment allowed the project managers to use the IBM© RUPBuilder to select, configure, create custom views and publish the defined set of processes for their projects. They could start from the pre-established set of processes and make further choices based on their project's unique needs. Additionally, they could publish the processes in Web sites.

The way of publishing a customized process was managed from the user interface, which gave the project managers the means to describe their process selecting components from the defined set of processes to compose their own customized process. They could also create different process views of the customized process for different members of the software team.

6 Conclusion and future prospects

This paper presented the effort of structuring and defining a set of software development processes for the on-board computer flight control software (SOAB), part of the Brazilian Satellite Launcher (VLS), developed by the Instituto de Aeronautica e Espaco (IAE). This set of processes was based on international space systems engineering standards and also standards of quality established by IAE. The result was a disciplined approach for software development, integrated into systems engineering, that increases the chance of releasing a software system more reliable, which meets the strict requirements for space missions. Furthermore, this approach brought a better integration between the systems engineering team and the SOAB development team, in a desired degree of maturity. In order to have this set of processes incorporated into the CASE environment, a visual representation of the processes was prepared, facilitating their use and integration into the resulting work products.

As future prospects, it is still necessary to identify and implement a mechanism of continuous improvement of the set of processes, based on the experiences acquired by the software team in employing them. The suggestions of the systems engineering team colleted mainly throughout the formal reviews have to be considered as well. This mechanism should take advantage of the facilities of the CASE environment in order to guarantee that the suggestions and feedbacks of the software team members, systems engineering team and quality group are considered in time. The continuous improvement of the processes ought to be a real and tangible goal to turn the development of critical space systems with embedded software less risky and more successful.

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A Brazilian Software Industry Experience in Using ECSS for Space Application Software Development

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Abstract. This paper presents the tailoring of ECSS software product assurance requirements aiming at the development of scientific satellite payload embedded software by a Brazilian software supplier. The software item, named SWPDC, developed by DBA Engenharia de Sistemas LTDA within Software Factory context, is part of an ongoing research project, named Quality of Space Application Embedded Software - QSEE, developed by National Institute for Space Research – INPE, with FINEP financial support. Among other aspects, QSEE project allowed to evaluate the adherence of a Software Factory processes to INPE's embedded software development process requirements. Although not familiar with space domain, the high maturity level of such supplier, CMMI-3 formally evaluated, facilitates the Software Factory to comply with the requirements imposed by the custumer. Following the software verification and validation processes recommended by ECSS standards, an Independent Verification and Validation - IVV approach was used by INPE in order to delegate the software acceptance activities to a third party team. ECSS standard tailored form contributions along the execution of the project and the benefits provided to the supplier in terms of process improvements are also presented herein.

Keywords. Software quality, software development processes, space mission lifecycle,

1 Software for Space Systems

In space systems, a software product is part of a network comprising several systems. Space systems include manned and unmanned spacecraft, launchers, payloads, experiments and their associated ground equipment and facilities. Such software includes firmware components. Space projects are generally expensive and demand considerable amount of time to be completed.

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The insertion of industry into the space programs environment as subsystem supplier has demanded improvements in the space agency's project management processes in order to successfully accomplish the projects. In different areas of application, one can see both industrial and governmental initiatives towards standardization and the use of best practices for project management. European Cooperation for Space Standardization – ECSS is a great result of cooperative efforts among the European Space Agency - ESA, National Space Agencies and European space industry association.

Typical space mission lifecycle is the basis of the model used by ECSS to manage the development of the different space mission subsystems, which includes space application software. Nowadays, space agencies have dedicated special attention to the software project management. Such concern is expressed in ECSS volumes for management, quality assurance and software engineering.

This article addresses the Software Product Assurance volumes [ECSS-Q-80A and B] only. The fundamental principle of this standard is to facilitate the customer-supplier relationship assumed for all software developments, at all levels. They have contributed to these objectives by providing a set of requirements to be met throughout the system lifetime which involves the development and maintenance of space application software. Such requirements deal with quality management and framework, lifecycle activities and process definition, and quality characteristics of the software product [3].

Once the objective of software product assurance is to provide the customer with adequate confidence, the standard is usually tailored for a particular contract by defining specific subset requirements.

In order to evaluate Software Factory model as a satellite payload embedded software item supplier, the standard was tailored for the *Quality of Space Application Embedded Software - QSEE* project, developed under the National Institute for Space Research – INPE coordination. INPE, within such context, plays the role of the customer [1].

This paper is organized as follows: section 2 introduces ECSS-Q-80 structure and tailoring guidelines; section 3 presents DBA's Software Factory model and the software development processes followed by the supplier; section 4 discusses the standard tailored form for this particular software development item, the satellite payload embedded software – SWPDC, a case study of QSEE project. Finally, section 5 concludes with contributions resulting from standard tailored form to the project execution and the benefits provided to the supplier in terms of process improvements.

2 ECSS-Q-80 Structure andTailoring

According to the structure of this ECSS Software Product Assurance standard, the requirements are grouped in the following three categories: (i) management requirements and software product assurance framework; (ii) software lifecycle activities and processes requirements; (iii) software products quality requirements, including both executable code and related products such as documentation and test data. Each requirement has a corresponding *Required Output* identified that, among others, is intended to assist the customer in selecting applicable requirements during the tailoring process.

Tailoring for software development constraints takes into account the special characteristics of the software being developed, such as the software type (database, real-time) and the system target (embedded processor, web, host system), and the development environment as well. Those issues are subject of Space System Software Engineering Process as defined in ECSS-E-40. Together, the two standards specify all processes for space software development [2].

In order to carry out the tailoring of the software product assurance process under the scope of QSEE project without addressing ECSS-E-40, two relevant aspects must be pointed out. First, the software product is a satellite payload embedded software, therefore, a critical item. Second, although the supplier is not familiar with the technology and software development environment imposed by the customer, the Software Factory maturity CMMI-3 provides the customer with confidence in terms of its solid software development structure based on well established processes. Thus, such tailoring took into account the software development processes and the software lifecycle adopted by the supplier.

3 DBA´s Software Factory Model

The Software Factory concept uses industrial manufacturing fundamentals, such as standardized components, specialized skill sets, parallel processes and a predictable and scalable quality consistency. It can reach a higher level of application assembly even when assembling new or horizontal solutions. Software Factories have gained recent popularity as a cost-efficient way to reduce the time spent on the software development. Conceptually, Software Factories represent a methodology that seeks to incorporate pre-built standard functionalities into software which is typically disaggregated by domain.

The macro-flow diagram on the left of Figure 1 depicts the software development lifecycle typically performed by DBA. The related sub-processes represented by each of the four columns on the right side of Figure 1 show the adherence to SW-CMMI key process areas: Process Control, Change Management, Configuration Management and Quality Assurance.

In order to be produced by DBA´s Software Factory (FSW), a Software PROJECT shall be characterized and a particular project team be allocated to sort out the requirements and software development project management activities. Figure 2 presents the relationship among the PROJECT and FSW teams.

Prior to implementing such project management structure, the following steps and documentation should be forthcoming:

1. Customer provides an initial view of schedule and scope of the proposed job.
2. DBA gives an initial assessment of the effort required to meet those requirements (including an estimate number of Function Points required), and whether it can provide such services.
3. Customer will then further specify the elements of an application development service order, along with the following items: (a) All available

documentation of the project, architecture, patterns, interfaces, etc.; (b) Hardware and software configurations for the development and production environment; (c) Restrictions that should be observed during the software development.

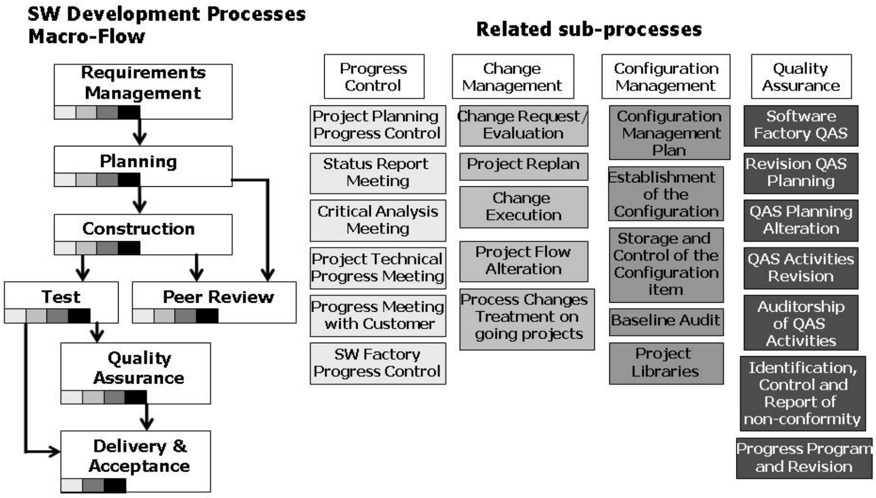

Figure 1. DBA Software Development Processes and related Sub-processes

4. Service Level parameters: DBA and Customer jointly establish the artefacts that are deployed at Analysis and Design and that describe the technical specifications necessary for FSW programmers to implement and test the code. Possible artefacts are: Use Case Specification; Information flow for System X - Template to describe the whole system information flow (to detail information flow for each Use Case).

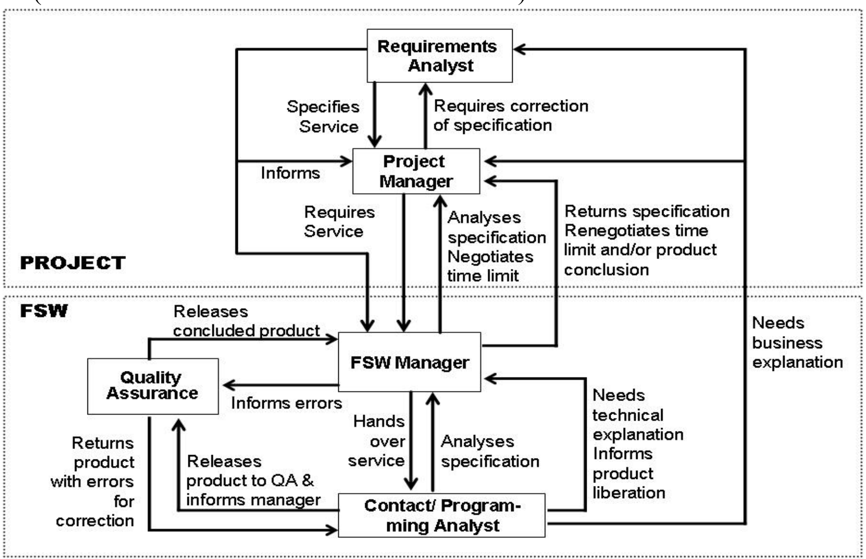

Figure 2. PROJECT and FSW relationship

5. The Project Designer will then issue a production order (OP) along with a set of artefacts to be provided (Use Case, Classes and Sequence diagrams).
6. The Project Test Plan including testing guidelines that should be followed for FSW developed product acceptance
7. Test Design **-** describes test cases for each technical specification.

Since SWPDC software supply by the FSW is subject of space domain application technology transfer to the Brazilian software industry, the PROJECT team was formed by one senior DBA Project Manager and two Software Analysts. The latter have been on-job trained in similar embedded application at INPE laboratory during six months before the SWPDC was effectively started.

4 Tailored Requirements

Software product assurance plays a mandatory role within the overall software engineering process. The complexity of software development and maintenance requires discipline to build quality into the product from the very beginning.

According to ECSS-Q-80B, the software product assurance requirements are grouped in three sets of activities: (i) the assurance programme implementation, (ii) the assurance of the development and maintenance process and (iii) the assurance of the quality of the software product.

Table 1. Requirements related to software product assurence programme implementation

Requirement	Description	Tailored Form	Tool	Document
Contractual Aspects	Supplier and Customer define a contract	Established when project QSEE was approved by governmental financial support (FINEP)	-	Agreements on Project Proposal
Software Product Assurance Planning and Control	Supplier provides a plan complying requirements and being approved by customer	SPA items included in DBA Software Development Plan document, reviewed and approved in SSR	Complia nce matrix	SDPlan
Software Product Assurance Reporting	Supplier provides mechanisms for assessment of the current quality of the product	Reviews data package and tool allowing the customer to follow each Production Order (OP) into the FSW	Reports from a proprieta ry tool (SAF)	SDPlan
Non-conformance	Software Reviewer Board and baseline established by supplier/ customer	Formal Reviews point out the discrepancies (RIDs) and project control meetings	-	RB
Software Problem	Supplier defines and implements procedures for logging, analysis and corrections of software problems	Software Problems identified in the FSW have well established internal procedure. RNCs are problems identified on acceptance testing.	DBA FSW work-flow involves QA team	SDPlan

The tailoring process was carried out following these three groups in a supplementary way by means of careful analysis of their requirements. Table 1, Table 2 and Table 3 summarize, as examples, some of the applicable requirements analyzed and their tailored form for SWPDC product assurance. The first two columns of each table contain the ECSS-Q-80 requirement and its description, respectively. The column entitled *Tailored Form* describes the way the recommended requirement has been tailored in this project. Whenever a facility is provided to support the requirement, the *Tool* column introduces it. The *Document* column lists the customized documents in which such requirement is complied with. Table 1 lists some requirements corresponding to the group (i).

Requirements Baseline (RB) is the main document provided by customer. It imposes six formal reviews: Software Specification Review (SSR), Preliminary Design Review (PDR), Detailed Design Review (DDR), Critical Design Review (CDR), Qualification Review (QR), and Acceptance Review (AR). RB also defines the documents to be provided by the supplier: Software Development Plan (SDPlan), Software Test Plan (STPlan), Software Technical Specification (STSpec), Software Design Document (SDD), Software Test Specification (TestSpec) and Test Report (TRep). The following documents are required from the independent team: Independent Verification and Validation Plan (IVVPlan), Independent Verification and Validation Test Specification (IVVTSpec), Independent Verification and Validation Report (IVVRep). The Formal Reviews are documented in Technical Review Report (TRRep) which includes identified discrepancies (RIDs). During the acceptance phase, Non-conformance report (RNC) is delivered by IVV team to the supplier with a copy to the customer.

In respect to ECSS requirements presented in Table 1, a brief analysis about their correspondence with DBA Software Development processes and related sub-processes (Figure 1) shows that such requirements have met the Progress Control and Quality Assurance sub-processes.

Table 2 lists some requirements corresponding to group (ii). Since ECSS-Q-80B subdivides the software assurance process requirements in three categories, that organization was also adopted in that table.

ECSS requirements related to software lifecycle are met by two DBA Software Development processes: Requirements Management and Planning. And by related sub-processes: Progress Control and Change Management. The process assurance requirements applicable to all software engineering processes are met by Peer Review, Quality Assurance and Delivery & Acceptance processes. And by related sub-processes: Configuration Management and Quality Assurance. Whereas the process assurance requirements related to individual software engineering activities are met by Construction and Test processes. And by related sub-processes: Change Management.

Table 3 lists some requirements concerning group (iii). The correspondence between the requirements on Table 3 and DBA processes presented in the Figure 1 macro-workflow is consequence of the software development lifecycle phases. Thus, the first requirement row meets the Requirements Management and Planning processes. Second requirement meets the Construction process. And the last two rows meet the Test, Peer Review and Delivery & Acceptance processes.

Table 2. Requirements related to the software process assurence

Requirement	Description	Tailored Form	Tool	Document
Software Development Lifecycle				
Life cycle definition and review	Software life cycle defined by supplier and reviewed by customer	Software development lifecycle followed by DBA FSW has been approved by the customer on SSR	DBA Work-flow	SDPlan
Milestones	A series of technical meetings or reviews shall be defined	Reviews have been established on the RB by customer according to space mission life cycle.	-	RB and SDPlan
Applicable to all Software Engineering processes				
Documentation of Processes	Software project plans cover all software activities	Development Plan and Test Plan provided by supplier and by the IVV team	-	SDPlan, STPlan, IVVPlan
Handling of Critical Software	Apply measures to assure software confidence	IVV team designs model-based testing for automatic test cases generation.	CoFI Condado	IVV Plan IVVTSpec IVVRep
Software Configuration Management	Supplier shall use a configuration management tool.	The system used by the FSW process has been approved by customer	VSS	SDPlan
Verification	Verification plan describes facilities, training and skills to carry out the verification activities	FSW comply the reviews imposed in RB adding pair review (internal verification technique). IVV Plan is provided by the independent team.	-	RB, SDPlan, IVVPlan
Related to Individual Software Engineering activities				
Software Requirement Analysis	Requirements specification shall be provided by customer as input.	Technical Specification document was elaborated by supplier taking RB as input customer provided	-	RB and Protocol Spec TSpec
Architectural Design	Use of a design methodology and design standards appropriated to the software type.	Customer required UML artefacts on Software Design, usually adopted in the FSW, and provided SDD document template.	Interprise Architecture	SDD
Software Delivery and Acceptance	Customer judges whether the product is acceptable, following previous agreement criteria.	The acceptance process defined in RB focus on testing at instrument level, subsystem and system. Model-based testing is used in the acceptance process.	CoFI methodology MME Condado	IVV Plan IVVTSpec IVVRep

Almost every ECSS-Q-80 requirement has been analyzed during tailoring process. The exceptions are: Supplier Selection & Control and Procurement processes because they are related to activities out of FSW scope. It is worth mentioning that the Assessment and Improvement Processes, Process Metrics and Product Metrics are internally executed by FSW to support the processes presented in Figure 1.

Table 3. Requiments related to the software product quality assurance

Requirement	Description	Tailored Form	Tool	Doc.
Technical Specification	Software requirements shall be documented in a Software Technical Specification	Complete, detailed and unambiguous requirements are provided by supplier taking into account RB as input.	Traceability matrix	RB and STSpec
Design and Related Documentation	Software design with minimum hierarchy dependency and interfaces among software components	SDD produced by FSW contains the solution to the requirements of the STSpec. Use Case artefacts from UML are recommended.	-	SDD
Test and Validation Documentation	Detailed test planning (test cases, procedures, results) shall be consistent with test strategy.	A set of document was defined by customer in order to cover the two testing level strategy (internal to FSW and IVV)	-	STPlan, TestSpec IVVPlan, IVVTSpec
Reports and Analysis	Reports of all assurance, verification and validation activities	Two report documents were required to cover the two testing level strategy (internal to FSW and IVV). Also a RIDs and RNCs..	-	TRep IVVRep. TRRep

5 Conclusions

The tailored form contributed to simplify the embedded software technology transfer process from INPE to DBA. Specific requirements concerning independent verification and validation carried out by a third party team were defined because the full validation of the software product on the target computer was not feasible within the FSW context. This team participation on the reviews allowed for early understanding of the software operational behavior which contributed to the applicability of model-based testing techniques as part of the acceptance process.

Although not familiar with space domain, the supplier maturity level, CMMI-3 formally evaluated, facilitates FSW to comply with the requirements imposed by the customer. The project-oriented approach adopted by DBA to deal with the well stabilized processes of its FSW minimized the difficulties inherent to adding new project knowledge domain to FSW environment.

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Satellite Simulator Requirements Specification based on Standardized Space Services

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Abstract. The high cost and the compression of the development timescale of a realistic satellite simulator motivated the definition of a set of functional requirements based on standardized space services, which is presented in this paper. In order to improve as much as possible reusability and consequently decreasing cost in development, the use of standards were intensively adopted specially for the satellite independent functions, namely, data handling and communication among ground and on-board systems. Functions related to the on-board data handling computer and its communication with the ground systems were based on the ECSS-E-70-41A standard, which focuses on telemetry and telecommand packet utilization definition. The protocol supporting the ground and on-board system communication, at several layers, were based on the Consultative Committee for Space Data Systems (CCSDS) recommendations. This paper presents a set of generic satellite simulator functional requirements modeled into the UML and SysML use case artifact. The satellite and ground station functions included are as much general as possible, as they were based on practical publications of related works and in space service standards.

Keywords: Satellite simulator, use case, requirement specification

1 Introduction

The use of software simulators in satellite operations allows the simulation of ground operations before and after the launching. They may simulate satellite behaviour, the space environment and ground stations providing a good basis to find unexpected scenarios that could not be tested before launching. Some advantages of developing satellite simulators are: (i) validate operational procedures; (ii) train operators before launch; (iii) validate the Satellite Control System (SCS) and the TM/TC database [8].

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Building a satellite simulator requires a precise specification of its requirements. In modern satellites, the on-board data-handling computer pays an important role in the satellite behaviour. For a satellite simulator, such functions should be precisely defined. A great part of such main functions are common from one satellite to another, so, one may use the standard ECSS-E-70-41A [3] as a starting reference. The ECSS-E-70-41A standard defines a set of services that address operational concepts covering fundamental requirements of satellite monitoring and controlling during satellite integration, testing and flight operations. This standard focuses on the utilization of telecommand and telemetry packets for the purpose of remote monitoring and satellite subsystems controlling. The protocol supporting the ground and on-board system communications, from physical to transport levels, including telemetry and telecommand protocol was based on CCSDS standards [2].

The satellite simulator behaviour is presented in Use Case notation of UML and SysML [7]. One reason to adopt use case is that it is an excellent technique for capturing the functional requirements of a system, allowing inclusion and removal of new elements as the software project evolves. The use case diagrams can be fully integrated with other analysis and design artifacts created using a CASE tool to produce a complete requirements design and implementation repository. Another important reason to adopt Use Case notation is that it has being used as a construct in the Reference Architecture for Space Data Systems (RASDS) [2].

This paper presents, in section 2, an overview of a satellite simulator, its main functions and general requirements. Section 3 contains a short introduction to the ECSS-E-70-41A standard. A breakdown of the software into modules, a description of their main functions and the model for the most common functional requirements for on-board data handling of a satellite simulator are presented in section 4. Section 5 concludes this article.

2 Satellite Simulator Overview

The satellite simulator addressed in this paper comprises functions for the whole satellite behavior, the ground station functions, the space environment and the flight dynamics aspects of the satellite in flying.

The simulator is expected to support the Satellite Control Center's operator team training and also the Satellite Control System validation. It allows the prior execution of operational procedures that will be performed by the Satellite Control Center during the satellite operation flight. The operational procedures include commands to control and monitor the satellite during its passage through the visibility area over the ground stations. Configuration facility is provided to allow nominal and contingencies in the satellite modes for operator's training.

In short, the main functions of a satellite simulator are the following:

- ingest and deal with all typical telecommand types like *direct commands* (which are executed as soon as it is recognized on board), *immediate commands* (which are executed by the on board data handling software, as soon as they arrive in the satellite) and *time-tagged commands* (which are stored on board up to be executed when the time-tag is trigged);

- generate platform and payload telemetry. Telemetries are the information from satellite sent to the ground systems. The types of telemetries that have been taken into account here are: (i) *real time housekeeping telemetry* (HKTM-RT). This telemetry is sent directly to ground station, as soon as it is acquired on board. (iii) *on-board recorded housekeeping telemetry* (HKTM-ST). It is recorded on board when the satellite is out of ground station visibility range and sent to ground station during the visibility; (iv) *payload telemetry* (PLTM) which refers to the payload-acquired data;
- provide attitude and orbit determination according to the satellite and the space environment;
- provide mechanisms to allow operators to make the time synchronization;
- control and monitor the ground station;
- keep ground and on-board communication according to the protocol established for the mission.

3 ECSS Stardards

The ECSS-E-7041A [2] is a standard addressing the utilization of telecommand and telemetry packets for remote monitoring and control of subsystem and payloads. It is to be applied to ground and on board satellite operations, as well as data transferred through these segments on packets layer. The services it describes are as much general as possible, allowing them to be adapted to any mission and to be tailored to the mission specific requirements. The following services are standardized in this document: (1) Telecommand verification, (2) Device command distribution, (3) Housekeeping & diagnostic data reporting, (4) Parameter statistics reporting, (5) Event reporting, (6) Memory management, (7) Function management, (8) Time management, (9) On-board operations scheduling, (10) On-board monitoring, (11) Large data transfer, (12) Packet forwarding control, (13) On-board storage and retrieval, (14) Test service, (15) On-board operations procedure service, (16) Event-action service. Such services may also be applied in a satellite simulator, as it is proposed in this article.

4 Functional Requirements Specification in Use Case notation

Many are the requirements of a satellite simulator. We propose a first level of breakdown to classify the functional requirements that characterize a satellite simulator [1]. Figure 1 illustrates this functional breakdown which includes: ground station (some satellite simulator does not include this function), satellite, environment and flight dynamics, and finally, the simulation management as main functions. Each of these functions is referred here forward as module.

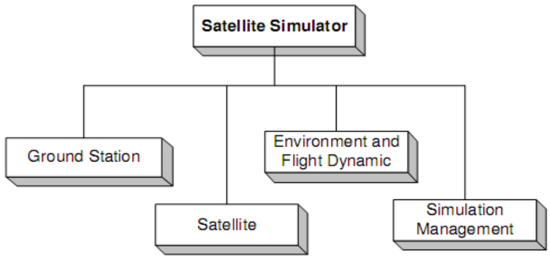

Figure 1. Satellite Simulator functional modules

The *Ground Station module* provides the functions for equipment commanding, telecommand transmission to satellite and telemetry reception from satellite. This module provides the interface between the Satellite Control System (SCS) and the Ground Station (GST). These interfaces should comply with those provided by a real ground station. In this study, the SCS is supposed to be connected with only one ground station at each time. In general, the information flows exchanged between the SCS and a GST is divided in real-time and post-passage. The first includes commands for the ground station equipment, for telecommand, for telemetry. As the ground-board protocol considered here is the CCSDS protocol, flows for the Command Link Transfer Unit (CLTU) and Command Link Control Word (CLCW) are taken into account. The post-passage flows represent the telemetry stored in files in ground station during a passage and sent to the Satellite Control Center after the satellite passage over the station [2].

The *Environment and Flight Dynamic module* provides the functions related to the satellite flight dynamics, i.e., the orbit and attitude calculus. It also indicates to the other modules the external conditions that may change the satellite behavior, like the sun illumination or eclipse and the visibility range of ground stations related to the satellite orbit.

The *Simulation Management module* allows configuring a simulation run, controlling its execution and creating a friendly user interface. Due to the independence of its main functions, this module was divided into two sub-modules: Configuration and Execution. The Configuration sub-module aims at attributing initial values to every parameter such as the ground station position, telemetry initial values, orbit parameters, etc. to be used during a simulation run. These functions are performed before the simulation run starts. The Execution sub-module comprises functions to support the real time execution like concurrency among the modules, temporization control, parameter visualization, screens customization, among others.

The *Satellite module* is in charge of receiving and executing telecommands; obtaining, packing and transmitting in established rates the telemetries according to the on-board subsystems behavior. Moreover, this module includes the satellite subsystems behavior as battery, thermal controller, attitude controller, etc. to be simulated.

The modules are described following the scenario-based technique for requirement elicitation named use cases [4]. A use-case identifies actors involved in a system interaction and names this interaction. In a use case description, an actor is an external subsystem or a user that triggers an event or receives a stimulus associated to a use case. An actor may be systems, people or equipment interacting with the satellite simulator. Since the satellite simulator was previously divided into four modules, a module interacting with another module plays the role of an actor. External entities like the Satellite Control System and the simulation conductor are the main actors of the simulator. Due to the importance of time-related events, as telemetry transmission rates, time-tagged telecommands, faults to be triggered in predefined instants, a special actor in this work is the **timer;** for example the $T_{TimeTaggedTC}$ timer indicates the exact instant a tagged TC should be executed on-board. Table 1 presents such actors.

Table 1. Actors

Actor	Description (or actor role)
Satellite Control System (SCS)	• Establish communication with the Ground Station • Control and monitor the GST • Control and monitor the satellite
Simulation Conductor	• Configure, according to the Training Plan, satellite, GST, environment and flight dynamics and simulation management, in order to characterize different situations for training operators of the Satellite Control Center • Interact in real time with the simulator during a simulation session run: read and modify parameter values
Timer	• Any timer that triggers an event depending on temporization
Ground Station	• Send telecommands to Satellite • Receives telemetry from Satellite • Receives visibility status from the Environment & Flight Dynamic • Receives parameter values from Simulation Management
Satellite	• Send telemetry to Ground Station • Receives telecommands from GST • Receives GST visibility status from the Environment & Flight Dynamic • Receives parameter values from Simulation Management
Environment and Flight Dynamic	• Send visibility status to the Ground Station • Send Ground Station visibility status to Satellite • Send satellite position in the orbit to Satellite Receives parameter values from Simulation Management
Simulation Management	• Send configuration parameters to Ground Station, to Satellite and to Simulation Management Environment & Flight Dynamics • Send parameter value changes to Ground Station, to Satellite and to Environment & Flight Dynamic

4.1 Satellite module description

A satellite generally comprises the following sub-systems: Thermal Control, Power Supply, Attitude and Orbit Control, Telemetry and Telecommand (TMTC), On-Board Data Handling (OBDH) and Payloads.

The simulation of the satellite behavior as a whole requires not only each satellite sub-system, but also, the satellite modes and the payload operational profiles to be simulated. The satellite functions were defined as much general as possible, since they were based on practical publications of related works [6] and in ECSS space service standard [3].

In order to organize the satellite functional requirements, a classification in module-based was provided to each satellite subsystem. The Satellite module was broken into six sub-modules, one to each subsystem. For sake of space, only the OBDH sub-module is presented in use-cases. The use cases are summarized in a Use Case Diagram and described in scenario-based technique presented in a Use-Case Table. Figure 2 illustrates the use case diagram of the OBDH sub-system.

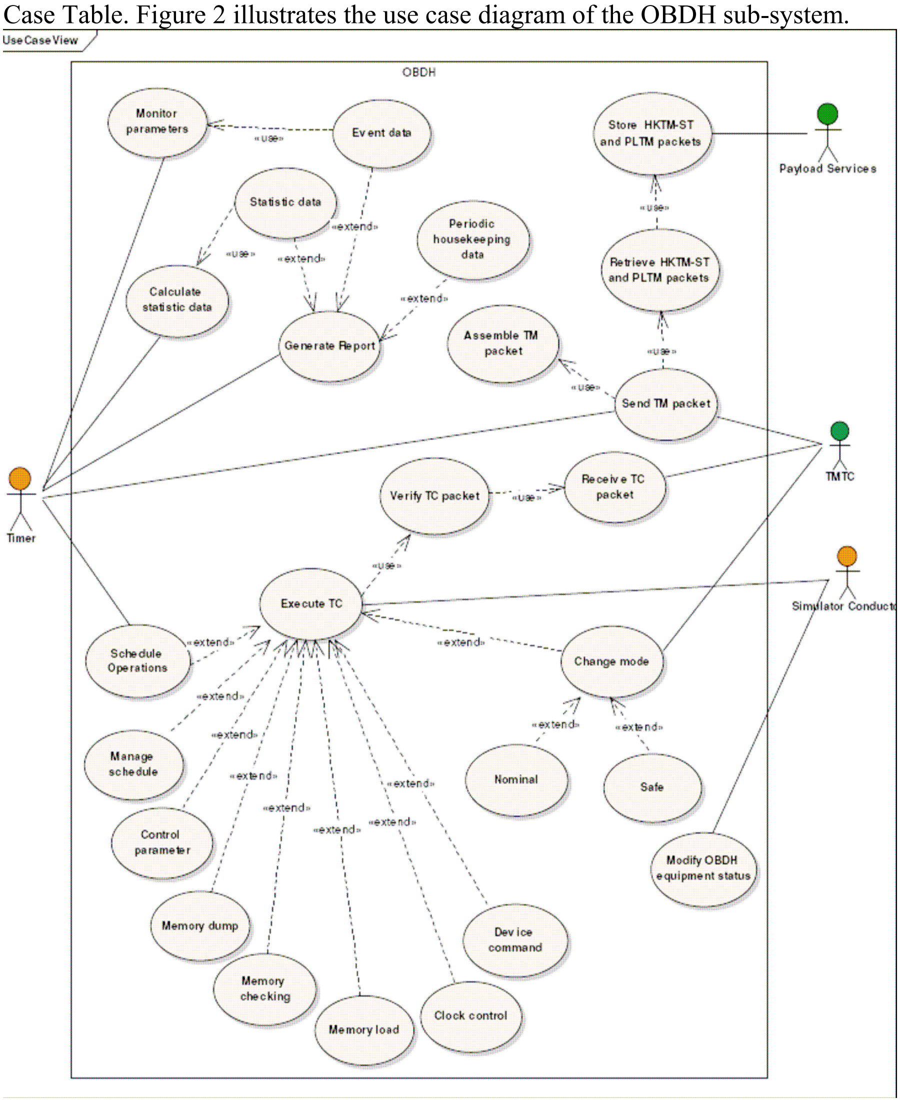

Figure 2. OBDH subsystem Use Cases Diagram

Table 2 presents the description of the following OBDH use-cases: “Execute TC”, “Memory Dump” and “Store HKTM-ST and PLTM packets”. The Use-Case Table is organized as follows: each line corresponds to one use case, the first column gives the requirement identification, the second brings the use case description, and the third associates the actor that triggers or uses that use case. The use case description includes an overview of the interaction its represents, entry and exit conditions. Besides that, the use case includes normal, alternative and exception flows characterizing the scenarios of a use case. The requirement SAT-OBDH.18 illustrated in Table 2 shows how an alternative flow is written. The scenario-based technique is given, in itemized flows, as proposed in the Scent methodology [5]. More details about the satellite simulator use cases may be found in [1].

5 Conclusion

This paper presented a description of standard requirements present in a satellite simulator using the UML Use Case approach. The Use Case notation allows easily connecting actors and their functions on a defined environment.

The choice of use case notation considered the following facts: it describes how the system shall be used by an actor to achieve a particular goal, it has no implementation-specific language and does not include detail regarding user interfaces and screens. Besides that, some other benefits can be obtained from use cases: it is an excellent technique for capturing the functional requirements of a system, it can be relatively easily added and removed from a software project as priorities change, it along with use case diagrams can be fully integrated with other analysis and design deliverables created using a CASE tool to produce a complete requirements design and implementation repository and, finally, test cases (for System, User Acceptance and Functional tests) can be directly derived from use cases.

A set of functional requirements were defined and described in the same way it was demonstrated in use case diagrams, use case functions table and detailed information about each use case for every module.

One starting a satellite simulator development could use the presented set of use cases as a starting point and aggregate new features as long as they become necessary, since the basic requirements are the same for several satellites. This paper provided a satellite simulator development with a generic framework from where a specific simulator design can be instantiated. The breakdown and the functions choices allow its reuse for future micro-satellite and small satellite programs in different missions.

Table 2. OBDH subsystem use cases description

Req ID	Description	Actor
SAT-OBDH.03	**Execute TC** *Description*: The OBDH execute a telecommand received by the simulation conductor or trigged by Schedule Operation that store the timed TCs. *Entry condition*: The $T_{TimeTaggedTC}$ timer was trigged OR TC packet was received *Exit condition*: The TC is executed *Normal flow:* 1. The OBDH verifies the TC packet 2. The OBDH identify the TC-APID 3. The OBDH execute one of the TC types: Device command, Memory Dump, Memory Load, etc. (see SAT-OBDH.04, SAT-OBDH.07, SAT-OBDH.08, etc.)	Simulation conductor or Timer indirectly triggering the use case Schedule Operation
SAT-OBDH.07	**Memory dump** *Description*: The OBDH has requested to dump data or program code from an on-board memory. See PUS 6 in [3]. *Exit condition*: The requested memory area is dumped *Normal flow:* 1. The OBDH obtains the data from the specified memory area 2. The OBDH prepares TM packets (HKTM-ST) for dumping the required data area. The OBDH stores the HKTM-ST in the storage area (see ST-OBDH.18)	
SAT-OBDH.18	**Store HKTM-ST and PLTM packets** *Description:* The OBDH controls the storage of HKTM-ST and PLTM packets on-board. *Exit condition*: The packet is stored or an error is indicated *Normal flow:* 1. The OBDH receives a HKTM-ST or a PLTM packet to be stored (see PL.3) 2. The OBDH stores the packet on its storage area *Exception flow:* 2.a. The storage area is full 2.a.1. The OBDH overwrites the oldest packet	Payload services

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Performance Analysis of Software Processes Supported by Simulation: a Resolution Problem Process Case Study

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Abstract: Results expected by organizations do not match the efforts spent to obtain processes defined in SDE. In the real world, one justifies this fact by considering the lack of adequate instruments and efficient programs of implementation and follow-up of the performance of these processes, together with the fact that the task is far from being trivial. The search for the achievements of these processes, the measurement and analysis of performance are referred to as a practical-key for the maturity and quality of the processes according to major market frameworks. In this scenery of problems and challenges, this work presents a proposal that supports the measurement and analysis of performance of software processes, and the improvement of these. The proposal is characterized by the agreed use of software modeling and simulation of processes with the performance analysis, the latter subsidizing the former. This work contains two well distinguished parts: a bibliographical review concerning key areas related to software processes, and a case study of one of the processes of SPICE. Viability of the proposal, a study on appropriate indicators of performance, a theoretic-scientific approach as contribution to the referred areas and an instrument that supports the definition and management of software processes are some of the results of this case-study. One concludes that a capable software process is a software satisfying the needs of the customer, and that it must be duly adjusted to the reality of the customer organization.

Keywords: Software Engineering, Modeling and simulation of process software, Process software technology, Process management, Analysis of processes performance.

1. Introduction

Results expected by organizations do not match the efforts spent to obtain processes defined in SDE-Software Development Environment. One of the points of this difference is mainly in the characteristics of complexity and use of

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permanent human resources in SDE.

On the other hand, it is worth noting the increased and dependence of software in all the business-oriented types, as well the growing demand for more complex systems. The organizations are dealing with problems with strong emphasis in the management of processes, in the improvement, and the maturity process of software [06].

The results of the efforts found in literature to supply this scenario, maturity models the and improvement of processes carried through for the organizations can be seen. As an international example the ISO/IEC-15504 can be mentioned as a result of the Project SPICE (Software Process Improvement Capability dEtermination), framework CMMI (Capability Maturity Model Integration) of SEI (Software Engineer Institute), and particularly to the Brazilian national environment, the MPS.Br model (Improvement of Process of Brazilian Software), that is a model of improvement and evaluation of process of recognized software that endeavors to take care of its necessities and to be nationaly and internationally used as a model of the software organizations [07][09].

The adoption of models and standards as guides are sufficiently promising, however they say what to do and not how to do it. In order to justify and the support the management for its action, proposals for the use of tools of management of processes and analysis that support quantitative methods are highly important.

Therefore, this work presents some results of experiments of a proposal that supports the definition, analysis of performance and improvement software processes. Such proposal is characterized by the combination of the modeling and simulation of processes of software with the performance analysis, the one beging subsidized by the other.

This work reflects part of the research carried out by the Software Engineering Group of Software of the LAC/INPE (Laboratory for Computing and Applied Mathematics/Brazilian National Institute for Space Research), in an environment of processes to support the activities of management of the Software Engineering (modeling, execution, simulation and accompaniment) in an integrated way.

2. On the software process

This section is introduced presenting two definitions for software process that evidence elements for the interest of this work.

"The process or a set of processes, used for an organization or project to plan, to manage, to execute, to monitor, to control and to improve the activities related to the construction of software "[08].

"A process of composed software consisting of a set of processes capable of leading the organization involved with the construction of products of software with quality and predictive costs, efficiently and managed with the possibility of constant improvement" [10].

A software process is understood or interpreted by a set of elements, from its definitions and from its relationship namely: activity, task, roles, actors, products and resources. A software process typically is identified by a collection of activities. An activity is identified by its position in the context of the process and by its relationship with other activities. Which are usually described by rules of the organization and of the process itself. An activity is part of the process that is defined according to its tasks. Abilities or roles are written and defined for the accomplishment of the tasks through its actors. Actors produce products (objective) of the process when playing their roles, their by consuming resources.

The quality of a software product is determined by the quality of the process used for its development and maintenance [05].

The citations presented stress the importance to legalize and to improve the organization processes of software, so as to gain quality and productivity. A process is the main element of SDE since the quality of a software product is directly related to the quality of the process used for its development.

3. Software process simulation

The Modeling and quantitative simulation as tools for the improvement process, had been initially used in the area of conventional manufacture. However, these tools had been applied to the processes of development of software only recently [04].

Simulations of software processes are found of general form in three classic models: event-discrete, continuous and hybrid. For the first model, event-discrete simulation, it is undestood that the interest events happen promptly in time and it does not matter what happens between them. Thus, for example, to initiate a codification, to finish the code, to initiate an interpretation and many others can easily be characterized in time. How the second model, of continuous simulation, aims at capturing the dynamic aspects that the previous model does not do. Models of continuous simulation aim at the capture and agreement of phenomena as for example, the activities of the software processes are developed by human agents and consume a certain time that incidentally causes modification in their answers as to productivity, product quality that it generates etc. Factors such as stress or motivation can diminish or increase these answers. How the third model, called hybrid model that appears when there are manipulation of the variables (continuous and discrete) of the two types of models involved in the study and that are considered jointly. Also, when from any modification that it makes in the one or the other model and that they modify the conceptual structure of the original model [04].

4. Performance and capability of the software process

The capability of the software process describes the gamma of results expected by the organizations, that can be reached with the application of the software process.

The performance of the software process represents the reached real results in its execution. Thus, the performance of the software process is focussed in the results, obtained while the capability of the process focussed on results expected [03].

To obtain the capability of a process is somewhat critical. On the basis of the attributes of a specific project, in the environment characteristics and the context in which the process is led, its real performance may not reflect the capability of the total process of the organization. For example, radical alterations in the application or in the technology employed can place the of the project staff in the situation of apprentices, which it makes capability and the performance of its project diminish in relation to the capability of total process of the organization [03].

The capability agreement must follow that of the performance. In other words, the way to the capability is in first place to obtain the capacity of the process by means of the agreement of the performance of the process in controlable and predictive conditions.

5. Establishing the quantitative indicators of performance

The measure represents the result, obtained with the use of the metric. Metric is the translation in a model of aspects of interest. Indicator the measurable reference of the metric. Thus, for example the indicator of error tax is interpreted by the metric: number of errors is counted in modules divided by the numbers of lines of the module. Metric is a translation or interpretation of the aspects involved in obtaining the indicator. By using the indicator in a real case, taking effective steps, one will obtaim a numerical value that represents the aspect translated in the indicator.

The suggestion of indicators of this work was carried out from discussions and analyses of the Software Engineering Group of Software of the LAC-INPE, and it is not intention to make sufficient here, to only show how the group work of the is being conducted as well as the first experiment of this proposal.

Three aspects had been contemplated for the process used in this case study, as shown in Table 1. By means of the indicators an index of planned productivity can be obtained.

Table 1. Indicators of performance, metric and objective global for evaluation of processes.

Indicators	**Interpretation (metric)**	**Objective of the organization**
Productive Capacity of the process or total resource in hours (PC)	Nhd [Number of hours and developers involved *numbers of days planned for the project]	it translates the availability of hours destined to the project without considering the occured stoppages
Planned Productivity (P_p)	Utilization * Efficiency ($\xi\mu$)	It reflects the relation of effective productivity for all planned capacity of the project
Utilization (μ)	Time effectively spend/number total of available hours	Utilization of an operation, translates the percentile relationship between the worked hours and the hours effectively destined in the period of the project
Efficiency (ξ)	Estimated time/effective time spent in the work.	related to the resources foreseen and accomplishit for the execution of an amount of production in a period of the project

It can be said that it is generally accepted that, the future of the metric of software is in the use of relatively simple metric combining different aspects that may permit some types of estimates and evaluations.

6. The problems resolution process

During the execution of a process of software construction, many facts harmful to the project can occur, either foreseen by the management or not. Any way actions must the be taken so that these facts do not hamper the normal course of the project, mainly those that may cause compromise of quality, the cost and schedule.

Occurrence is defined as any event or fact that must be considered as a potential element of risk for the project and that needs evaluation for the group responsible for such task.

The process of solution of problems must be initiated from the moment where any person involved in the project finds a problem. For this purpose some procedures they must be followed [02]:

- To open Occurrence - the "reporter", any person involved in the project and that finds a problem, must fill an occurrence report, supplying information on the problem;
- To analyze Occurrence - the analyst, after being notified of the occurrence must verify the correct fulfilling of the information supplied by the reporter and thus analyze the occurrence. Once analyzed, the analyst must to confirm information on the problem to verify the possible impact, the product to be corrected and if the occurrence is justified;
- To solve the Occurrence - the "developer" or soluction provider (person who solves the of occurrence), after being notified must solve the described problem in the occurrence report and thus supply the information of the solution. The solution must be directed for revision and validation;
    - To review the Occurrence - the "reviewer" must look forward the information supplied and compare them with the criterion of closing, which will be closed it if the criteria is met, otherwise, the occurrence must remain open indicating re-working necessity.The "developer", person who will solve the must then be notified to do the re-work.

7. Executing the model of process of resolution of problems

The initial model for experimentation was constructed in the event-discrete environment of simulation. This model is shown in Fig 1.

This section illustrates a hypothetical analysis that was condricted . The presented analysis rapidly shows the evaluation that could be made as an initial revision of a favorable and feasible idea of change of process.

The used data are hypothetical and aim at representing the information from real estimates of the management based on actual data. The shaped process typically reproduces the routine of a company used for the study. The company produces, throughout three phases of the cycle of life of the project of software around 500 problems. The considered effort was of 6,5 [h/h/d] (hour-man-day), the remaining 1,5 hours was destined to the necessary stoppages (routines meeting of the team of the day, equipment configuration etc). The process of Resolution of Problems adopted has an activity of analysis, with an actor for this activity; three activities of troubleshooters, being an actor for each one of the three different phases of the project; and one activity of editor, with an actor for this activity. In phase 1 requirement survey is included, analysis and structural project, in phase 2 codification, implementation of all the products and tests, finally in phase 3 them are the final tests and the implantation of the product. A typical band of problem raised in the order of 10%, 60% was adopted respectively for each phase, 30%. It is pointed out that the two first phases possess constant interactivity, being that it was considered for phase 1, 10% of problems of primary order (initial), the remaining problems being concentrated on phase 2. For this example, each detected revision between the interactions of phases 1 and 2 approximately 30% of the defects that are in this point are attenuated for phase 2 which increased significantly its tax to 60%. The activities of the trobleshooters are efficient enough, closing in the average of 85% of the problems in the first interaction. Therefore, 15% stand after being revised by the editors still for copyholders, conditioned to the trobleshooters.

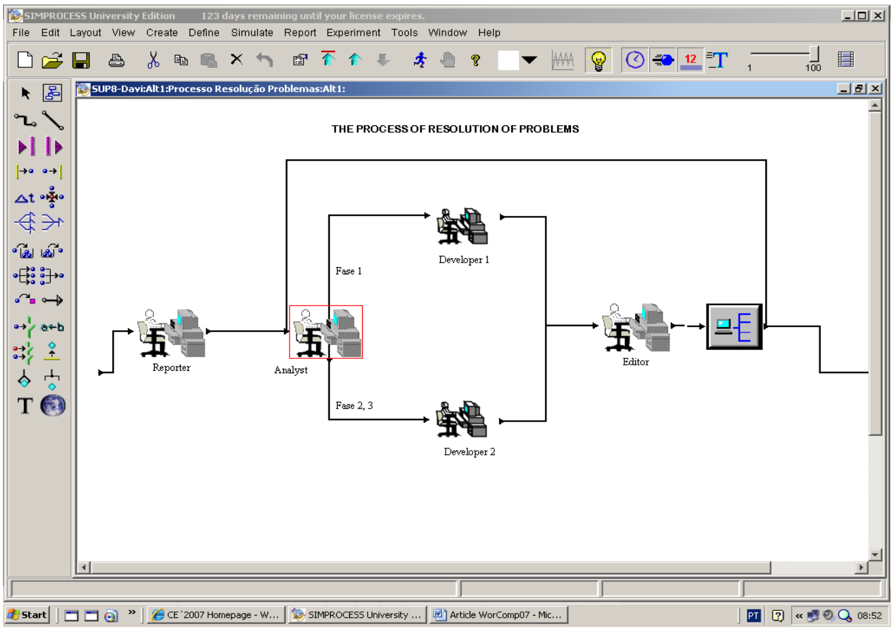

Figure 1. Screen of the logical model of process resolution of problems in the Simprocess® simulator environment. [11]

For this example, the done question was, "considering aggregation of roles of the actors during two first fase, which we would be the impact in the performance process" The additional data in the simulation as to the effort in the accomplishment, ability in deciding the problem, type of the problem (classification as to the phase critical index) and others were limited to in the codes of the environment, making possible an ample gammut of freedom to modify parameters in the experimentation and in the analyzis of results.

7.1 – Experiments and results

For this work two modalities of simulation had been considered. In the first one the team (human resources) kept it constant in relation to the format of the organization as to its activities i.e., kept the process "as it is"; and in the second modality, the roles that contemplate the activity had been aggregated, aiming at a multi-functional team, i.e. modified the process for "as it would be if". In both cases the indices of productivity, utilization, efficiency and average time of resolution of problems.

Deficiencies of the model of simulator and the executors of processes could have been perceived clearly, as:

- One does not have a standard time for the activities (in function of the three aspects: the individual, the type of the activity, the complexity of the activities);
  - no statistics information of any type is offered, as for example, probability distribution in agreement (agreement of the estimates of the managers of the company in study). Aiming the objectives of the research of the Software Engineering Group of the LAC-INPE, is definition of a model of gauging of parameters for these and other aspects, which includes these deficiencies by means of experimental results [01].

Results in this case study emphasizes evidences, such as:

- processes must necessarily be treat continuously, and aspects like efficiency and income must be analyzed jointly (as shown in Table 2, some partial results);
  - the lack, or non-availability of a resource in a given moment may to cause the reduction of the performance, which reflects directly on the performance of the process.
  - the simulation revealed to be a relatively simple resource to organize and to understand the use of systematic resources.

Table 2. Comparison of the tried alternatives (calculated from the hypothetical data)

Indicator	**Original process**	**Modified process (adding functionality)**
Efficiency (ξ)[%]	~81	~90
Utilization (μ) [%]	~74	~85
Planned Productivity (Pp = $\xi\mu$) [%]	~60	~76
Average time of resolution [h]	4,0	2,5

8. Conclusion

There are various options to increase the effectiveness of the analyses, solution and revision of process. To determine new potential results based on the prediction of the results of the simulation. However to evaluate the potential change in more depth and to evaluate also some alternative strategies of the execution it is interesting to take in to consideration resources you add to the inserted models of quality in the engineering processes.

It is fundamental to point out that the types of to be considered changes depend on the organizacional culture. What may work for an organization, most of the time many not work for another one. The simulation is a very efficient tool to explore alternatives. Corroborated by diverse authors [04, 05, 07], however they only assist in the aspects that had been considered in the model. Feelings and decisions still are in the reality of the organization and the actors that control and assume them.

The process that was shaped for approaching this work is particularly useful to explore these questions considered qualifying in the process in study. For each potential option, a result in productivity, utilization, efficiency etc can be predicted. Some of these many not be immediate became of staff training, but others may be immediate with the hiring of expert developers.

The approach to this work appears as in the mentioned areas of this work (modeling, simulation and analysis of performance) being quite interesting, therefore it support the metrology of the engineering of software for analysis of performance of software processes, and for the management of processes of software development.

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Concurrent innovative product engineering

Be Lazy: A Motto for New Concurrent Engineering

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Abstract. This paper is a position paper to point out that concurrent engineering is entering its 3rd generation. 1st generation concurrent engineering was proposed in 1989 when DICE project started. The primary purpose of the 1st generation was how effectively we can reduce time to market. Their only concern was time and "earlier and faster" were the keywords then.

Then 2nd generation concurrent engineering came. We became aware that if we really have to process things in a concurrent way, we have to discuss at a strategic level. The tactical discussion would not solve the problem. That was what we found out after many years of practicing concurrent engineering. The primary task in 2nd generation concurrent engineering was how we can set a strategic goal across all different development processes. To achieve this, communication and collaboration became essential. So some researchers, including myself, called this 2nd generation concurrent engineering "collaborative engineering".

Now, we are entering 3rd generation. With the growing diversification of customers and with our traditional markets going out, we have to consider every constraint as soft and negotiable. In short, our 3rd generation concurrent engineering is "negotiable engineering". Everything is put on a negotiable basis. There are no more fixed dimensions. Everything changes in a dimension and sometimes the number of dimension itself changes. Our way of solving the problem changed to constraint-driven from our traditional way of goal-driven.

This paper describes how concurrent engineering changed with time and what will be our new challenges in our 3rd generation concurrent engineering.

Keywords. Concurrent Engineering, Yesterday, today and tomorrow, Soft and hard constraints. Negotiaion, Constraint driven, Postponement, Lazy evaluation

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1 What is in the back?

With the growing diversification, more flexibility and adaptability are called for in product development and marketing. Therefore, new business models are proposed for marketing and product development. One of them is one to one marketing where product development focuses more on individual aspects and considers life time value of a customer. But unless the product is very large or very special so that it has to be made to order, which means production would not start unless price covers all the expense, we have to compromise between mass production and personalized production, because if we produce products completely to individual order, then the price would become too much high and we cannot sell the product. So if the product has to be sold at a reasonable price to secure marketability, we have to compromise between mass and personalized productions.

2 What 1st Generation Concurrent Engineering Brought to Us

This means that every item or part to be developed will be put on a negotiable basis. Our old product development was such that each developing item or part is a box which has fixed sizes, i.e., height, width and length with order priorities and that how we can pack them together appropriately in a larger box. Thus, fundamentally the problem of our old product development was a packaging problem or a scheduling problem (Figure 1).

Concurrent Engineering changed the situation [1], [2]. It told us that by noting the content of each item or part, some items or parts can be processed at the same time. This means that the size of items or parts become changeable if we note their contents (Figure 2).

This is quite revolutionary because until the emergence of concurrent engineering, everybody endeavoured only how we can pack them adequately. i.e. All our efforts were done until them with all the sizes as hard or non-negotiable constraint. Until concurrent engineering was proposed, there were no ideas to relax the constraints. What concurrent engineering really proposed was how we can relax the constraints.

But initial concurrent engineering only noted a temporal constraint. If we can process some items or parts together, we could reduce time to market. So their only concern was how we can reduce time.

3 2nd Generation Concurrent Engineering

As the initial or 1st generation concurrent engineering spreads, it soon became clear that we should change our ways of production. We processed items or parts sequentially and information flew in one way from upstream to downstream. But to effectively process some parts at the same time, we have to communicate. At the earlier stages, communication remained at the tactical level. But soon it was realized that to more effectively relax the temporal constraint, we have to communicate and negotiate. Thus, communication to strategically determine the goal across all development processes became important (Figure 3) [3]. Therefore, some researchers, including myself, prefer to call the method "collaborative engineering" [4] rather than concurrent engineering. We should note that the primary activity of this collaboration is nothing other than constraint negotiation or constraint relaxation. But most of our concern was how we can process everything faster or how we can reduce time. So our attention was paid only to time constraints. This was because if we put our products faster into market, then it would be more probable we could wind up as winner.

4 Creating a New Market

But this is based upon an argument that our market does not change much. If we borrow the words from Kim and Maubogne [5], our attention was paid only to the red ocean. Everybody has to fight for the old traditional market so that even a minute earlier means better chance of win. But as they point our we are now entering the age of blue ocean. If we look aside, the blue ocean is expanding infinitely.

With the growing diversification, the customer's preferences changed remarkably. Each customer has a different sense of value based upon his or her life. Thus, our traditional market which was based upon an averaged sense of value lost its meaning. How we can create a new market or how we can find a blue ocean becomes our most important challenge.

5 Diversification: Even One Customer' Sense of Value Changes with Time

When we talk about diversification, most people only think of spatial diversification, i.e., from customer to customer. The argument is how customer's requirements vary from customer to customer at a fixed point of time. But we should note that diversification is happening not only with respect to space, but with respect to time. Even one customer changes his or her sense of value through out his or her life, because their life style changes with time (Figure 4).

6 All Constraints are Turning Soft Now!

This means that all the constraints are now negotiable or turn to be soft. In our traditional concurrent engineering, all data are single elements. Even if data is in the form of a list, the number of elements in it did not change. What the first and second concurrent engineering did was how we can effectively change the value of composing elements. The number of elements was a hard or non-negotiable constraint.

But now the number of elements in the list can be changeable or negotiable. Apparently there are no hard or non-negotiable constraints. What becomes important for us is to prioritize the constraint according to their level of hardness or negotiability.

It becomes useless to rush. It would be far better to choose the right time to make a final decision. Once a final decision is made, then some of the constraints turn into hard or non-negotiable ones, we have to solve the problem by prioritizing these hard or non-negotiable constraints. Therefore, our way of solving the problem becomes more constraint-driven, and once again constraints are very much on a negotiable basis. It should be noted that some of the elements are not known at the earlier stages so that the size of a list changes with time.

7 From Goal-driven to Constraint-Driven

This calls for a new paradigm of concurrent engineering. Constraint driven or negotiation based concurrent engineering. This new framework will be our 3rd generation concurrent engineering. Then, how can we deal with the problem?

Postponement or lazy evaluation is the solution. We have to know how much later we can make our decision. What will be our latest time when we could make our decision becomes more important then making decisions as early as possible. Things are turning in the opposite direction. “Postponement” and “Be lazy in our evaluation” will be the keyword for our new or 3rd generation concurrent engineering.

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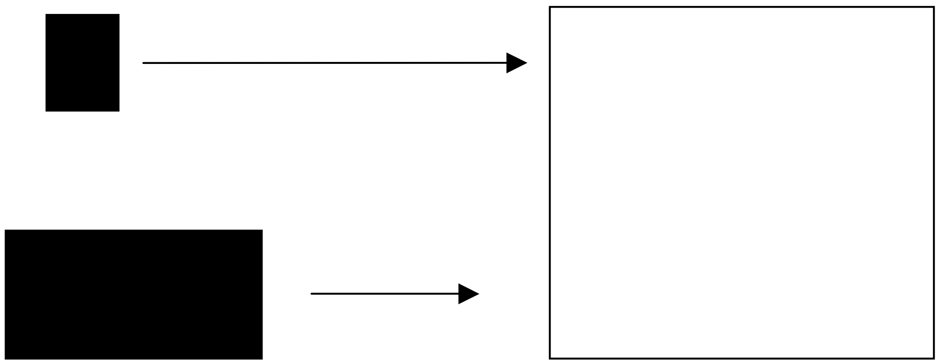

Figure 1 Packaging Problem

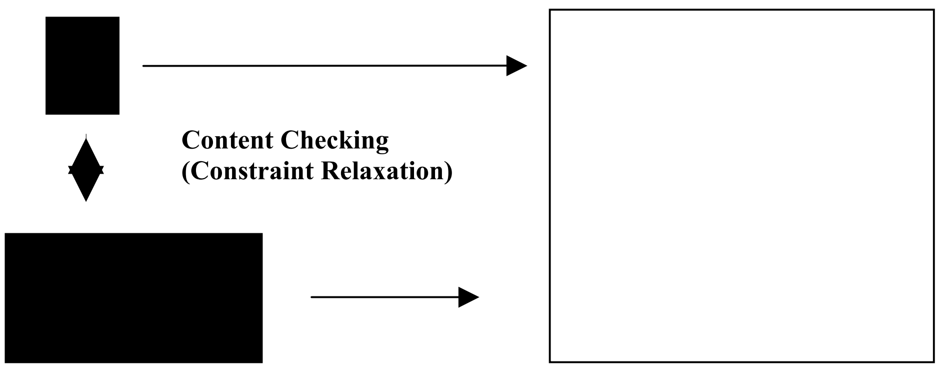

Figure 2 Packaging Problem With Constraint Relaxation

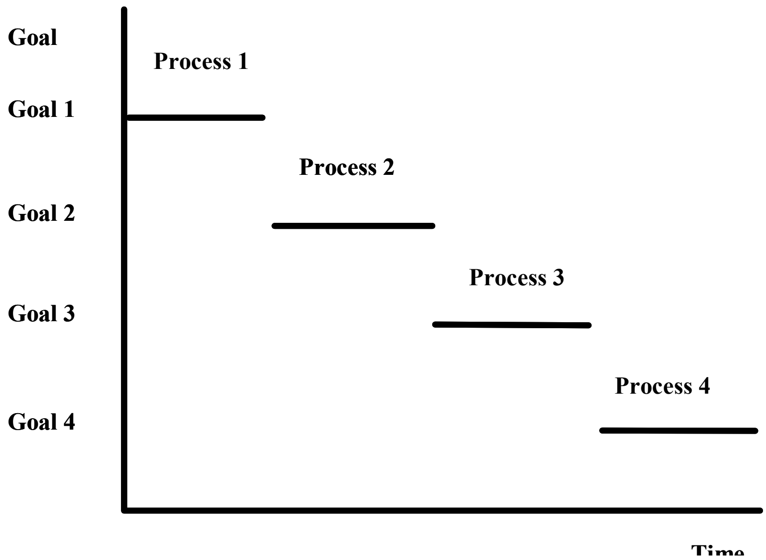

Figure 3 (a) Old Sequential Product Development

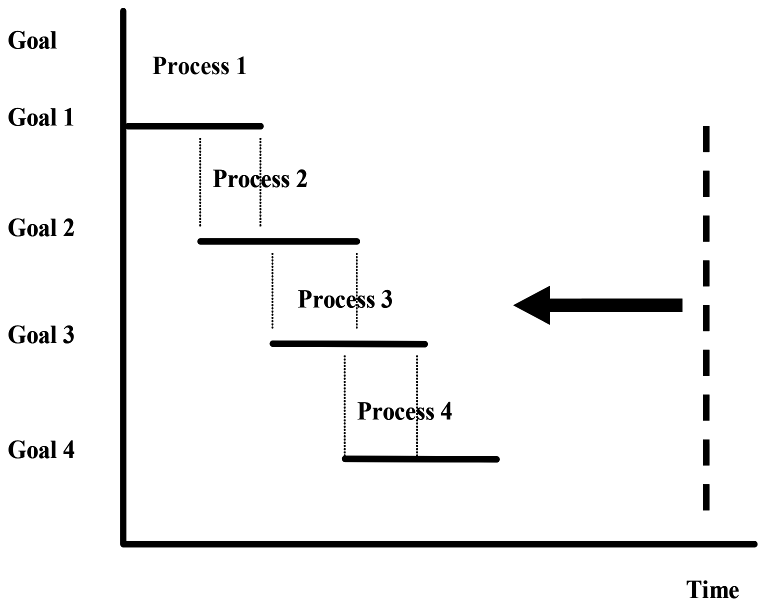

Figure 3 (b) 1st Generation Concurrent Engineering

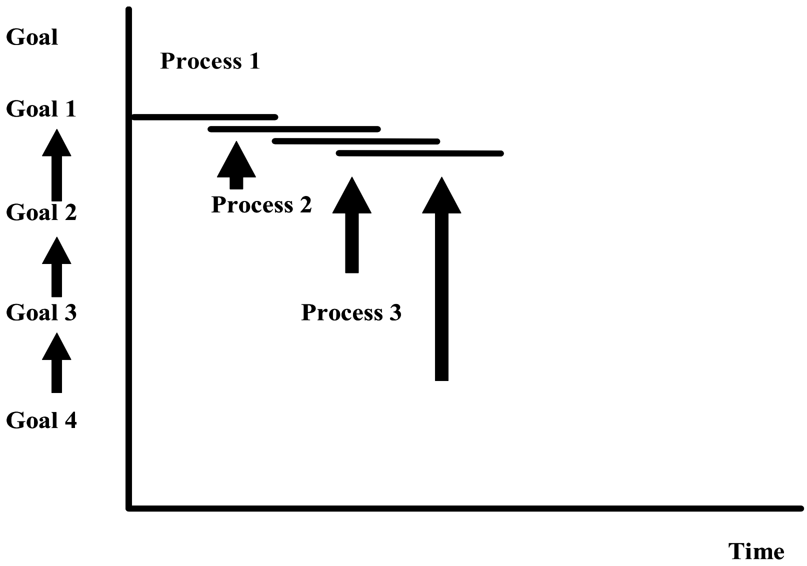

Fig.3 (c) 2nd Generation Concurrent Engineering

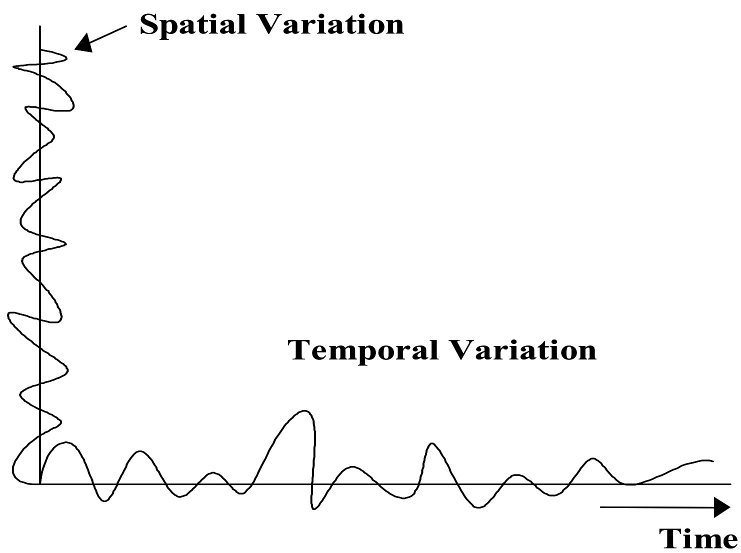

Figure 4 Diversification

A Study on the Application of Business Plans in New Product Development Processes

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Abstract. The present work presents a study on the application of business plans (BP) (a widely used document for investment decisions of new enterprises), with standard new product development processes (PDPs). The main objective was to find out whether it may be applied and, if so, at which moments it should be used in the PDP. The main source of information in this exploratory research was the existing literature concerning product and business development processes, business plans models and similar documentation, and project selection and evaluation methods. Then, these contents have been compared using the PDP stages as references. As a result, the study points out that a business plan is a document that models business, and it can gather enough information for investment decision analyses. It can also be elaborated concurrently with the PDP stages and used at the PDP decision gates. However, business dynamics has favored other forms of documentation for early decisions, such as synopses, presentations and even web-pages (for external resources). Business plan contents are still relevant and useful for new enterprises investment decisions.

Keywords. Business plan, new product development processes, project selection and evaluation methods

1 Introduction

Economic sustainability of existing and startup companies strongly depends on their ability to take advantage of market opportunities. However, to identify them and to decide upon which one of them will mostly be feasible in an uncertain future, is a subject that still attracts attention.

The central point of this problem is the fact that one cannot foresee the future [19]. Therefore the success of a given company in the long term cannot be guaranteed [5]. In this scenario of uncertainty in several industrial sectors and of imperfect companies, the best alternative in order to invest is to search for elements that contribute to reduce failure risk [5].

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Business planning has emerged as a way to improve chances of a new venture to succeed, yet with no warranty. The first step in this process is to perceive a given opportunity and then transform it into a business effort. The way to convey such transformation is through a business plan . A company may be created or used to explore this opportunity by operating, manufacturing or developing a new product [17]. There is always an idea of a product or service behind a given opportunity. However, only a feasibility study, which can be built upon a business plan, will indicate its potential to be converted into a profitable business. Hence, not only must one focus on an idea for the best product and never lose sight of it, but one must also pursue the business as a whole [5].

Although the literature on business plans and topics related to product development process is vast, they are rarely studied together. And when that happens, operational details are seldom presented. Also, the so called "business project" approach [3] does not bring out a reference model capable of guiding a given product development project in a way that is fully integrated with the corresponding business. Not even suggested models of product development processes [4, 15] include all necessary details to create a new company, as they assume it already exists.

In the present study, no trace has been found of a product development process reference model that supports the creation of the enterprise that will be delivering the given product. Although businesses and products are usually developed altogether in practice, an integrated framework to support both the product development team and the entrepreneur is missing.

The present work aims to bridge the gap between these themes, so that decisions concerning new product development can be made based upon a broader vision: one that considers both technical and business aspects presented in a business plan.

2 New Enterprises and Investment Decisions

2.1 The New Product Development Process

A recent research conducted by Hustad [7], that involved PDMA (*Product Development and Management Association*) affiliated companies, has pointed out that there are several models of product development processes (PDP) put in place. Also, there are significant differences among them.

In addition to these models, there are also PDP models found in the literature, which serve as a basis for activity planning in product development projects [15]. Among these, the ones based upon decision portals or gates between their main phases are noticeable, as proposed by Cooper [4] and Rozenfeld et al [15]. In these models, due to uncertainty, investment decisions are fractioned into several moments, and bets increase in the same proportion as risk decreases. This approach avoids risky "all-or-nothing" decisions. At the gates a company evaluates how development projects are doing in such a way that its resources are more efficiently allocated. There are basically four kinds of decisions: approve, disapprove, freeze or recycle the project [4, 15].

Decision making is a collective task and, therefore, it happens by means of meetings with development team members and higher management [*ibidem*]. As a result, revision points are credited on account of proper participation of higher management, when it is ultimately useful: at points where high risk and/or costs are involved [14]

On the other hand, PDP is a process of "information assembling". However, decision makers do not always take part in this assemblage. Then, how is it possible to establish a common and yet collective vision of what the project is? Furthermore, what kind of analysis is made to decide whether a given alternative deserves investment or even more resources to be allocated?

Whatever the form of documentation is to represent a given project, it should be such that it is adequate to the kind of analysis to performed at every gate. This could be presented in the form of one or more of the approaches that follow.

2.2 Project Selection Approaches – What Occurs in a Decision Gate

The decision to invest in a given project involves the analysis of both qualitative and quantitative factors. There are several approaches to project selection, which can be grouped into three main categories [4]:

- Benefit measuring techniques;
  - Economic models;
  5. Portfolio management methods.

In the benefit measuring techniques approach, one gathers criteria to be used when a given project is analyzed. Grades can be used, as well as binary logic (yes/no) when one compares data from each given project against reference values. This approach is mostly qualitative, as it involves a subjective evaluation sense, which can incorporate an evaluator's personal criteria.

In the economic models, a timeliness study on the economic behavior of each project is performed and financial indexes are used in order to allow for a detailed comparison from different projects. This approach has a quantitative nature [4, 8, 13].

On the other hand, portfolio management methods aim at maximizing return of investment (ROI), selecting projects that are aligned with the company's strategy and balancing the project portfolio. It allows holistic decisions as it mixes both qualitative and quantitative factors. To do that, one applies a group of techniques that come from the two previous approaches, among others [4, 15].

Despite the fact that either economic models and benefit measuring techniques are not ideal when used exclusively, ROI metrics that derive from them are fundamental to support decisions in each one of the approaches presented [4]. Nonetheless, the main element that justifies the existence of a given company is profit making. Positive results are not enough; it is necessary that the generated profits are better than those expected from other investment alternatives. Hence, the essence of an economic-financial evaluation is to measure a given project's return such that comparisons can be made against other investments [15].

However, in order to test a given project's feasibility, no matter what approach is used, a model is necessary – something that represents its technical, economic and commercial performance. In the literature about PDP, there are some planning tools, such as the business case. It is very similar to business plans in its content and partially similar to project planning. In the business literature, though, business plans have become the main piece of documentation for business modeling [1, 2, 5, 17].

2.3 The Business Plan

Business plans are usually associated to the entrepreneur and his dream to foster a new company [1, 5]. But a business plan can be used both by new companies and established ones, large or small [1, 2, 12, 16].

Companies can be perceived as systems that, in turn, need several internal subsystems. Systems have their performance evaluated by means of models that represent them. Model conception and development cause people who conduct experiments to become self-conscious of concepts and values that influence understanding, planning, action and reaction of a system's elements. Hence, initially one has a tacit/mental model of the system [2].

A business plan is used to formalize and make the model of a given system explicit. To do that, it has qualitative and quantitative aspects. The qualitative part is discoursed and refers to the description of a functioning system and of the model projection inserted in the system. The quantitative part reveals the economic model of the project and is targeted towards measuring the economic return of the model [*ibidem*], yet allowing for trade-offs – sensitivity tests of controllable and uncontrollable variables of the system [18]. Since the qualitative part is the one that carries the description of the technical and commercial model, it is essential for the development of the economic model [2].

On the other hand, a business plan is a document that contains description and characterization of a given business, the way to operate it, its strategy, its plan to conquer market-share and its projections of revenue, expenses and financial results [17].

However, a business plan concerns company or product? Egg or chicken? Indeed, a company does not exist without a product. It is seen as the outcome, or the result of work or of a process, and as something that adds value to the one who uses it or consumes it. But the product does not exist either, without the process that originates it and that makes it available to the market. Therefore, they are interdependent and each one's feasibility influences the other's.

In other words, the product (good or service) is an offer of value to the market and can be used in an exchange process to generate revenue [10]. As a result, there is no offer without the process that bring it into existence. Decision towards investment in a company cannot treat product and business separately. In order to compare projects and decide, understanding of the whole is necessary. Hence, the model must represent the performances of both product and business.

3 Methodology

The present work has been carried out through an exploratory research on international and national literature about product development processes and businesses, business plan models and similar documentation, and project selection/evaluation methods. To accomplish that, a list of fundamental questions and key-words has been placed, which has been constantly revisited due to new coming pieces of information.

Significant results have been registered and analyzed using mind maps and block diagrams. In the light of commonly cited phase-gate PDP models, it has been possible to figure out relationships between terms and topics.

4 The Application of BPs in PDPs

According to the information gathered in the present work, product and business feasibility are interdependent; product feasibility studies must consider business feasibility and vice-versa. However, such studies demand models that represent the system performance of dimensions comparable to other investments.

Both the PDP and project selection approaches used in it point out to the need of a model that makes a product's technical, economic and commercial performance explicit. This is because the decision making process within the PDP demands meaningful ways to present data for extensive approach-dependent analysis.

Since a new product will have economic and commercial performance only if there is a company the makes it available to the market, it is believed that flexible business plans may be the missing model to support investment decisions in the PDP.

Therefore, in an existing company, a business plan can be built concurrently with the PDP, analyzed at each gate and updated at each phase. This would allow an overall view for everyone, including possible external investors. After all, companies should not be limited by their own resources.

In a newborn company, where “egg and chicken come out at the same time” there would be significant gains if the new business development process is integrated to the PDP. Although no reference model to develop new businesses has been found, business plans have supported the process to build new companies.

However, there is a need for reference models to support both new products and new businesses. The demand for a “guide to unexplored lands” is evident. Innovation hides in scenarios where new companies offer new products to new markets. These products are sometimes discarded in investment rounds because there are no known ways to explore them. even when they represent remarkable opportunities.

Nonetheless, the development of a new product, carried out by an existing company or a startup, consumes resources, not always available. In both cases, external sources will be needed to leverage the business.

In order to search for investors, loans, partners and strategic alliances, an adequate tools is needed [2]. No investor can evaluate an opportunity without a clear demonstration of what the company is [12] and this is nor far from the reality of PDPs. At gates an idea is “sold” in order to obtain more resources (money and/or human) for the next development phases, no matter they come from internal or external sources.

As external investments are obtained in exchange for business participation [1, 5, 6, 12], the larger the value perceived by the investor is, the less the cost to participate will be. Value perception is, in turn, directly proportional to the existence of concrete success evidence (like patents, prototypes, preliminary contracts, among others) capable of minimizing failure risk.

On the other hand, in a creative process like the PDP, or a new business development process (NBDP), such evidences only come later on. Thus one arrives again in the origin of this problem: the future and uncertainty. To risk or not to risk valuable resources in search of success evidences?

But the ability to create or obtain them in the beginning of the PDP, or of the NBDP, has a substantial leverage effect on the company's value, which can, in turn, reduce investment cost dramatically. Recent studies [6, 12], point out that maybe there are no other elements that allow such efficient business leverage.

Therefore, product and business success are linked. Business plans formalize an integrated model for investment analysis in the PDP. Companies that need to raise external resources to develop new products will mostly benefit form them.

5 Discussions

Although the advantages presented previously are evident, there has been no strong relationship between performance and the use of a formal business plan [6, 11]. Also, there are doubts concerning the effectiveness of the enterprise planning activity as a whole [11].

Most of the criticism on Bps is related to startup evaluations by venture capitalists. One of them is that investors typically focus first and foremost on the quality of a venture personnel; they invest in people not in paper [6]. As there is no way to foresee the future, a team's capacity to becoming reality rather than a fantasy is desired. Therefore, team experience with the proposed business and its formation is crucial.

Another criticism is that not always investors base their decisions on business plans. The dynamics of venture capital investments has demanded faster and practical alternatives to be analyzed than a document that can have as many as 100 pages (with appendices and annexes). Some approaches could be used before the presentation of a complete BP, as electronic presentations, web-sites, two or three pages summaries or synopses, among others [6, 12].

About the BP application in the PDP, research is demanded on how to integrate it operationally. After all, the necessary time for BP writing and analysis can be extensive, therefore they precede all the system synthesis. Thus, in the development of initial phases, when there are many alternatives to choose from, a more simplified form of model, such as an electronic presentation, or synopsis, could be more adequate to the decision process.

Once the decision of initiating a project is taken, the BP can be of use in decisions such as to approve, to disapprove, to congeal or to recycle the project.

6 Conclusions

It was verified that NPD and BP literature are seldom presented in a correlated way. The subjects are generally treated separately, even though they are known to be interdependent.

To capitalize a market opportunity implies in a product and a business existence. A model that represents a system's feasibility and its performance is needed. The BP is a document that has been used to make this model explicit.

The BP is a document that can be adapted for diverse goals. It must incorporate business and product related questions. It can be simultaneously developed with the PDP and be used at the process decision gates, after the initial idea selection. It may be useful, over all, for companies who need to raise external resources for its development projects, as it is meant for the evaluation and capturing of potential investors.

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A case study about the product development process evaluation

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Abstract. The significance of business process approach has been increasingly recognized on new product development management (NPD). The challenge is how to build models to support it. This paper presents a model named PDPNet to provide it and describes an application case study in a agriculture machine enterprise. The data collect instruments are participant observations and document analysis. The results contains the description and an evaluation of the maturity level, considering the model proposed. The conclusion presents considerations about the support disposal by the model during the application, the challenges findings, and proposals about future research.

Keywords. Product development process, maturity model, transformation model

1 Introduction

New product development process (NPD) is vital to competitiveness in all sectors of economy. Among the best management practices is the business process (BP) approach [10], which seeks to integrate activities from different enterprise functions, in order to obtain performance excellence. To apply this approach is fundamental the use a formal NPD process, that means to produce a map describing the new product development process and provides a set of techniques that make this possible [17].

Kalpic and Bernus [9] demonstrated the importance of this approach in a case study specifically at the new product development area and explain how reference models can be helpful in project, management and execution of BP. Since the emergence of the BP approach on NPD, more or less elaborated models have been proposed to help professionals to identify the best available practices [12, 16].

The bibliographical review presented in section 3 analyses some one of most knowledge models and as a result two aspects to be noted. The first is the lack of NPD transformation models. The second one is the need to integrate the three types

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of models, i.e. process, maturity and change management. This implies the conception of distinct models evolving and kept independently, but which could be used together, allowing the diagnosis (by means of maturity assessment), identification of needed practices (with the process model) and prioritization and identification of transformation strategies in the change model (NPD change model).

Since 2002 a network of researchers and professionals interested in PDP have developed a reference model, PDPNet, composed of three independent and integrated parts: a process model, a maturity model and a transformation model. This work, through a case study, constitute an evaluation of the maturity according the model proposed and a description of the change management model application.

The objective of this paper is to present the PDPNet model and the account of an application case at an agriculture machinery enterprise. The study contributes to the development of the model by identifying perceived improvements and assessing its application potential.

2 New Product Development Process Management

One of the classical definitions of the product development process is given by Clark & Fujimoto [2] and marked the beginning of the utilization of the BP approach in product development management. Until then effective product development had been seen as the responsibility of engineers, thus disregarding the integration of marketing, planning and product introduction activities in factories.

In the last decade, it has expanded to include activities related to strategic planning and production follow-up and recalls, as proposed initially by Clark & Wheelwright [3]. Several theoretical models have been utilized as reference to design and improve NPD, e.g. Pugh [12], Clark & Wheelwright [3], Cooper [5], Ulrich & Eppinger [18], Ullman [17], Baxter [1] and Clausing [4].

These models focus mainly on describing practices—i.e. activities, phases, methods and tools—acknowledged as effective in product development projects. Nevertheless, these practices are often dependent on each other, i.e. the adoption of one of them depends on the existence of the others. This—aggravated by the broad and multidisciplinary nature of NPD process—makes it difficult to identify which practices, tools and techniques should be prioritized in specific cases where the model is being implemented.

In the late 1990's, there appeared several NPD models with distinct characteristics, focusing on the assessment of evolution levels: the maturity models. Besides indicating practices, a maturity model allows the assessment of the evolution level of companies as regards its adoption. The most famous of these models is the CMMi model by Software Engineering Institute [7]. After studying this model, it is possible to notice that—despite allowing level identification—it approaches practices rather broadly; it does not specify the best way to implement them as some of the more detailed process models do, e.g. the model described by Creveling [6].

3 The PDPNet Model

The PDPNet product development process was devised by a network of research groups and professionals in the field of product development management. These researchers got together in a practice community on the Internet and met regularly from 2002 to 2004 [13]. The result of this collective work has been recently published as a book, write in Portuguese, and as a web site [14, 15]. The model comprises three distinct parts: process reference model, maturity model and change management model, as detailed at the figure 1 and the following items.

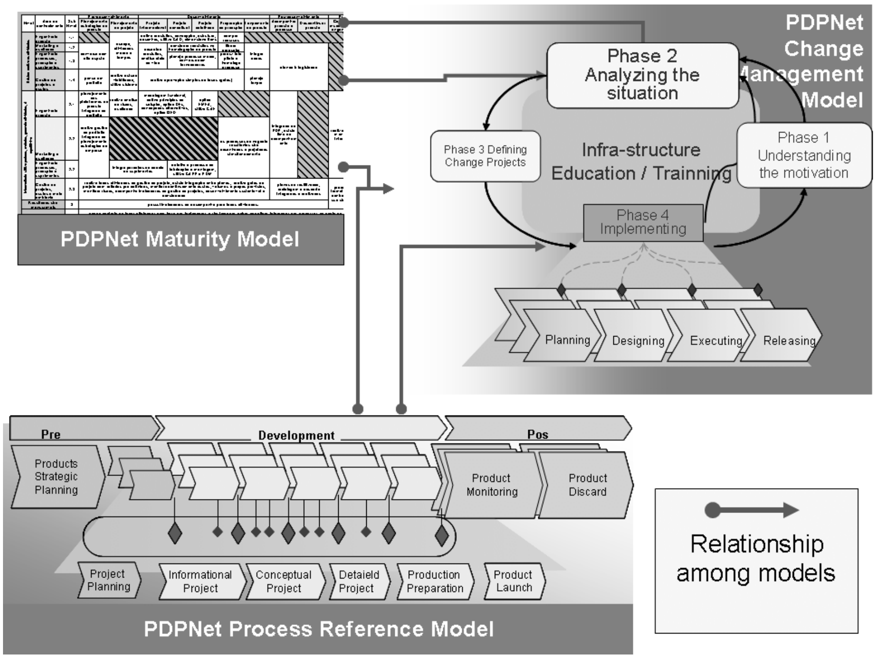

Figure 1. Reference Models

3.1 The PDPNet process reference model

The PDPNet process reference model depicts the best practices for the management of product development processes, presenting and relating phases and activities to several practices and methods available in the field. Its goal is to integrate available practices and to elucidate them in detail irrespective of the company's evolution level.

The reference model is divided into three macro-phases.

Pre-development macro-phase. Pre-development is the link between the projects developed by the company and its goals. It includes the company's the strategic product planning, which involves the Corporation or Business Unit Strategic Plan deployments on project portfolio, with the evaluation and track of selected projects.

Development macro-phase. This macro-phase includes the phases entail the detailing of technical, commercial and production information, involving elements such as technical drawings, prototypes, homologations, records, partnerships with suppliers and production processes.

Post-development macro-phase. In this phase one may assess the product performance in the market, its withdrawal and improvement processes that could be implemented.

3.2 The PDPNet maturity model

The NPD maturity model is used to support the identification of the evolution level reached by a company at a given moment. It depicts maturity levels and shows which activities should be formalized and implemented at each one of these levels. The description shows, therefore, a hierarchy of priorities in terms of activities so that higher levels can only be achieved if lower levels have already been reached. The model—according the CMMi model—utilizes five possible evolution stages:

Level 1 – Basic. When the company systematically carries out a set of practices deemed as essential for the effective management of product development. It is subdivided into five sublevels, each one grouping practices according to areas of knowledge: product engineering, marketing and quality, manufacturing process engineering and projects, costs and environment management.

Level 2 – Intermediate. Practices are standardized, thus results are predictable. At the previous level it was sufficient to have them performed, even with variations. This level is also subdivided into four intermediate levels consistent with the knowledge areas

Level 3 – Measurable. Besides being standardized, there are indicators that assist in assessing the performance of activities and the quality of results.

Level 4 – Controlled. The company works systematically to correct practices whose indicators have deviated from expected values.

Level 5 – Continuous improvement. There are institutionalized processes to improve the BP itself. They may take place in the short run or in the long run. The authors propose two models. The first model is the "incremental improvement process", one of the processes that give support to the NPD reference model. The second one is the NPD transformation process model, which aims at deeper and long-term improvements.

Each maturity level indicates a set of institutionalized practices, as in the CMMi model. In the PDPNet model this is verified by formalized activities.

3.3 The PDP change management model

The PDPNet change management model describes how to implement desired changes so that companies may reach the maturity level. It is based on concepts of change management and project management, since broader change actions become projects.

The core of the model is the infrastructure for change. The first step is to define an organizational structure through which the change may occur. Defining responsibilities clearly avoids the common mistake of identifying improvements in the development process, assigning them to a professional—or to a group—without an effective follow-up process, which could result in inaction in the long run.

The second infrastructure aspect to be tackled is the team's modus operandi. Since it is composed of dedicated professionals whose role is critical to routine NPD activities a simple routine is needed. It cannot compromise members' performance in the remaining activities.

Finally, to enable the Committee members to make decisions and prioritize improvement projects more effectively it is necessary to provide them with reliable and adequate information about the product development process. When this infrastructure has been created, the model proposes that the transformation cycles should be initiated. There are four distinct phases: **Phase 1** - Understanding the motivation and necessary changes; **Phase 2** - Analyzing the situation; **Phase 3** - Defining change projects and **Phase 4** - Implementing actions.

4 Method

The research methodology employed was a single and holistic case study according to Yin [19]. The BP of the agriculture machinery company (soil preparation and planting) in question constituted its analysis unit, considering both the product development process and the actions taken to improve it. The complete activities involved three steps which have been described at sections 5.1, 5.2 and 5.3.

During the investigation the researchers accompanied the implementation by visiting the company for 18 months on a fortnightly/monthly basis. Data were collected via documents and field observations.

5 Analysis and Results

The company under consideration is located in Brazil and has 400 employees. It produces a variety of agriculture machinery, especially for soy bean and corn crops. It exports to several countries, is ISO-9001 certified and is known in the market for its quality products.

The company operated in a classical functional manner. The functions that participated in product development were: product engineering, process engineering, prototypes, ferramentaria, technical assistance and Production and Planning. The functional area of product engineering involves around 15 engineers and designers. The company's functional approach was another problem acknowledged by its top administration. There were several inefficiencies such as faulty manufacture of tools, delays in detailing the process and delivering the product, among others concerning the application of classical management methods. The main inefficiency was the average time of new product development, which was estimated to range from 1.5 to 3 years.

The main phases of the improvement program were described in the sections below.

5.1 Diagnosis of new product development process

This phase comprised a critical analysis of the company's problems, whose goal was to assess its maturity level in the management of the new product development process. The diagnosis was carried out by the researchers in the first semester of 2005, during four weeks on a weekly basis.

The analysis was conducted internally by the NPD director with the help of one of the designers from the product design area, using the maturity model assisted by the process reference model. These professionals began by identifying the documents that described the company's NPD process. The most important documents were the Quality Assurance System procedures. The documents and these professionals' experience assisted in carrying out the activities and identifying the level of formalization. The results were discussed with the researchers.

The results showed that the company had a well established set of institutionalized procedures for more conventional and routine development activities, deriving from the Quality System.

However, some relevant gaps were identified according to the maturity model:**Product portfolio,** the company did not have a formal system to manage the portfolio of new products; **Project planning,** it did not seriously take into account aspects such as risks, customers' needs, project strategies; **It did not have phases and gates (phase transitions),** although there was a procedure to carry out development activities, phases were not formalized; **Flaws in institutionalized procedures,** there were certain flaws in the identification and control process of new product projects; **Functional structure,** the company displayed a classical functional organizational structure.

The company was classified as being in Level 1.1. of the model. The assessment allowed the group to have a shared vision of the main inefficiencies that needed to be tackled.

5.2 Structuring the NPD improvement program

The group chose to introduce two fundamental measures: to define formally the project manager's role and to define the improvement team.

A matrix structure was established by creating project manager positions. There were three areas so as to incorporate new markets and types of equipment an a new functional area was also created to address the performance of tests, prototypes and high technology projects.

A team of managers from the product engineering area, the Engineering Committee, was in charge of the program. People of related areas are invited to participate as specific needs arise. Results generated by teams are presented to the Committee, which has the responsibility of validating new standards.

This infrastructure evolved and was consolidated at the end of the work, when it was named as Project Office. It assists in the improvement program as well as in the work carried out by the project Managers. The tasks assisted are: elaboration of standards and procedures related to the NPD process, consolidation of information and product portfolio reports, generation of information on performance and progress of NPD projects, generation of information about NPD improvement projects, assistance in conducting process improvement processes.

5.3 Identifying and carrying our improvement projects

The main goal selected for the first phase was to reach Level 1, i.e. the basic level of the maturity model, thus obtaining a stable development process. Four initial projects were chosen: 1) Introduction of a system to create and manage the project portfolio (medium term); 2) Implementation of system to control resources (medium term); 3) Improvement of document management system (short term); 4) Mapping of NPD process with phases and gates (long term).

The mapping project was put on hold, and the teams' efforts were directed to the other projects. Two projects were finished on time: Aggregated project plan and Solution of specific problems in the document management system.

A third project was partially implemented in this period of time: project to implement a resource control system. This project involved the introduction of information systems capable of integrating resources from diverse functional areas in a single pool, discriminating their allocation in each project. It allowed the introduction of weekly planning of activities performed by people involved in the development of the company's products.

As the previous projects were finished new improvement projects were initiated: Mapping and optimization of the project procedure for supplied parts and Organizational restructuring of areas related to NPD.

The first project is over now and the second one is in its final phase.

This effort resulted in a project prioritization system that contributed a larger quantity of products to the company. The final result was the achievement of the basic maturity level, as initially planned.

6 Conclusions

Results from the case study and the analysis of the model indicate that the PDPNet model helped to build a permanent transformation process of the company's NPD business process, which indicated the best practices as well as allowed the establishment of a system—internal to the organization—to keep this ongoing until strategic goals were reached.

The PDPNet model has classifications in process areas and types of basic elements (activities, phases and gates) that were followed in the three models. This aspect was fundamental throughout the implementation, in particular the classification of knowledge areas and phases in the maturity model. They allow the direct identification of activities that are related to gaps in terms of the company's maturity evolution. Then, users may identify which methods, tools and principles can be implemented to improve the activity.

The transformation model, surprisingly, gained more importance than the other models in the case in question and was fundamental to the success of the implementation. When the company's professionals understood the concept of systematic changes deriving from improvement projects the team's focus was enhanced and the performance of improvement actions advanced. This suggests that transformation models should be studied and be regarded as important as the process and maturity models as to the pursuit of efficacy in NPD management by processes.

In terms of research project, the work emphasizes the importance of continuing to develop the change management model, which played a fundamental role in the implementation under consideration.

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Product Development Systematization and Performance: a case-study in an automotive company

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Abstract. Product development process (PDP) has been recognized as a source of competitive profits and nowadays has received special attention from companies. Recent literature suggests that to get an effective systematization it is necessary to analyze and improve this business process. Then PDP models had been a common place in the research agenda. This article describes the case of product development systematization in a specific automotive enterprise. During the case research it was collected recent data of company performance and history information regarding changes on its PDP model and practices. This research allowed us to identify actions, best and bad practices and analyze the impact on performance in order to identify aspects to be studied. Finally, this research discusses gaps between implemented activities and PDP models related in the bibliographical review.

Keywords. Product Development Process, Systematization, Performance.

1 Instruction

Recognized as a source of profits, product development process (PDP) nowadays has been viewed with key-point of success once through PDP systematization companies can reduce their costs and development time and increase their product quality. Available literature suggests that to get and effective systematization it is necessary to continuously improve the PDP so that it can follow the continuous necessity of develop better products to be launched to the market. Then PDP models describing phases, best practices and methods for product development had been discussed a lot in the agenda [2, 5, 9, 12-14]. Even considered as a key-point of success, it is not commum to find companies carrying or working on PDP systematization. In addition, a small number of studies can be found discussing effective PDP models implementation, considering steps this implementation represents and also how to proceed PDP improvement and performance impacts are aspects were not be explored sufficiently.

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Actually, automotive companies have good maturity level if compared with other market segments and the idea that originated this article was thecase of product development systematization in a specific automotive enterprise. During the case research it was collected recent data of company performance and history information regarding changes on its PDP model and practices. Through a holistic case study [15] this research identified actions, best and bad practices and analyzed the impact on performance in order to identify aspects to be studied at theory. To analyze PDP systematization and performance it was selected six concluded product development projects which were developed on two different periods of time: before and after a set of PDP systematization actions. Results of the two project groups were compared through some key performance indicators.

2 Product Development Process Reference Models

Product development process (PDP) is not a process made by independent activities and under the responsibility of marketing, production, process and product areas anymore [5]. Nowadays companies understood to get an efficient product development it is necessary to get a multifunctional team working together, following same directions and goals. To apply this approach is fundamental to use a formal PDP that means to produce a map describing new PDP. Business process modeling, or enterprise integration, provides a set of techniques make this possible [2]. Kalpic and Bernus [3] demonstrated the importance of this approach in a case study specifically at this area. Authors explain how reference models can be helpful in activities related to project, management and execution of business process. Since the emergence of the business processes approach on NPD, more or less elaborated reference models have been proposed to help professionals to identify best available practices [4, 5].

3 PDP Sistematization

To be effectively systematized, PDP needs to be reviewed into companies. It happens by activities belong to PDP or not; as example activities can belong to continuous improvement process that is a support process that can be applied for all process into a company. This research considers both processes as we consider they also can help PDP systematization. Into this context, the standardization of activities is one of the key-points to get systematization, once if activities are standardized they can be faster understood, used and multiplied into the company. As consequence, standardization can eliminate wastes of the process.

Nowadays there are some published researches that suggest PDP systematization based on a reference model [4, 10, 11, 14]; main point is that they don't discuss or analyze their effective applicability. [4] developed a research with focus in a re-organization of the management of PDP model. Many activities and tools discussed by the literature – specially applied on production process into companies – can also be applied to PDP, if they are right adequated to its particular characteristics such as creativity and intangibility. Some of them are described by: Benchmarking; 5S Program; Lean Thinking; Kaizen culture; Stage-Gate, etc.

During the analyses of case study it was possible to find many of these activities and tools been implemented and used by that company. They will be better explained during next chapters. Detailed discussion about list of those activities and tools available on literature can be found on [1].

4 Case-Study

The case study of this research is a Brazilian unit of a worldwide auto parts. The site selected is a technologic center located in Brazil since 1999. First product development activities under local team responsibilities happened in 2001, when it was allocated first product engineers. Before this all responsibilities were located in the USA and Brazilian team only supported them. In 2002 it was established a Project Support Office (PSO) to support developments which local project managers as strategy to increase business in Brazil. In 2006 they had 35 projects, 25 advanced projects (strategic developments without a agreement from customer) and many business opportunities for future competition in the market.

5 Product Development Process into the Case-Study

5.1 PDP Reference Model used by the company

Figure 1 brings a general vision of PDP model into the company. It is called *Phase-Gates*; it was a way they found to analyze development during their evolution and to give direction (from high-levels of the organization). These directions can be: stop developing, keep working or re-make.

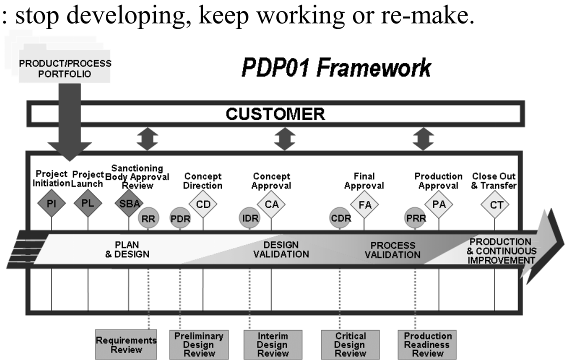

Figure 1 - PDP Model into the company

There are two types of gate-review: technical ones, called *design reviews* represented by lozenges on Figure 1 and management gates, called *project reviews*, represented by circles; this last kind of gates has the goal to verify if actual status of a specific project is aligned with proposed plan on the scope, by the beginning of the project, including key-dates, scope, customer requirements, costs, timing, etc. Communication with customer happens during all development guarantying its participation and that they are following the voice of customer during the project. PDP model empathizes plan and design begin phases. It also suggests a global project categorization by types (A, B, C and D), where A category represents a most complex product and process development and D represents a routine project. Each category has its own requirements and steps to be followed.

5.2 History of Enterprise PDP Implementation into de Site

Product development process adopted by the company was firstly published by the head-quarter in the USA in 1995, just after APQP manual published by the cars-makers. The proposal of model was to define a standard for all new product development project, ensuring conformance with requirements from customers.

In 1997 PDP model was reviewed at the first time and again in 1998. The most recent PDP model revision happened in 2001, when it was eliminated micro-activities from the model and also the ones considered as not added-value to the customer. This revision represented a decrease of more than 50% when compared with previous revision. On this new scenario, all required activities from PDP model represented only 105 activities. First re-organization into product development department was held in 2001, when - by continuous efforts from Brazilian high-level hierarchy with headquarters in the USA – it was allocated first product engineers and project managers in Brazil. From 2003 it was formalized a parallel structure to support product developments. It was called *Project Support Office* (PSO) and they standardized and created practices to control, organize and make new product development activities. It was held many training sessions to the team to share knowledge, with an independent supervisor.

PDP systematization was leaded and facilitated by PSO; they identified gaps, defined and implemented plans and verified their efficiency with indicators previously defined. Many post-project audits were held to capture new knowledge, lessons learned and best practices and to turn them available to the rest of the team.

5.3 Process Vision Culture

During the research it was possible to note systematization of PDP into that site was based in an introduction of a model to structure activities, where many areas of the company worked together, focusing their own tasks but looking for a common goal: better products to be faster offered to market, following company strategies. This model is known and adopted by a multifunctional team but it was noted some of people didn't know all PDP activities as they should. Otherwise they know exactly and in details their responsibilities into projects and what is the best to way to do them. Main problem regarding PDP model into the company refers to people from multifunctional team but who work outside that site. To solve those issues

PSO team established activities and tools as set of efforts demonstrated at the Figure 2, including process culture diffusion, training e projects audits.

The figure demonstrates that it was more intensive done last three years.

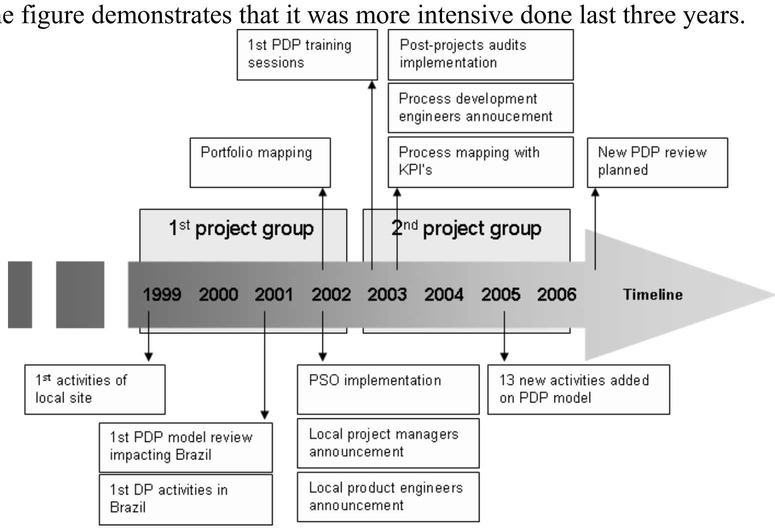

Figure 2 - Examples of PDP Systematization Steps into Case Study

6 PDP Systematization and Projects Perfomance

To analyze effectiveness of PDP systematization into the site it was firstly selected six different projects, which were developed in two different periods of time: before and after a set of PDP systematization. Results of the groups were compared through key-performance indicators previously defined: number of allocated people; planned budget/timing x executed budget/timing; planned x executed nationalization; number of compliments from customer. Criteria for project selection are described below and represented on Figure 3:

- each pair should belong to the same product line and complexity;
- 3 projects from each group (1 or 2) should be executed at same period;
- all projects should be concluded until the date of this research;
- each project from each pair should be executed during different periods.

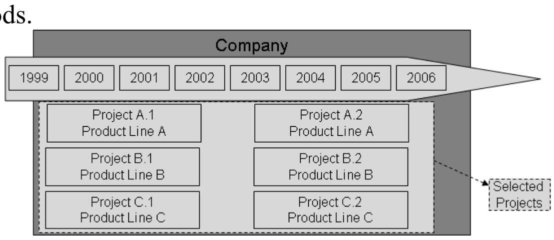

Figure 3 - Selected Projects by Group

After a research on available literature it was identified activities and tools suggested by literature that could facilitate PDP systematization. Examples are listed below; full list can be found on [1]:

- use electronic mock-up to simulations;
- use quality tools to ensure performance: FMEA, QFD, DFE, etc;
- define specific department to support product developments;
- define and monitor performance key-indicators;
- implement *stage-gates* methodology;
- implement a depository of lessons learned;
- use concurrent engineering;
- define programs to stimulate continuous improvement practices;

Characteristics of the activities and tools were divided by three different groups with the goal to better understand maturity level of first and second project groups:

- formal: activities and tools with frequency, methodology and responsibilities previously defined; in other words, there is a formal procedure to be executed;
- *ad-hoc*: activities and tools happens according punctual necessity; it doesn't matter about frequency or responsible. There is a known methodology but it doesn't require a formal procedure to happen;
- *no-exist*: suggested by literature but didn't find on the case.

The results of the data collected are represented as follows:

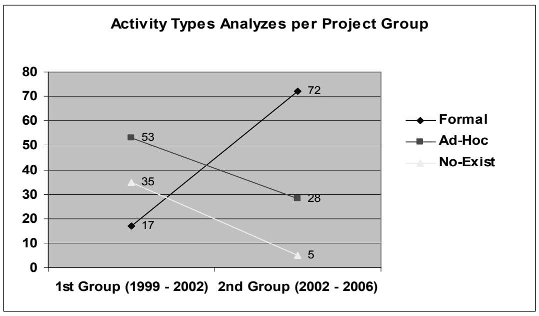

Figure 4 – Comparisons of Two Project Groups

Analyzing presented results by the number of found activities and tools in each project group we have a significant increase of formal activities on the same time we have a decrease of ad-hoc and not-exist ones. It represents that the effort located to PDP systematization resulted in a formalization of most activities and tools they had or they knew. Regarding key-performance indicators we have:

	Product Line A		Product Line B		Product Line C	
First project group (1998 - 2002)						
	Project A.1		Project B.1		Project C.1	
	Forecast	Actual	Forecast	Actual	Forecast	Actual
Category	B	B	B	B	C	C
Involved People	15	12	30	30	9	9
Timing	2 years	2 years	3 years	3 years	14 months	14 months
Budget	100	90	100	100	Not defined	Not defined
Nacionatization	0%	0%	Not defined	3%	10%	10%
Fails aftermarket	Not defined	1000 ppm	Reduction of 70%	Reduction of 70%	0	0
Formal complaints from customer	0	0	0	0	0	0
Second project group (2002 - 2006)						
	Project A.2		Project B.2		Project C.2	
	Forecast	Actual	Forecast	Actual	Forecast	Actual
Category	B	C-B	B	B - A	C	C - B
Involved People	10	10	20	20	9	9
Timing	2 years	2 years	2 years and half	2 years and half	2 years	2 years
Budget	100	90	100	80	100	95
Nacionatization	10%	10%	More than Project 1	35,30%	Not applicable	Not applicable
Fails aftermarket	500 ppm	500 ppm	1000 ppm	445 ppm	1000 ppm	445 ppm
Formal complaints from customer	0	0	0	0	0	0

Figure 5 - Key-Performance Indicators from Projects

Results are present in percent and not in real numbers due to confidential requirements from the company. Indicators demonstrate that first projects (belong to the first group) met expectations of the company and the customer because timing, budget and quality requirements were met. By the other side, analyzing all data it is possible to note that goals of the first group were easier than the second group, especially for timing and costs and as consequence, easier to be achieved.

Local responsibilities also increased a lot for the second group once during the first projects they only supported activities in Brazil.

The second group of projects presents better results with compared with the first group and also they have targets more difficult to be achieved. One example is budget defined to the projects.

7 Conclusion

Examples of PDP models seem to be generic and application weren't found on the literature. It is necessary to implement some of them to study their performance and impacts in a practical business scenario. Case-study demonstrated that companies' models are following literature, but usually after an adaptation in a specific segment such auto parts. Indicators used on case-study validate previous discussion found on the literature that the implementation of activities contribute to PDP systematization brings wins profit and reduce development timings, and, in addition, keep the company with competitive advantages. Project analyzes show PDP systematization brought positive results so that this research suggests it can be important to have a reorganization of complementary processes to PDP, such as continuous improvement process. One of hypotheses that this research suggests is it can be essential to have a systematized continuous improvement process with focus on PDP and not only as a support process for PDP, as described by literature.

The case study demonstrated it is necessary to have continuous improvement activities being formalized for PDP activities.

Fully analyzes of continuous improvement capability model can be found on [1], where the author investigates available models on literature – some of them already applied to PDP – and suggests a utilization of that model as a support to PDP. Similar than we have on project management literature (CMMI and others) there is a specific continuous improvement model that can help PDP systematization, showing where the company is, where they need to be in a close future and also where this should be is a longer future.

It was possible to prove that even with its non-measurable characteristics it is possible to define measurable indicators to verify actual and forecast scenario for PDP systematization.

Analyzing case study results it was also possible to see available projects categories are not enough to describe all projects into portfólio they have, in other words, it is not clear to multifunctional team how projects can be added to one or other categories. A prove of this if that two of the six analyzed projects were changed their category during the development. It demonstrated that probably there is a necessity to nationalize project categories according local necessities (with bases on global ones).

Projects behavior, even if in different categories, was similar, considering first and second groups separately.

A continuation of this research could be a validation of the hypotheses that continuous improvement process needs to be not only a support process but also a systematized process with focus on PDP, once it was demonstrated that continuous improvement activities helped to improve product development results. It could also be analyzed same scenario of other auto parts companies other in companies from other segments.

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An approach to lean product development planning

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Abstract. A product development system (PDS) is based on two pillars: "do the thing right" and "do the right thing". While the former leads to operational efficiency and waste reduction, the latter guarantees the fulfillment of all stakeholders needs. In this context, Toyota's PDS has a superior performance. The lack of formalization of the Toyota PDS system, though, makes it difficult to replicate. Research on this system has resulted in the identification of several principles, tools and techniques, but did not present a way to make them systematic. This paper aims to propose a systematic way to make the lean engineering product development planning. The method allows the creation of an activity network, which provides at the same time value creation and waste reduction. The first part of the paper identifies the needs to the lean development planning. In sequence the method conception is presented. Finally the method is evaluated against the identified needs and improvement opportunities observed on an aerospace product development example.

Keywords. development planning, product development, lean philosophy

1 Introduction

New product development (PD) can be understood as some kind of information based factory [1]. The goal of the PD process is to create a “recipe” for producing a product [2], which reduces risk and uncertainty while gradually developing a new and error-free product which can then be realized by manufacturing, sold, and delivered to the customer.

PD is a problem-solving and knowledge-accumulation process, which is based on two pillars: "do the thing right" and "do the right thing". The former guarantees that progress is made and value is added by creating useful information that reduces uncertainty and/or ambiguity [3], [4]. The latter addresses the challenge to produce information at the right time, when it will be most useful [5], [6]. Developing complex and/or novel systems multiplies these challenges; the coupling of individual components or modules may turn engineering changes in a

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component into “snowballs”, in some cases causing long rework cycles and turning virtually impossible to anticipate the final outcome [7].

Not surprisingly, overtime, over budget and low quality are commonplaces on PD projects. A great exception in this scenario, and benchmark on the automotive industry, is the Toyota Motor Company. Toyota has, consistently, succeeded in its PD projects, presenting productivity four times better then their rivals [8]. To deliver better products faster and cheaper, some firms are attempting to use the same principles as Toyota’s, and create “lean PD” processes that continuously add customer value (i.e., that sustain a level of “progress” toward their goals) [9], [10]. Unfortunately, unlike Toyota Production System (TPS), that was formalized by Shigeo Shingo and enforced by Taichii Ohno, the Toyota development system has not been well documented [11], [12].

This paper aims to propose a systematic way to make the lean engineering products development planning. The method allows the creation of an activity network, which provides at the same time value creation and waste reduction.

This work consists of three parts: (1) the identification of the needs to the lean development planning; (2) the method conception; and (3) the method evaluation against the identified needs and improvement opportunities observed on an aerospace product development example.

2 The needs for the lean development planning

Literature review allowed to understand the real needs for the lean development planning (LDP). First it was necessary to clarify the meaning of value creation and waste reduction on the PD context. Next, the main issues on the PD processes, LPD prerequisites and PD projects planning were pointed.

2.1 Value creation and waste reduction

The value, as defined by the final client, is the basis of lean thinking. In a program or project, the value is the raison d’être of the project team, which means they must understand all the required product/service characteristics regarding the value that all stakeholders of the program expect to receive during the product life cycle [8], [5], [13].

There is no recipe, though, to value creation. Value is: (1) personal, because something of high importance to a group or person may not be valuable to others; (2) temporal, since it is not static, but evolve according to stakeholders’ change of priorities; (3) systemic and enterprise wide, as the parts, subsystems or company’s sectors only add value if they contribute for the whole; and (4) fuzzy at the beginning of the lifecycle, due to the few information available to determine the whole value and, sometimes, even the final client [5].

The inherent complexity of the development of complex engineering products is a serious obstacle to value creation. According to concurrent engineering principles when a product is conceived it already constrains its life cycle processes and the organizations that perform those processes, creating a total perspective where the product plays only part of the whole complexity [14]. Thus the “total” value includes not only the product's perceived benefits, but also the benefits achieved through the life cycle processes and performing organization. Value for a stakeholder, then, is the total and balanced perception of all benefits provided by the results from the life cycle processes; as a total perception are considered not only the results related to the product, the processes and the performing organization, but also the fulfillment of all functional, cost, schedule and risk requirements [15].

Concerning waste, in manufacturing for instance, Toyota has established a set of seven waste categories that make easier the task of waste finding and elimination. These categories were further adapted to the PD environment [1], [10], [16]. Table 1 shows the seven wastes countermeasures from the PD perspective [15].

Table 1. Wastes countermeasures on product development

Waste	Product development perspective
Overproduction	Synchronize the information and resources capability and schedule. Use pull events instead of phase gates.
Transportation	Define optimized information flows (what, when, to whom and how). Avoid multitasking.
Waiting	Include only dependencies that represent the value flow.
Processing	The project network must include all and only the activities from and to support the value flow. Guarantee the allocation of the right people and materials.
Inventory	Define clearly what, when and who will perform each task. Execute resource leveling.
Unnecessary Movement	Avoid micro planning that may lead to information inconsistency.
Defective Product	Create a verification and validation plan to check the right value delivery.

2.2 Issues to the Lean Product Development Planning

The identified issues are related to the PD process, to the lean prerequisites to PD and to the traditional planning methods.

A PD process has to be capable to deal with: (1) product complexity, as customers demand products more and more complex; (2) process complexity, regarding integrated development, process standardization, amount of information involved, etc.; and (3) uncertainty between supposed and verified characteristics and ambiguity due to multiple and conflicting interpretations.

In order to be lean, the PD process must adhere to the lean principles (Table 2) and avoid traps such as [5]:

- The 'preconceived solution': a solution that has worked in the past and that has become institutionalized as a 'monument'.
- The existence of a powerful advocate with a vested interest in a specific design approach or solution to a problem.

- The tendency to underestimate the difficulties in developing a new technology, particularly if this occurs simultaneously with the development of a new product or system based on that technology.

Table 2. Lean principles applied to development planning.

Specify value	The value (as defined earlier) to all stakeholders must be identified and balanced into a solution.
Identify the value flow	The best value creation sequence must be identified, allowing the information to flow and consequent value delivery.
Guarantee the flow	Remove the obstacles from the value flow, avoiding waste and synchronizing the development activities.
Work with a pull system	Instead off pushing scheduled activities, which themselves push information and materials through the development process, pull events must be defined. Pull events differ from phase gates by not damming information, but allowing its flow.
Seek perfection	The development process continuous improvement is achieved by the capability of the process and effective knowledge management.

Finally, traditional planning falls short on lean development due to the following aspects:

- In order to guarantee the ‘schedule stability’ a point and low risk solution has to be frozen early in the process in detriment of others viable solutions [8].
- The main objective of planning is the control and not the execution [17]. Thus, more importance is given to the activities themselves instead of their results [8].
- It incorporates a transformation view, by assuming that translating a plan into action is the simple process of issuing and executing ‘orders’, analogously to a MRP (Manufacturing Resource Planning) [18].
- The systemic vision loss caused by successive product and work decompositions [15].

3. A lean perspective on the development process

The ideal PD process should work analogously the single-piece flow in manufacturing [19], representing a value flow from conception to production, without stops due to bureaucracy and loop backs to correct errors. On PD, adding customer value can be less a function of doing the right activities (or of not doing the wrong ones) than of getting the right information in the right place at the right time [8], [9]. Hence, the focus of lean must not be restricted to activity “liposuction” (waste reduction), but address the PD process as a system (value creation) [9]. Value creation can be divided into three phases: value identification, value proposition and value delivery [5]. Figure 1 shows the elements on these three phases [15].

During value identification the value demanded by each stakeholder is understood and decomposed into value items that are unambiguous and verifiable through measures of effectiveness.

While creating the value proposition, teams are defined according to the development scope (set of value items). A set of pull events is also defined, in order to allow a pulled development. Examples of pull events are important deliverables and major verifications. Activities are defined in order to allow the execution of the pull events. Activities are performed by the teams whose deliverables incorporate the value items in the scope of the pull event.

The value delivery occurs while the activities are actually performed and the resulting deliverables benefits are perceived by the stakeholders.

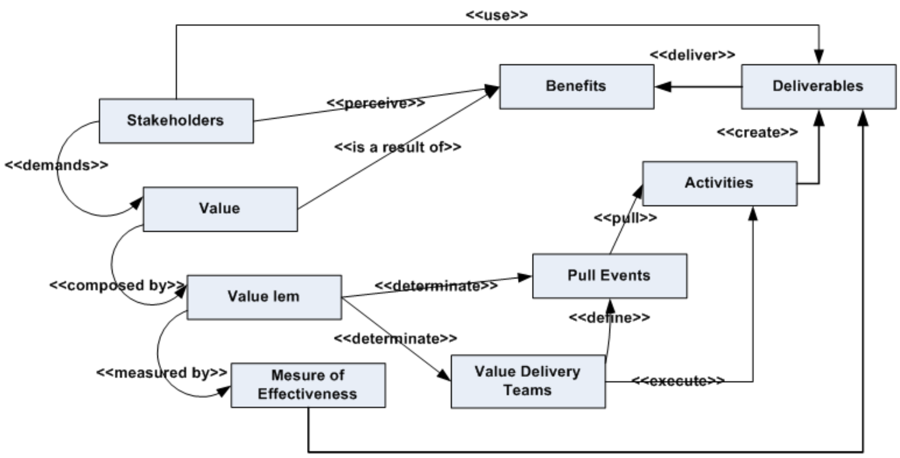

Figure 1. Lean perspective on PD process [15].

3 The Method

The approach described in this section applies the lean principles, based on value creation and waste reduction, to derive a project activity network that is based on a value creation sequenced set of confirmation events that pulls only the necessary and sufficient information and materials from the product development team. The purposed method has four steps (Figure 2):

(1) **Value determination**: having the product vision as an input, this process defines the Value Breakdown Structure – VBS. The VBS differs from the usual WBS, where the latter decompose the work, to make major project deliverables or perform project phases, into smaller and more manageable chunks, and the former deploys the stakeholders' value into unequivocal and verifiable parameters, called value items.

(2) **Set-based Concurrent Engineering (SBCE) prioritization**: determines the most critical product modules or organizational processes, which will be developed through a set of alternatives. During SBCE, the development team does not establish an early system level design, but instead establishes sets of

possibilities for each subsystem or process, many of which are carried far into the product and process design.

(3) **Pull events determination**: No process along the value flow should produce an item, part, service or information without direct request from the afterward processes. The pull events arte associated to physical progress evidences (i.e., models, prototypes, start of production, etc.) and are important moments to knowledge capture. Differently from tall gates where information batches are created, pull events guarantee the value flow, make quality problems visible and create knowledge.

(4) **Value creation activities sequencing**: the activities to be performed are defined and sequenced based on the pull events.

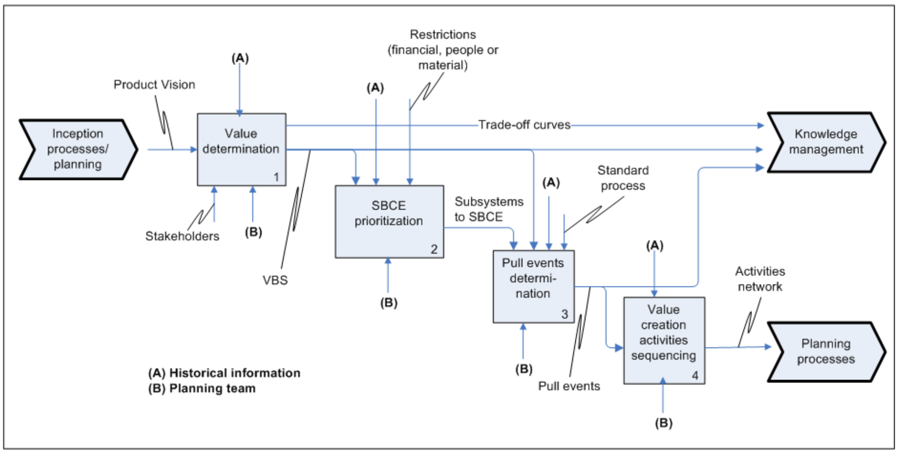

Figure 2. The purposed method.

4 The method evaluation

The method was evalueted according its capacity to fulfill the previously presented needs (Table 3):

(1) **Value determination**: this step guarantees the value specification principle; it avoids preconceived or any other solution that does not match the expected value; the focus on value is the basis to planning to execution; finally, analogously to the others steps, it uses and generates historical information that contributes to continuous improvement.

(2) **Set-based Concurrent Engineering (SBCE) prioritization**: the multiple alternative development prevent the early abandonment of promising solutions and gives room to the coexistence with preconceived and advocated alternatives as well; it helps to guarantee the flow, since reduces rework cycles.

(3) **Pull events determination**: the pull events are the back bone of the value flow and have the main role to fulfill the pull work principle; by pulling the value delivery they allow the planning to execution.

(4) **Value creation activities** the pulled value creation activities are the value flow itself; by being put in motion, they are the very planning to execution.

Table 3. The method coverage on the identified issues.

		Value determination	SBCE prioritization	Pull events determination	Value creation activities sequencing
Lean Principles	Specify value	x			
	Identify the value stream			x	x
	Guarantee the flow		x		x
	Pull the value			x	
	Seek perfection	x	x	x	x
Traps to value creation	Preconceived solution	x	x		
	Powerful advocate with vested interest	x			
	Develop a new product with new technology		x		
Issues on traditional planning	Early solution freeze		x		
	Planning to control and not execution	x		x	x
	The transformation view			x	x
	Systemic vision loss	x		x	x

As the basis for a contrived example of development planning, was used the data collected from a finished and successful project, which produced a stall recovery system to be used during flight tests. Table 4 presents a comparative analysis of the original planning and the one resulting from the method application. On this particular example there were better results at each of the four steps.

Table 4. Lean principles applied to development planning.

Step	Original Planning	With the Method	Impact
Value determination	Only client's needs related to the final product were considered.	All the stakeholders' needs related to the final product and the life cycle process were considered.	Create Value
SBCE prioritization	Only one solution alternative mainly describes in the contract.	Many alternatives on the parachute launching subsystem (critical to SBCE) would reduce the rework that actually happened.	Reduce waste
Pull events determination	Homologation and test activities were superficially defined.	The test and homologation events were best sequenced and scoped.	Create Value Reduce waste
Value creation activities sequencing	The plan was focused on activities based on the standard process.	The plan was focused on the value and based on the value flow.	Create Value Reduce waste

9 Conclusions

The research method presented in this paper provides a useful approach to planning to complex engineering products development. Conclusions are that the developed method: (1) fits the product development environment; (2) adheres to the lean principles; (3) faces the traditional planning deficiencies; (4) exploits the improvement opportunities from the studied example.

This work contributes to the PD discipline by the appliancation of the lean principles, based on value creation and waste reduction, to derive a project activity network that is based on a value creation sequenced set of confirmation events that pulls only the necessary and sufficient information and materials from the product development team.

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Managing new product development process: a proposal of a theoretical model about their dimensions and the dynamics of the process

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Abstract. The development of products consists of a process that involves knowledge and several functional areas and presents a high degree of complexity and iteration in its execution. The literature presents several models and approaches for characterizing the new product development process. However, they usually do not adequately represent its dynamics. The present work aims at characterizing the product development process based on the nature of its elements covered by the literature. A representative conceptual model of this process is proposed within two levels of integration. The theoretical model is based on six dimensions (strategic, organizational, technical, planning, control and operational) integrated in the levels of structural and operational. It also identifies what the elements that compose the operational dimension are and how the interaction between them might be characterized. The paper also emphasizes the need for new studies with a detailed analysis of the interaction and the integration of the elements here presented.

Keywords. Product development management; product design; new product development.

1 Introduction

New product development (NPD) presents several characteristics that differentiate it from other processes, as follows: high degree of uncertainty and risks in the activities; difficultty to change initial decisions; the basic activities follow an iterative cycle; the creation and handling of a high volume of information and multiple requirements to be considered [14]. NPD is defined as the transformation of a market opportunity into a product available for sale [9], through a set of activities [14] executed in a logical way, sequentially or concurrently [6].

Several models were created in the last decades containing rules, guidelines and procedures for managing product development [7]. The models initially described

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the process as a linear system, with discrete and sequential stages, while more recent studies consider that the development process evolves through stages, but with overlap and feedback loops [10].

According to ref. [8], the development projects became a collaborative entrepreneurship with highly complex interdependencies. In doing so, the search for more effective organizational patterns in the development process shall include a detailed analysis of how the development really happens [4].

Considering then the inadequate representativeness and applicability of theoretical models and frameworks to deal with the dynamics of the product development process, this paper aims at characterizing this process through a representation of its dimensions and the elements that compose it, beyond analyzing the interaction between each party.

2 Research Methods and Techniques

This paper can be classified as a theoretical-conceptual research. The development was based on a literature review, in which papers related to management, coordination, integration and decisions in the product development process were gathered. A search in the following journals was initially done from the period of 1999 to 2006: *Journal of Product Innovation Management, Management Science, Research and Development Management, Production and Operations Management e Research Policy*. After that, papers were obtained by key words in the following databases: *emeraldinsight; extenza-eps; blackwell-synergy; sciencedirect*. Finally, other papers were selected by cross-reference, adding up to 52 papers in total.

The research can be divided in two main parts. In the first part, several ways of classifying the product development process were conducted. Then, based on the previous analysis, a classification of the dimensions that compose the NPD process was proposed. The topics that compose each dimension were then grouped according to this classification. The second part of the literature review was aimed at identifying the elements that characterize the development process itself and the way they interact. To do this, the papers that have an empirical approach were analyzed considering approaches and tools in which these elements are considered.

3 Literature Background

3.1 Approaches and classifications of the development process

According to ref. [3], the study of NPD management, widely and in an integrated way, is quite new. Since it is a vast knowledge field [3] it can be classified in several ways. In the literature, several approaches were found and there is an overlap of themes in some areas. Product development approaches can be classified according to an academic perspective [3] that includes [9]: marketing, organization, engineering and operations management. Another way of looking at NPD process is according to the perspective of the functional areas, that conceive

NPD in a different way, thus complementary. Other emphases can be found in the product development literature, for example, the use of methods and techniques.

Ref. [3] presented a classification framework of the more relevant topics in product development management. Three dimensions have been proposed: strategic, operational and performance evaluation of the product development. The strategic dimension is divided into two main topics, including subjects related to portfolio management, capacity dimensioning and inter-organizational and inter-functional integration. The operational dimension is divided into the following topics: the development process itself and the use of methods and techniques and the work organization.

Ref. [9] proposes an approach based on the decisions. They affirm that while *how* products are developed differ not only across firms but within the same firm over time, *what* is being decided seems to remain fairly consistent. In this way, they propose a classification that organizes the decisions into two categories: the decisions within the context of a single project and the decisions in setting up a development project. On one hand, the authors in ref. [9] divide the decisions within the context of a single project in four categories: concept development, supply-chain design, product design, and production ramp-up and launch. On the other hand, the decisions in setting up a development project are divided into three categories: product strategy and planning, product development organization, and project management.

Other authors in the product development literature have used the approach based on decision. Ref. [10] considered three levels of NPD decisions: strategic, review and in-stage. The 'strategic' decisions are related to market and product strategies and portfolio management. The decisions in the 'review' level occur between stages, while 'in-stage' decisions refer to those in the operational level of each phase. In the same line of thought, in ref. [1] the decisions are classified in four levels: strategic planning, tactical planning, operational planning and planning infrastructure. The work in ref. [13] stemms from ref. [9] and proposes a division into two systems: the operational system and the development system.

From the classifications shown earlier, the strategic and the operational dimensions are explicitly cited in almost all of them [1,3,9,10]. Its concepts are also considered in the classification proposed in ref. [13]. Other dimensions that can also be also highlighted are the organizational and the project management that are cited in almost all classifications.

3.2 Dynamics of the development process - approaches and concepts

The increasing complexity and the cooperative environment in the design process requires a more effective coordination of it [8]. On the other hand, coordination underlies many of the management problems in designing products rapidly and effectively [2]. The most used representations and techniques do not adequately describe the dynamics of the development process [6] and this requires an analysis of how the development really occurs [4]. Considering this, several authors are working on new approaches and concepts aiming at providing tools that will help in the coordination, integration and in the development process decision making.

Ref. [2] proposed the ‘coordination structure’, an approach to model the organizational situations that considers the concepts of responsibility interdependence, social networks and shared objects. The approach that was proposed, according to the authors, provides the foundation upon which information is communicated and processed.

The work in ref. [6] was based on the Dependency Structure Matrix (DSM), proposed in ref. [16], to deal with the information interdependence among tasks. The proposed approach has the objective of designing project plans that produce greater concurrency and better iteration management, focusing management attention on the essential information transfer requirements of a project.

In doing so, the concepts presented here should be considered, once they affect the way models are developed and applied and the way that the development process works [10]. Ref. [15] states that uncertainty reduction will be facilitated by higher levels of integration across functions and the use of modes of integration that have higher potential for information processing.

4 Proposed Conceptual Model

4.1 Dimensions of the development process

A classification of the dimensions of NPD process is proposed based on the literature review. This classification stems from refs. [3,9]. Therefore, instead of considering an approach based uniquely on the decisions, the nature of the topics that compose each dimension is considered. The resulting classification contains six dimensions, the ones that are predominant in the literature, plus the ones that resulted from the classification based on the nature of the elements. The proposed dimensions are: strategic, organizational, technical, planning, control and operational. The strategic dimension represents the attempt to articulate the market needs, the technological possibilities and the company competencies, in a way that allows the business to perpetuate [3]. Decisions in this dimension are related to market and product strategies and the portfolio management [10]. Some decisions that can be cited as being strategic are: what is the timing of product development projects? [9]. The organizational dimension consists of topics related to the social systems and the environment in which the product development activities are held [9]. A particular aspect of the classification herein proposed is the inclusion of product development models in this dimension, considering that they represent the structure that the product will be developed through. This characterises it primarily as an organizational element, since this dimension contains not only the elements of a unique project, but also what refer to the whole company. Other topics like competence and technology development policies were included in this dimension as well as the integration along the supply-chain. Another dimension that distinguishes this classification from the ones in the literature is the technical dimension. This dimension includes the product development methods and tools. They are means that exist to support the product development activities [14]. These tools can be fit into any area of the classification proposed by [11]: project techniques, organizational techniques, manufacturing techniques, information technologies and supply-chain. Some of theses tools are shown in table 1.

Table 1. Product development dimensions and topics

Strategic	Organizational	Technical	Planning	Control	Operational
Portfolio managemen Market intelligence Platform renewal Capacity dimensionin Budgeting	Organizational structures New product development models Competence development policies Technological development Supply-chain integration	FMEA QFD DFMA CAD CAPP CAE PDM Robust Design Modular Design, etc.	Scope definition Resources and cost planning Activity definition and duration estimating Activity sequencing and schedule development Risk identification and analysis, etc.	Scope verification Cost control Schedule control Quality control Project team management Risk monitoring and control, etc	Development execution: application of the strategic definitions, in a defined organizational structure, in accordance with project plans, making use of specifics methods and tools.

Planning and control dimensions are in the context of project management. The classification herein proposed, based on the differentiated nature of its elements, divided the project management techniques in two other sub-dimensions: planning and control. The items presented in table 1 were based on ref. [12]. Finally, the operational dimension does not present specific topics, but consists of the project execution itself. It is about the application of the strategic definitions, in a defined organizational structure, in accordance with project plans, making use of specific methods and tools.

4.2 Decisions and integration levels

The decision levels proposed in this article are based on the two category division proposed by ref. [9]. However, they are distinguished in some aspects. Their classification is based on the decision perspective, that considers *what* is decided in the development process, instead of considering the way the development happens (i.e. *how*). In this sense, the decisions were organized in two categories, as follows: the decision in the context of a single project and the decisions in setting up a development project.

The present work uses both *how* the product is developed as *what* is decided. Therefore, it proposes two levels of integration in the product development process. The first level refers to *how* the product is developed and was herein called the structural level. At this level, the decisions are aimed at setting up the organizational context and they refer to corporative patterns [9]. Thus, the integration at the structural level corresponds to the definition and the alignment at the company about the standards to be used during the development project.

The second level refers to the application of the organizational standards in a specific project. Therefore, this level contains both the decisions in a single project, like the planning and execution of the development project. The integration at the operational level corresponds to the application of the organizational patterns in the project being developed. In such a way, the development process could be represented, in a macro view, by six dimensions and should be integrated in two levels. At a higher level, there would be the integration in the organizational context. The development would then happen through the integration in the operational level, where the standards would be applied according to the project particularities. The development of the product would be the result of the application of the elements that compose the five dimensions (strategic, organizational, technical, planning and control) at the operational dimension that characterises the operational integration.

Figure 1 illustrates these dimensions and the integration levels mentioned.

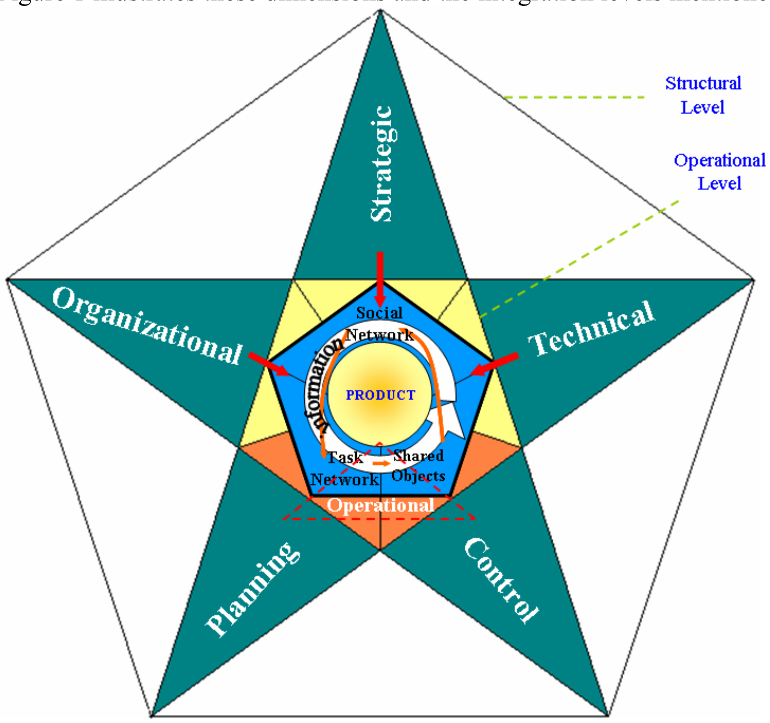

Figure 1. Representation of the conceptual model of the product development process

4.3 The elements and the dynamics of the product development process

Once the product development takes place at the operational dimension, the understanding of how it really happens is of great importance [4]. In this way, it is necessary to consider the information exchange and issues associated to reworks during the development [4], the changes [2], the overlaps [9], among other things. The current analysis did not consider only approaches or methods that deal only with subjects associated to coordination or the dynamics of the product development process. It aims at identifying and analyzing the elements that compose the operational dimension and that explain the dynamics of the development project and uses the concepts found in the literature review.

Initially, there were identified three basic elements that compose this dimension. Two of them were based on the elements that compose the coordination structure proposed by ref. [9]: the social network and the shared objects network. The third element uses the concepts of the interdependence modelling from ref. [5] that considers the interdependence between tasks and resources.

In this sense, the present work proposes that the operational dimensional is composed by the following elements: a social network, a task network and another shared objects. The social network comprises the people or groups participating in the development. The task network includes the activities necessary to develop the product. Now, the shared objects represent the information that are created and transformed during the project as, for example, the customer requirements, the product specifications, the project of the components [2], and so on. In this way, product development occurs through the integration of these three elements: the social network uses the shared object to execute the tasks and doing so, it will generate new shared objects or transform the previous ones. Considering the task of concept development, for example, the social network would use: *customer requirements* (shared objects) to *develop the product concept* (task). So, the generated concept (shared object) will be used by the social network to *develop the product specifications* (tasks), for example.

A fourth element that can be included in the previous representation would be the flow of information within the project. It can be considered as a mean through which the process happens. As can be seen figure 1 shows the conceptual model of the development process with their dimensions, elements and a representation of the dynamics of the operational dimension.

5 Concluding Remarks

Since this study is part of an on-going research and it is not fully completed, conclusions should be taken with care. Nevertheless, some concluding points deserve attention. Firstly, it has been identified in the literature that it seems to exist a lack of a conceptual model that represents all dimensions and interactions in the new product development process. Secondly, the theoretical model shown in this article comes and meets the needs of a more adequate representation that describes the dynamics of the development process pointed out by some authors earlier cited. It integrates different perspectives of new product development process, considering the nature of the elements as the basis for its elaboration. Finally, even as a preliminary study, the conceptual model here proposed seems to contribute to the understanding of the dynamics of the product development process, given the separation of the operational dimension of the other five that constitute the structure of the development project. This gives a clear notion that, although the methods and techniques that compose each dimension are very well understood, the conjoined application of them in a development project needs to be better detailed and studied.

In this sense, future studies shall be developed considering the points here addressed and a detailed analysis of the conjoined application of the topics that compose each dimension in the operation dimension seems to be also important. In addition, an analysis of how the integration of all these elements occurs, together with methods to optimize it would contribute to the understanding of such a complex process as new product development.

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A support tool for the selection of statistical techniques for industrial product development and improvement processes

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Abstract. This paper presents a structured model to help the user choose the most appropriate statistical technique to solve problems relating to the product development process. Starting from a well-defined problem, the model helps the user convert the problem into statistical objectives. Based on those objectives, the decision model then defines a sequence of structured questions whose responses lead to the selection of the statistical technique. The sequence of questions is supported by examples, detailed explanations of the concepts involved, links to sites associated with the case, and a glossary of statistical terms. Statistical techniques are support tools for the New Product Development Process (NPD) and are used in various activities of this process. The main result expected from the use of the model is the dissemination of the application of statistical techniques during the NPD process in companies, especially small and medium companies, where this type of support is most lacking. To enable companies to use and test the structured model, a decision support system will be developed for free access on the Internet.

Keywords. Statistical Techniques, New Product Development Process, Web-based System.

1 Introduction

The industrial sector shows an increasing demand for statistical knowledge to deal with quantitative or qualitative data. This demand is partly a result of normative processes (ISO, TS, QS) and of quality improvement programs strongly based on statistical techniques. These techniques include the Six Sigma programs for the improvement of manufacturing processes and DFSS (Design for Six Sigma) for the improvement of new product development processes. These programs have created methodologies based on quality techniques and tools to lead to the solution of industrial problems. These tools and techniques can aid in the solution of different problems relating to the improvement of products and processes and of the new product development (NPD) process.

DFSS is based on the integration of tools such as QFD, Pugh's Matrix, and statistical tools of multivariate analysis and Design of Experiments in NPD. The objective is to establish an integrated set of tools as a means to efficiently translate information in the development phases, favoring the incorporation of technical, strategic and financial values to the product in order to meet consumer and market needs. While Six Sigma programs work in the ambit of reaction and correction of existing problems in the domain of the process, DFSS is used for the prevention of problems through the use of quality tools and statistical techniques in the product's conception phase [2].

The product development process, in turn, has been systematized and structured in so-called reference models, which represent the process and serve as a guide for its application. Starting from a generic reference model, a company can define its specific model, also known as standard process, which becomes a "manual of procedures" and serves as the basis for the specification of product development projects, thus ensuring the repeatability of the company's projects as well as constituting a repository of best practices.

Many of the activities of product development and process improvement make use of quality tools involving statistical techniques. Throughout NPD, from the conception phase of a product to its removal from the market, methods and tools are employed to support the execution of the diverse activities of this process. However, for the business user to apply the best statistical technique, he must be familiar with the available techniques and with all the presuppositions required for its correct application. This knowledge is normally a specialist skill, since a variety of questions and conditions must be analyzed before a specific technique is selected. In particular, the transition of a practical problem into statistical/research objectives is the first obstacle to the choice of the most suitable technique. Despite the advances in computational systems, which seek to improve the interface with the user and to automate some of the steps of statistical analysis, the phase prior to the application of the technique, involving the choice and planning of which analysis to use, is not effectively aided by existing software programs.

Based on the experience of the authors and on interviews with company users and specialists, a series of problems commonly encountered in the use of statistics was drawn up, which include learning strongly based on the teaching of the execution of the technique. Six Sigma programs, for example, are usually based on the execution of exercises carried out immediately after the presentation of a technique, which, to a certain extent, directs or guides its application. The interpretation of the data centers on the needs of the statistical software and on the output data supplied in the analysis. The companies interviewed indicated that a problem is the difficulty in recognizing which technique to use in real situations, even when there is a previous notion of the technique. It is difficult to understand how to organize thoughts, i.e., how to plan the study, from the definition of the sample to the identification of variables to be studied and the type of analysis that is viable.

The Six Sigma and DFSS programs are examples and an opportunity to integrate the statistical method to practical problems in the industrial context as a way to understand and analyze the solutions to problems. Despite the many efforts and advances in this area, the application of statistical techniques is still limited. There is a potential (a range of techniques and new possibilities for use) as yet unexplored by industry, but the use of statistics is not seen as something easy. It would be necessary to help users understand how this reasoning works, especially in terms of associating the theory with their reality and with their problem.

This article proposes a structured model for the selection of statistical techniques. Starting from a decision structure composed of questions and possible answers, the user is led to one or several statistical techniques that are suitable for his problem. This proposal is more than a simple guide, since it also provides knowledge to help the user understand the process of selection, based on the presentation of examples, a glossary of statistical terms and a description of key concepts to grasp the techniques.

2 Methodology

The approach most widely adopted in this project is the hypothetical-deductive approach proposed by Karl Popper in 1935. This approach allows for the creation of a set of postulates, tools and hypotheses that one attempts to refute by means of experiments, based on which one deduces the consequences, which, when refuted, are replaced by others [4].

With regard to technical procedures, this work is classified as action research, since it focuses both on action and on the creation of knowledge or theory about the realization of innovative projects. Action research is recommended for new approaches where new ideas must be explored and knowledge must be created from the standpoint of practical aspects. A close association must be conceived and made with an action or with a solution for a collective problem, in which the researchers and participants representing the problem are involved cooperatively or participatively [8].

Based on this methodological reference, the model foresees the phases of bibliographic review, content systematization that includes the classification of statistical techniques and modeling of the decision process for the choice of technique, and elaboration and organization of the content. These phases are described below.

2.1 Bibliographic review

The model was built based on consolidated information available in didactic books about techniques and application of statistics in a wide range of areas of knowledge. In this bibliographic review, information was collected enabled us to outline the decision structure for selecting the technique best suited to the problem in question. The most exhaustively consulted references were [2, 3, 5, 7].

2.2 Content systematization

2.2.1 Classification of statistical techniques

The classification of statistical techniques was organized to characterize the gamut of possibilities. The classification was based on the categorization of books on statistics summarized in the works [3, 8].

This phase is fundamental, since it is this combination of possibilities that allows for the indication of an analytical technique.

The proposed model initially broaches the use of several techniques, the ones most frequently used in the industrial sector, which are highlighted, for example, in DFSS.

2.2.2 Modeling of the decision process for the choice of a statistical technique

Based on the classification of the techniques, the possibilities and ramifications were defined, resulting in a structured decision model with the logic of what information would be necessary to recognize the statistical technique.

2.2.3 Elaboration and organization of the content

The structured model was used as the basis to elaborate the support contents, which will enable the user to know and learn more about the concepts involved in the analysis. From previous experience, it is known that the use of statistics produces better results when one presents practical examples relating to the user's daily routines. Thus, for each concept, the system intends to associate a description, with additional references (links), examples of cases and a glossary of terms.

2.3 Definition of the target public

The definition of the target public refers to the user of the model. The initial target public is a professional of the industrial sector possessing basic knowledge of statistics, with a degree in engineering, administration or the graduate of training courses such as Six Sigma or other quality programs encompassing statistical techniques. Thus, the user of the model is not a layman in the use of statistical techniques. We believe the system will serve as a support tool in various activities involving an understanding of data on the market and the product that is being developed. Therefore, the target public may be the product development team itself, which already has a way to treat and analyze data integrated with the team's technical knowledge.

2.4 Requisites of the model

Based on this context, the structured model should aid users in their selection of statistical techniques applicable to the improvement of industrial products and processes. This model includes some basic properties that are summarized in four main points: (1) It should help the user understand the research problem for the use of statistical techniques. (2) It must be a learning instrument that teaches terms employed in statistics, concepts and access to links to delve deeper into the subject. (3) It should allow the user to standardize his research projects following the logic of the model. (4) It should favor the insertion of new techniques, broadening the range of possibilities for the problems involved in new product development.

3 The structured model

The selection of a suitable Statistical technique to solve a company's problem or to provide information about it depends on the user's technical knowledge and on an understanding of a series of questions of the Statistical domain for this decision. Starting from the theoretical review described in the bibliographic review phase and on the experience of the authors in the application of Statistics in the area of product development, a structure was outlined and subdivided into the following stages: (1) Scope of the problem; (2) Definition of the statistical objective; (3) Number of variables involved in the analysis; (4) Type of relationship among the variables; (5) Number of explanatory variables or number of samples; and (6) Measurement scale of the variables. The analytical technique is indicated based on a route (combination of the answers given by the user). Figure 1 presents the proposed decision model.

The selection of the technique is the result of a sequence of questions. These questions were drawn up based on the stages defined previously. One or more suitable techniques can be identified based on a set of answers given by the user. This process is described in greater detail below.

The application of statistical techniques usually involved general objectives, which allow one to direct a subset of techniques. In this work, since our focus is on the product development process and on the DFSS methodology, it was possible to specify several objectives, called the scope of the problem (stage 1), which represents the cycle of improvements of a product or process. This cycle is based on diagnostic, optimization, control and analytical techniques.

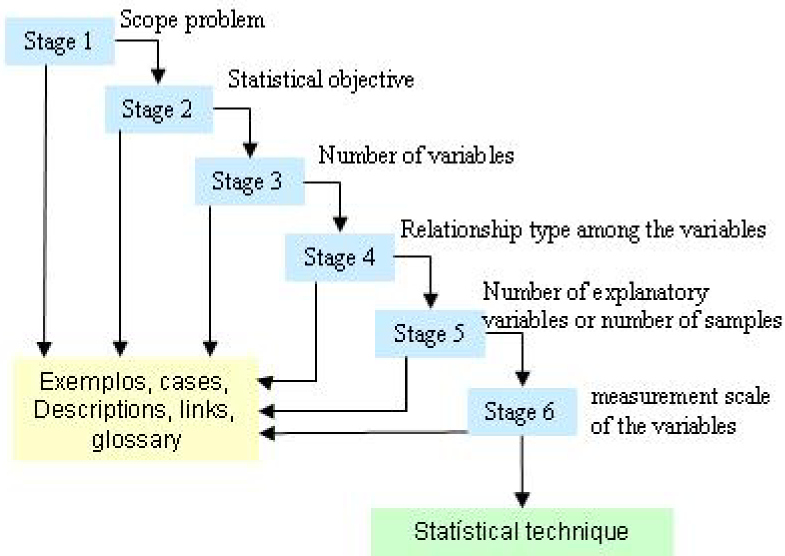

Figure 1. Structured model for the selection of a statistical technique

Diagnostic techniques are techniques of preparation and deepening of knowledge of the research problem. For example, the analysis of a mensuration system involves checking the capacity of the mensuration instruments and procedures to supply reliable measures for subsequent analysis. This group includes reliability analysis to evaluate the performance and quality of product development.

Optimization techniques are defined as the experimental design and surface-response methodology techniques.

Control techniques are those that monitor and ensure system quality, and are basically the techniques pertaining to Statistical Process Control (SPC).

Analytical techniques were classified as the statistical techniques most frequently used in industry and applicable to the PDP (product development process). The group of analytical techniques includes the following: hypothesis testing, simple regression, logistic regression, multiple regression, ANOVA, multivariate analysis, etc. The structured decision model was created for this group, since it comprises techniques that can be used during the phases of PDP.

In the group of techniques associated with analysis, the following statistical objectives can be specified (stage 2): relate, model, associate, verify, test or compare. Thus, the user's research objective should be aligned with some of these predefined statistical objectives.

Proceeding along the decision structure, one questions the number of variables involved in the analysis (stage 3). This option helps the user understand and classify his study as one variable at a time (univariate), two variables (bivariate) or K variables simultaneously (multivariate). In each stage, the process of choice is supported by examples, a glossary of terms with an explanation of the meaning of each of the statistical terms used in that stage, a more detailed technical description about the terms, and links for the user to consult.

In stage 4, one questions the type of relationships among the variables, e.g., dependent (simple or multiple) or independent. In stage 5, one verifies the number of explanatory or independent variables in the problem, or else the number of samples. And lastly, in stage 6, a question that is common to all the possible alternatives, the user classifies the measurement scale of the variables involved, i.e., as metric (intervallic) or nonmetric (nominal or ordinal).

To validate the proposed structure, new tests should be conducted to test the sequence of questions and their applicability to different cases. We believe that statistical technical language should always be accompanied by simpler language aided by examples. When the user is able to translate and relate statistical ratiocination into his daily routine, he will also be more qualified to read books, articles and other studies that deal with statistical techniques focusing on his area. As he uses the model for various studies (projects), this language will become incorporated into his everyday life. Thus, in the end, experiments planned more scientifically and reliably gradually become part of his routine.

It cannot be stated that all problems can be classified from the questions suggested here, but it should be noted that this classification encompasses most cases, although one can expect to encounter situations that do not fit into the set of foreseen possibilities. However, this is an initial proposal, which should be improved and perfected based on the results of its application in companies and on refinements of the available knowledge about the use of statistical techniques.

4 Results expected from the model

Some of the principal contributions expected from the use of this model are: (1) greater utilization of statistics in tests and experiments on existing products and in the development of new products, helping improve quality through a better understanding of how the characteristics and quality of a product are correlated and affect its performance; (2) An understanding of the nature and workings of alterations to products can be obtained through statistical analysis, such as the treatment of data from tests and simulations, contributing to basic research in the study of new technologies and materials; (3) The possibility of applying and perfecting techniques and methodologies for the dissemination of statistical knowledge integrated to product and process quality improvement; (4) The possibility of generating new methodologies to understand what variables are critical to the quality of a product, adapted to the sector under study; (5) Render viable the integration of statistical techniques as PDP tools.

5 Final considerations

This article presented the development of a proposal for the elaboration of a support model for users in the selection of statistical techniques applicable to industrial product and process improvements. The resulting systematics refers to a decision model that attempts to reproduce the questions a professional knowledgeable about statistics would ask himself in the selection and planning of a statistical technique.

The main users are professionals with a basic knowledge of statistics, who aid product development or quality project improvement teams in the use of statistical techniques for treating data, helping them understand, conceive and measure product performance. The model is also easily applicable to the stages of a Six Sigma project.

We intend to continue this project in the future, developing an interactive system in the Web environment, which will enable the user to include new information in the model, such as examples, definitions, comments about best practices, articles about cases of application, etc. In addition, the system will constitute a tool integrated to the reference model for the product development process [6], since it is already available for consultation on the URL hppt://www.pdp.org.br. Many activities of the model use statistical techniques. Details of which technique to use and how to use it would be supplied by the proposed system.

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Is the design process integrated to product development?

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Abstract. The objective of the article is to compare the Engineering and Design fields in relation to the Product Development Process (PDP). In both areas we can identify different methodologies that guide, each one under its own optic, the Product Project. Although aiming the same objective, the Product Development, these two fields present a certain disconnection, if we compare the models presented in the literature. This can be explained by the fact that Engineering traditionally develops the products with emphasis in the technical aspects of the products and Design investigates the interfaces of the users with the products. Considering this, this article consists in a theoretical discussion regarding to an appropriation of planning models of the Product Development by the Design field, from the the problem solving process as well as the systematization and coordination of the creation activity. As conclusion, the work presents a methodological systematization with the implementation of new techniques for the process of Design, focusing at the trends adopted for the corporations that search constant innovation, efficiency of the products and services, and adaptation to the changes, among others factors.

Keywords. Design Process; Product Development; Design Management, Product Development Process.

1 Introduction

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Nowadays, accordingly to new understanding, businesses have to focus on what can be done to please the external clients as much as balancing its profits so that they do not go bankrupt. In this case the demand for a better understanding of Processes are very important in Business as in Production terms.

The concept of process is considered here like in its origin from the Latin word *procedere,* as a verb that indicates the action of going forward, going ahead (*pro+cedere*) [12]. It is considered also as a peculiar sequence of changes that intends to reach a certain goal. Process is used to create, invent, project, transform, produce, control, keep and use products or systems.

For a better understanding, the concept of Business Process [11] in this work will be differentiated from the *Design* Process concept. The first will be considered as the management action, while the second as the projectual action [13]. Following this, in this paper, *Design* is considered the processual activity, which is developed since the enterprise's strategic business, named strategic *Design,* to its operational aspects, named Operational Design [18]. The term *Design* will refer not only to the result of the design action, but also to designate the process of transforming actions.

Another initial consideration must be done in respect to the differentiation between Design Process and Product Development concepts. Design Process is considered here as a project activity will be considered as a project activity oriented to the resolution of interface problems that someone can have with his surroundings and Product Development is considered the activity developed by the Engineering field, in which many functional sectors of the enterprise are involved.

Comparing the definitions of DP e PD, we can see that in both areas a group of systematic project activities is developed, and these group of activities involve organization, people, functional areas, the product itself through information transformation, data, inputs, considering the enterprises technological and human resources. From the realization of these activities it is possible to create and produce products that fulfill the expectations of the markets where they are requested, as much in Design as in Engineering approaches.

Considering this, it is possible verify that there is an overlapping between the Product Development (PD) and the PD activities, when developed by Engineering or by *Design*. To both Engineering and *Design* areas, the basic principle of Product Development (PD) or the Design Process (DP) is founded in one kind of Process, hence the initials (PDP) for Product Development Process, which is a transformation process through which an idea becomes an object (product) with the premise that it be industrially produced in sufficiently large scales in order to satisfy *stakeholders* conditions, and also conjugate and harmonize knowledge from a handful of different natures.

Subsequently, in this work, the terminology Product Development Process (PDP) will be adopted in this work, considering that in PDP, both Engineering and *Design* areas, Product Development or Design Process include activities that act in an integrative interdisciplinary way, for they develop a "group of systematic activities" that encloses product, processes, people and organization, they are either simple or direct.

Then, this paper aims to discuss the overlapping between these two fields, Design and Engeneering, the first under the concept of Design Process and the second as Product Development. Doing this, it searches a new correlation between both areas, improving the Design Process.

2 Product Development and Design Process: Strategic Level

2.1 Engineering's Actuation

Product Development (PD), at a strategic level under the Engineering's approach, is characterized accordingly to the Product Development Management (PDM). The work of [7] allows us to identify two (2) distinct approaches of PD: the Engineering Production approach, which focuses on the development processes and products production and the Marketing approach, which focuses on strategies of products intended for the market.

When discussing the PD issue, from a strategic level, as a permanent attempt of articulating the market's necessities, technologies possibilities and the enterprises competences in such a horizon that allows the enterprises' business to have continuity, the same author, the Portfolio Management is characterized by three (3) objectives:

1 - Aligning development project strategies with the business strategy;

2- Maximizing the *Portfolio* values by taking into consideration the available resources; and

3- Balancing the projects under many different criteria.

This first objective, aligning the strategies of the development projects with those of business, suits perfectly to work developed by [20] They presents a Product Management structure is a work that is about a model that an excellent reference for improving the Product Development Process (PDP), where the approached PDP one structure presented by the authors penetrates all of the organizational business model.

Still, these authors present, in details, an amplified vision, including all PDP's phases, coming from Pre-Conception, through Development until it gets to Post-Development. In the Development phase, a special emphasis is given to the Engineering activities.

Subsequently, the work developed by [20] does not only present approaches from the Engineering optic, but also from Business, Marketing, Production, Strategy, Quality, Information Technology, Knowledge Management, among others.

However, an area that was not totally explored is *Design*, as the approach given by the authors identified it only in the Conception Project, where *Design* is mentioned merely as the study of Ergonomics and Aesthetics of a product. In other words, the authors considered the activities developed by the Design in a reduced way, as we will see further and reinforced the notion that Design is an activity that operates mostly in a formal way.

The authors excluded, at this point of their work, other characteristics of Design activity, like, for instance, the activity considered as being an expression of cultural values, whose *Design* objects, resulted by the Product Development Process (PDP) are the carriers of preoccupations, motivations and dominant values in determined historical moments in a society.

Part of the difficulties in understanding *Design*, its benefits and actuation inside enterprises, comes up with the need to study how this activity is seen and how its relations on a business environment happen. A discussion about the design practice, its importance and influence on the business objectives, may contribute to the understanding of this activity and how relations should happen for its effectuation.

It is also important to emphasize that, throughout history; the professional of this activity has developed in distinct manners due to the social-economical, cultural and technological characteristics existing in each country, which lead to different actuations of the designer in society.

2.2 *Design*'s Actuation

The strategic level of *Design* practice is characterized in literature by the field of Design Management (DM).

It is possible to identify some of the main authors proceeding from business, who focus on organizational, planning and strategic managing, and innovation models and even adopt the term strategic *Design*.

It was in England, according to HETZEL apud [18], in a joint action of London's *Royal College of Arts*, and of the *Design Management,* of *London Business School,* directed by Peter Gorb, that the awareness of the roll that *Design* can have over economy and its enterprises came up. In 1975, in the United States, Bill Hannon and the *Massachusetts College of Arts* established the *Design Management Institute* (DMI[23]), in Boston, which is nowadays a reference in Design Management, and which also, together with the *Harvard Business School*, develops the TRIAD, first international research project about Design Management. The link of the two institutions was reinforced and the school has diffused the cases edited by the DMI since 1995. In 1989, the *Design Management Journal* was launched, the only periodic dedicated to the professional of this area. [18].

According to [22], *Design* Management "organizes and coordinates all of design activities, they include "structuring of projects and activities, planning of duedates, selection and planning of personnel, planning and controlling the budget" always having the enterprise's objectives and values as a basis. What should be incorporated to the enterprise's mission and to its basic premise for efficiency is the awareness and accepting of design as a quality and strategy factor by the management. According to the author, PM's activities are done in the operative

[23] DMI's goal is helping design managers to become leaders in their professions; making studies available, financing, promoting and conducting research in design management and sustaining the economical and cultural importance of design (DMI, 2004).

processes are - the concrete accomplishment of the works to be done – and in the strategic projects they are – definition of objectives.

These works, following the same tendency observed in the production engineering field, start comprehending *Design* not only from the operational point of view, but also, they materialize when what is important is to correctly develop the efficiency-product in the design process, and being integrated and participating in the enterprises strategic definitions starting from the highest deciding level and interacting with all of the relevant areas of an enterprise [16].

3 Product Development and Design Process: Operational Level

3.1 Engineering's Actuation

As soon as one approaches Product Development's (PD) operational level as an activity done by Engineering, one focuses on the operational matters of the product development, which are centered on specific projects and a special attention is given to the project itself and to the use of methods and techniques. This approach quotes two (2) models widely used, they are:

- The funnel structure one, with its variations by Clark & Wheelwirght apud [7]; and The "*stage-gate*" generic structure one, with its stages and decision processes by Cooper apud [7].

Cheng also presents a list of bibliographic references that approach specific topics of the operational level.

3.2 Design's Actuation

From the *Design* perspective, at the operational level, this activity, according to [16] is defined as "actions turned towards the design process, sorted as work "from the inside to the outside" in intellectual conception style and functional simplicity (European) as well as of what is worth selling and advertising (American). It does not integrate to other areas and the form follows the function (with an emphasis on the practical-operational functions)".

Nevertheless, opposite to what was presented in Cheng's work [7], in the *Design* field, there was no significative development of methods and techniques that guide the *Design* Process in the way that Product Developments presented nowadays, in constant improvement and in accordance with new business structures, horizontalized and by processes.

Despite having a moment in which Design has looked for developing a methodology of its own, which would congregate many branches of knowledge, whether they are artistic or technological, apparently, throughout history, there was no development of project methodologies, methods or techniques according to the requirements of the product, like Engineering does it.

On the contrary, the empiric methods and a strong basis on creative processes is a common practice of the professional dedicated to this activity. Maybe, that is what led the other areas to see *Design* as an area that only worries about the product's aesthetics. Due to its lack of attachments with a methodology, more strongly based on an analytical thought, whether it is reductionist (Cartesian) or deterministic (cause/effect) or even to the mechanicist methods or the deepening of the system theories

A historical analysis of the design methods evolution shows a connection, initially, with scientific disciplines like General Systems Theory**,** Information Theory, Decision making Theory and Creative Process Theory. However, what is found in the *Design* methods is that, in its majority, its methods have two (2) good bases, one base guided by the systems theory and another guided by creativity.

Among the many analyzed authors who dedicated themselves to building up a new methodology for *Design upon the systems theories,* the main authors are: Bruce Archer [2], Hans Gugelot e Christopher Alexander quoted by John Christopher Jones [14], Gui Bonsiepe [5], Bernad Bürdeck [6], Bernard Löbach [15] and Mike Baxter [3].

There are others with a tendency for searching a Method based on creativity and with techniques like brainstorming (Alex Osborn, 1938), Sinetics (Gordon e Prince, 1961) Jones which consists in the analogy between a problem to be solved and a similar one, and also the lateral thinking – characterized by Edward de Bono [4] as a deliberated and systematic process that allows us to activate our capacity of developing and implementing solutions with an optimized productivity – and with this focus, many authors who consider perception as the guidelines to the project can be found, they are: Bruno Munari [19] which consists in the analogy between a problem to be solved and a similar one, and also the lateral thinking – characterized by Edward de Bono [4], Tomás Maldonado [17] Taboada and Nápoli [21].

4 Conclusions

With what has been exposed, it is important to observe that Design Process (DP), as well as Product Development (PD), activity developed by Engineering, are very wide human activity branches that center on problem resolution, creation, and coordinating and systemic activities.

Each problem to be solved implicates generating balanced results for a number of products developed under the optic of technology, of production, of the market, of the user, of the economy among other factors presented by the two activities.

This fact led processes to be systemized, the information flow to be mapped and the group of activities to be clear and objective, so that, activities and tasks of the process itself that aggregate value to the PD could be done, moreover, capacitating people with different skills and knowledge, generating indicators that improve the process' performance for a constant improvement.

However, in the *Design Process* activity, one can see a stronger preoccupation in developing a knowledge body, operational models with strong links to business, marketing, planning, strategies and management. That means an advance in the developing of *Design* at a strategic level, as shown before. In this case, the term used by professionals of the area is D*esign Management.* With this new scenario, the methods and techniques previously used became outdated or simply were not used anymore by most designers. So, there was a failure of the methodologies that had been developed more rigidly until the 70's. The teaching models and, consequently, the professional activity were slowly substituted by empiric methodologies with strong links to the creative process.

However, contrary, the methodologies or models developed by Engineering searched to systemize activities performed at the PDP, and taking advantage of the analytical theory, organized the steps logically the phases of the product's project to reach the pre-established objectives. In its majority, methodologies present systematic procedures that conduct the analysis, generating proposals so that they can be verified and, therefore, contrary to the project requirements initially defined.

In the repetition of these models, a constant perfecting and continuous improvement on each phase of the Product Development was attempted. These constant improvements allow models developed to provide more trust in all of the process, whether it is during the collecting, analysis, proposals generating or making decisions that a Project's team requires in order to continue the Product Development, and allow the enterprise to reach its goal its desired success.

Subsequently, from the operational level perspective, *Design* can be considered as an integrating part of the knowledge body needed from the Product Development Process Management (DPM) as well as Marketing, Product Engineering, Manufacturing, Logistic and it does not, in anyway, substitute the PDM. It can be considered one among the several processes that as a group of activities aggregates values to the products developed and that deals with information in a differentiated way, as it adopts as a focus of its actuation, the interactions Man/Object/Environment.

So, *Design Process* must reconsider its methodologies, models, at an operational level. In other words, it must explore, develop and update in the same way as Engineering does. Besides that, these methodologies must consider in its structure *Design's* main tasks, which are identifying and evaluating structural, organizational, functional, expressive and economical relations targeting the enlargement of a global sustainability and environmental protection; offering benefits and freedom to a human community as a whole, to the final individual and collective users, protagonists of industry and commerce; and still must support cultural diversity, despite the world's globalization; give to the products, services and systems, forms that are expressed semi-optically and be coherent with the aesthetics of its own complexity.

In this sense, it maybe that the lack of a speech in favor of *Design* comes from this lack of demonstrating that its performance contributes for the progress, from the development and application of the methodologies available, or even from the creation of a model that can suit the new market conditions, executives, organizations and even go against the new business models that make all of the market's technologic, economical and industrial context more dynamic.

The current methodologies and the models are little systemized and little deepened. That permeates teaching, and with that, professionals without a more dynamic and contextualized project methodological basis are formed, without the knowledge of managing tools, like diagnosis, accompanying, evaluation, time and investment return, without any security in the evaluation of the market's product results, which needs to accompany the dynamic now found in the many industrial sectors.

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Collaborative concurrent engineering methodologies, methods and tools

Concurrent Design in Software Development Based on Axiomatic Design

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Abstract. To shorten the lead-time of software, the design tasks should be arranged reasonably. Development process reconfiguration is the key to the concurrent design. Axiomatic design builds the functional-structure model of products by zigzag mapping among domains. The independence axiom demands that the independence of the functional requirements should be maximized. The relationship between tasks is established by analyzing the design matrix. The diagonal matrix shows that the design tasks are mutually independent, and can be concurrently processed so that the overall developing time can be greatly shortened. The triangular matrix shows that the design tasks should be processed sequentially so that the whole process can be managed effectively. By using axiomatic design to analyze the design tasks, the design process can be arranged reasonably and the lead-time can be shortened. The module-junction structure diagram shows the sequence of the software development.

Keywords. Concurrent design, axiomatic design, software development.

1 Introduction

With the rapid development of computer technologies, the application of computer is becoming more and more complicated. Large-scale and highly complicated software projects emerged continually. Software development becomes a system engineering which needs many people to participate. To shorten the developing time to the greatest extend, the tasks should be arranged reasonably. Object-oriented technology, such as Object Modeling Technique [1] and Object-Oriented Software Engineering [2], ensure the development of large-scale software in the perspective of technologies and management. But there are still many problems at the stage of development and maintenance. Such as, no method can optimize the software system [3].

Concurrent design is a comparative design methodology, which enhances productivity and leads to better overall designs. The core of concurrent design is

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the process integration which includes two parts: multidiscipline team method and engineering of product life-cycle [4]. Concurrent means that the development activities occur in the same time and multidiscipline developing teams collaborate to carry out the design. The development process reconfiguration alters the sequential development process into concurrent development process to reduce the lead-time of product and consider all the factors of the design and development. But there is lack of the effective methods to guide the reconfiguration.

Concurrent design can be applied to the software development to optimize the software system and shorten the lead-time. Development process reconfiguration is the key to the concurrent design. Function decomposition is the basic of process reconfiguration, which shows the relationship between the design tasks. It is even as Axiomatic Design (AD) can do. AD provides a framework and criteria of function decomposition. AD can ensure the combination of software modules in a reasonable sequence and manner.

2 Concurrent Design in Software Development Based on AD

2.1 Background of AD

Suh proposed AD in 1990. AD has been considered as a theoretical foundation of designs because it can provide efficient tools and logical analyzing processes to obtain good design. AD makes it easier to integrate and analyze design requirements, solutions, and design processes.

Design in AD contains the following four domains: customer domain, functional domain, physical domain and process domain. Each domain has its corresponding design elements, namely, customer attributes (CAs), functional requirements (FRs), design parameters (DPs), and process variables (PVs). The zigzag mapping among domains is the process of product design (see Figure 1) [5]. The independence axiom, which demands maximizing the independence of the functional requirements, can be used to judge the rationality of design. The information axiom, which demands minimizing the information contents of the design, can be used to select the optimum design.

The mapping process can be expressed mathematically in terms of the characteristic vectors that define the design goals and design solutions. At a given level of the design hierarchy, the set of functional requirements that defines the specific design goals constitutes the FRs vector in functional domain. And the set of design parameters in the physical domain, which has been chosen to satisfy the FRs, constitutes the DPs vector. The relationship between the two vectors can be expressed as

$$\{FRs\} = [A]\{DPs\} \quad (1)$$

Where [A] is a matrix defined as the design matrix that characterizes the product design. Equation (1) is a design equation for product design. The design matrix is of the following form for a square matrix (i.e., the number of FRs is equal to the number of DPs):

$$[A] = \begin{bmatrix} A_{11} & A_{12} & A_{13} \\ A_{21} & A_{22} & A_{23} \\ A_{31} & A_{32} & A_{33} \end{bmatrix} \tag{2}$$

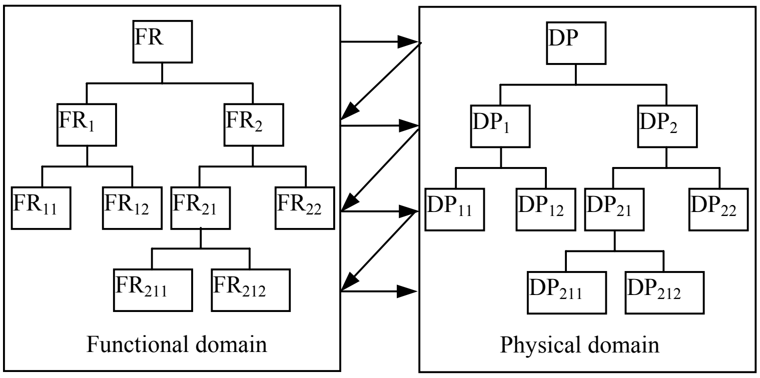

Figure 1. Zigzag mapping between FRs and DPs

When design matrix is either diagonal or triangular, the corresponding design satisfies the Independence Axiom. The former is called an uncoupled design while the latter is called a decoupled design. Any other form of design matrix is called full matrix and will result in a coupled design.

The functional-structure model of products is built by zigzag mapping among domains. The independence axiom ensures the functions' independence. The relationships between tasks are established by analyzing the design matrix. The uncoupled design shows that the design tasks are mutually independent, and can be concurrently processed so that the overall developing time can be greatly shortened. The decoupled design shows that the design tasks should be processed by sequence so that the whole process can be managed effectively.

In the same way, AD can be used to the software development. According to object-oriented technology, a system can be divided into many objects. Corresponding to AD, these objects are FRs. An object encapsulates attribute (corresponding to DPs) and method (corresponding to the relationship between FRs and DPs) (see Figure 2) [6].

In addition, "Module" has special meaning in AD. Such as,

$$\begin{Bmatrix} FR_1 \\ FR_2 \end{Bmatrix} = \begin{bmatrix} a & b \\ c & d \end{bmatrix} \begin{Bmatrix} DP_1 \\ DP_2 \end{Bmatrix}$$

(3)

$FR_1 = aDP_1 + bDP_2 = M_1DP_1$ where, $M_1 = b(DP_2/DP_1) + a$

$FR_2 = cDP_1 + dDP_2 = M_2DP_2$ where, $M_2 = c(DP_1/DP_2) + d$

Object = FR
Attribute Data structure = DP
Method $FR_i = A_{ij}DP_j$

Figure 2. Graphic representation of an object

Suh [6] defined a kind of module-junction structure diagram to represent the relationships between modules in the system (see Figure 3).

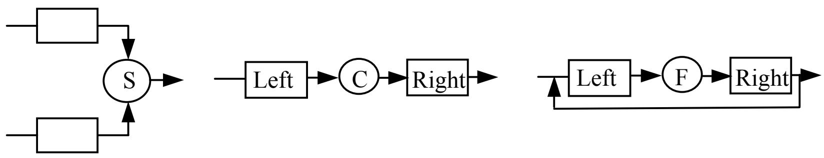

Figure 3. Graphic representations of the relationships between modules

2.2 Steps of Concurrent Design in Software Development Based on AD

The steps of concurrent design in software development based on AD are shown as follows.

Step 1: Analyzing the software using AD

In this step, designers apply AD to decompose the fundamental functions requirements and design parameters, which are generalized from the customer attributes into levels of sub-function requirements and sub-design parameters. The result is the functional-structure model and a full design matrix.

Step 2: Defining modules of the software

Software module development is a powerful method to the complicated large-scale software. It is an effective measure to control the design complexity. Function decomposing is a course that a software system is decomposed into sub-systems objectively and steadily according to the demand of the module development. The functional-structure model is a reasonable decomposing of both functions and components. In this step, designer can define the design or organize a multidiscipline development team to implement different modules and realize the software's functions.

Step 3: Reconfiguring the sequence of modules

The relationships between modules are uncoupled or decoupled on the basis of AD. The uncoupled relationships mean that these modules can be carried out simultaneously and the decoupled relationships mean that these modules must be performed in sequence so that the effect of former modules can be considered and the iterations of design can be reduced. In this step, we can get the module-junction structure diagram that indicates the design sequence. The design tasks can be assigned according to the diagram.

3 Case Study: Software Development of AD

We are planning to develop the axiomatic design software [7]. To arrange the design process reasonably and shorten the lead-time, we use the method proposed in the previous section to analyze the design tasks.

3.1 Analyzing and Design

The software of AD should meet with the following customer attributes:

(1) Recording the design process and building documents;
(2) Providing friendly graphical user interface (GUI);
(3) Helping users make reasonable decision;
(4) Managing the whole design activity.

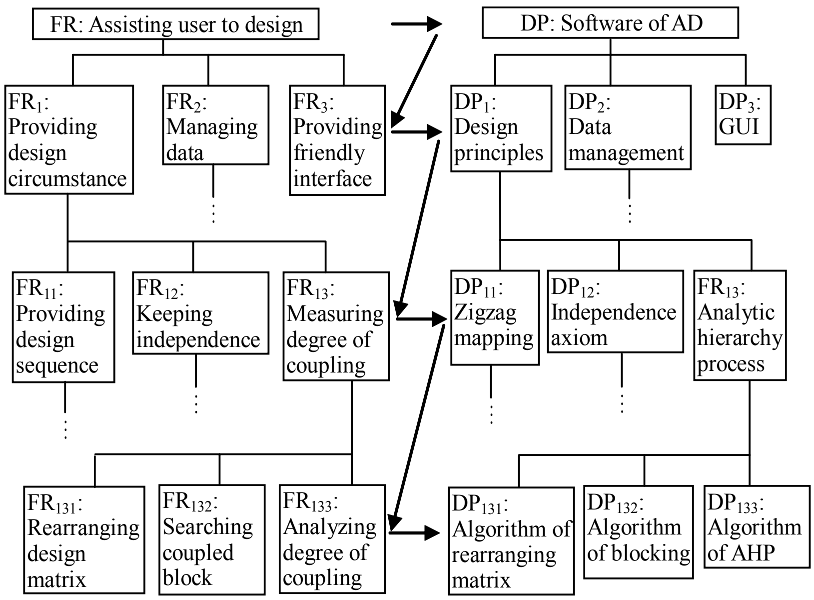

Figure 4. Functional-structure model

In this section, we just show part of the software. Figure 4 is the functional-structure model obtained by zigzag mapping and Table 1 lists the full design matrix. In full design matrix, the element “1” indicates that its corresponding FR is influenced by its corresponding DP and element “0” means no interaction. The shading parts in Table 1 show the interaction of FRs in the same decomposing branches and the white parts show interaction of FRs in different branches.

Table 1. Full design matrix

				DP						
				1					2	3
				1	2	3				
						1	2	3		
FR	1	1		1	0	0	0	0	0	0
		2		1	1	0	0	0	0	0
		3	1	1	0	1	0	0	0	0
			2	1	0	1	1	0	0	0
			3	1	0	1	1	1	0	0
	2			0	0	1	1	1	1	0
	3			0	0	0	0	0	0	1

3.2 Defining Modules of the Software

Figure 4 illustrates the objects and attributes of the software. So there are 7 design modules of the software, that is,

(1) Zigzag mapping
(2) Independence axiom
(3) Algorithm of rearranging matrix
(4) Algorithm of blocking
(5) Algorithm of AHP
(6) Data management
(7) GUI

3.3 Reconfiguring the Sequence of Modules

Table 1 shows the design is decoupled. That is to say, these modules must be performed in some sequence so that the effect of former modules can be considered and the iterations of design can be reduced. Figure 5 is the module-junction structure diagram. “S” indicates these modules can be designed concurrently and “C” indicates these modules should be designed according to the sequence that the arrows show.

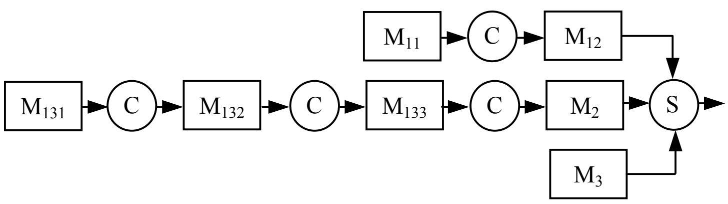

Figure 5. Module-junction structure diagram

4 Conclusion

Large-scale software projects are system engineering, which need many people to participate in. To shorten the lead-time, the design tasks should be arranged reasonably. Development process reconfiguration is the key to the concurrent design. Function decomposition is the basic of process reconfiguration, which shows the relationship between the design tasks. This is what AD can carry out. AD provides a framework and criteria of function decomposition. Axiomatic design builds the functional-structure model of products by zigzag mapping among different domains. The relationship between software modules is established by analyzing the design matrix. The uncoupled design shows that software modules are mutually independent, and can be concurrently processed so that the overall developing time can be greatly shortened. The decoupled design shows that software modules should be processed in sequence so that the whole process can be managed effectively. The module-junction structure diagram shows the sequence of the software development. The diagram can be used to guide the corresponding work.

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A Systematical Multi-professional Collaboration Approach via MEC and Morphological Analysis for Product Concept Development

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Abstract. In this article, a systematical approach that attempts to integrate conventional quality function deployment (QFD) and morphological analysis in terms of effective multi-professional collaboration (MPC) knowledge handling in product concept development is presented and illustrated. For this purpose, a MPC-enabled product conceptualization paradigm was established. It consists of four scrupulously interacting modules, namely, user needs elicitation module using means-end chain (MEC) technique, design knowledge interaction module using design knowledge sharing model, product concept clarification module integrating QFD with functional analysis technique, and optimal concept alternative module using multi-attribute evaluation model (MAEM) within morphological analysis. A case study on the design of eating assistive device for patients with cervical cord injuries is used to demonstrate the performance of the proposed approach. From the case study, the authors also illustrate the effectiveness of concept design prototype with remote collaborative product design communication platform and rapid prototyping system which were applied in collaboration.

Keywords. Multi-professional collaboration, Product concept development, Means-end chain, QFD, Eating assistive device

1 Introduction

In order to develop an innovative product, it is important to know the demands of consumers. The designer must understand the user's specific requirements and marketing strategies and then integrate all of the information into a distinct design which differentiates competing products from each other.

User-oriented assistive device development is a usability-based innovation concept, which focuses on the use of disabled patients' current and future needs, as well as their characteristics, in the design of innovative and/or improved assistive products. Consequently, to develop a successful eating assistive device for patients with cervical cord injuries, user requirements need to be carefully considered by implementing the multi-professional collaboration approach during product

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conceptualization. The key phases in the expression of this concept are: requirement identification, knowledge synthesis and idea creation to fulfil the need, product development to substantiate the idea and the user's need, and verifying the fulfilment of the need.

Central here is the systematic approach to interpret the subjective and implicit consumer needs (e.g. functionality, usability, aesthetic sensibility and values, etc.) into objective and explicit product conceptualization, in order to, through the creation of the distinctive and superior product, substantiate the fulfillment of these needs. For this purpose, a MPC-enabled product conceptualization paradigm was established. It consists of four scrupulously interacting modules as shown below:

1. User needs elicitation module using means-end chain (MEC) technique for requirement identification.
2. Design knowledge representation module using design knowledge sharing model for knowledge synthesis and idea creation.
3. Product conceptualization module integrating QFD with functional analysis technique for product development to substantiate the idea and the user's need.
4. Optimal concept alternative module using multi-attribute evaluation model (MAEM) within morphological analysis for verification.

A case study on the product concept development (PCD) of eating assistive device for patients with cervical cord injuries is used to demonstrate the performance of the proposed systematic approach. From the case study, the authors also illustrate the effectiveness of concept design paradigm with remote collaborative product design communication platform and rapid prototyping system which were manipulated in collaboration.

2 Related work

It is well known that assistive devices can help disabled persons become more independent and increase their quality of life. However, there are many differences between the disabled persons' conditions as well as due to the limited amount of available assistive devices. Generally, seriously disabled persons haven't yet had access to the functionality of assistive devices. For example, patients with cervical cord injuries have two types of eating assistive devices to choose from; one is an expensive, power-controlled device that is unsuitable for patients with a serious cervical cord injury, while the other involves feeding via a caregiver. In order to develop an eating assistive device that can be used by a patient with a serious cervical cord injury independently, it is important to construct a systematic approach that integrates the MPC knowledge and information technology support system for implementation the requirement identification, knowledge synthesis and idea creation to fulfil the need.

2.1 User needs elicitation module and MEC

Products or services are usually presented in terms of their attributes, such as functionality, usability, quality and aesthetic sensibility. Although the consequences of using them are affected by the end user, these attributes may be related to the realization of personal values and emotional situation. In general, consumer needs start the early stage of new product development process, and the determination of correct and complete information requirements sets the stage for an effective development process that increases the likelihood of satisfaction in the implementation and allows for early correction of errors while the cost is lower [1]. One of the primary goals of the collection and adoption of user needs information in new PCD is the identification of customer preferences [2]. In order to deal with the task, a MEC approach is used to identify the attributes, consequences and values perceived by the user. Since its introduction into the marketing literature by Reynolds and Gutman [3], MEC has become a frequently-used qualitative technique in formulating the strategy of product development and marketing promotion in many fields.

An MEC methodology illustrates the connections between product attributes, the consequences or benefits of using product and personal values; A-C-V structure (Figure 1), where the means is the product and the end is the desired value state. The purpose of the MEC theory is to explain how product preference and choice is related to the achievement of central life values [3].

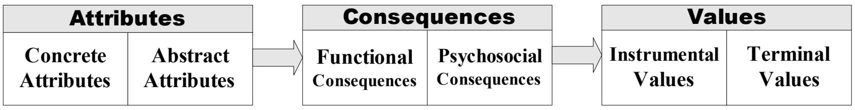

Fig. 1. MEC via A-C-V structure of user's product percipience

Integrated with the data-collection technique called laddering, it was proposed by Reynolds and Gutman [4], which is implemented in-depth, one-on-one interviewing process for eliciting A-C-V linkages from consumers for revealing the structure of MEC. Laddering is able to lead consumers to clearly communicate their inner important attributes, consequences and values and then form the structure of MEC, which are put into a hierarchical value map (HVM) (Figure 2), depicting the cognitive or motivational decision structure of the consumer [5]. An HVM is gradually built up by connecting all the chains that are formed by selecting the linkages whose values in the implication matrix are at or above the cutoff value.

The laddering technique consists of three phases:

1. elicitation of crucial attributes, It is usually followed by the Kelly Repertory Grid technique or the rank ordering method to record and analyze the entire set of laddering across respondents for classifying the relation between the constructs and organizing them into hierarchical relations [4,6,7].
2. laddering depth-interviews. This is a one-on-one interviewing technique, using primarily a series of directed probes and a series of "Why is this important to you" questions that produce the following ladder [8]:
   Aircraft type ->more space ->physical comfort ->get more done -> accomplishment ->self esteem
3. analysis of results. In this phase content analysis is used to categorize the idiosyncratic responses into a smaller number of categories. Subsequently, an implication matrix is constructed, which shows the links between the concepts in terms means and ends.

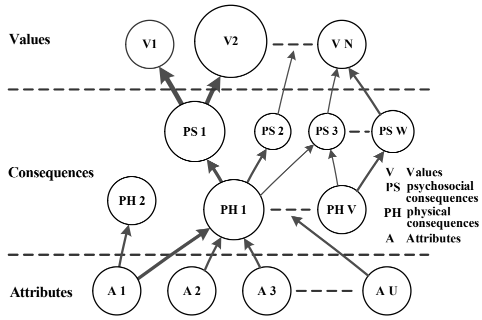

Fig. 2. Hierarchical value map for revealing the structure of MEC

2.2 Collaborative knowledge to support MPC

As the complexity of new product development processes increases, the designing process has to integrate a great number of expertises who are based on the collaboration between the different type of challenges.

To increase design performances and consequently to satisfy customers' requirements and expectations, the decision-makers (generally the project managers) have to adapt the designers' work-context to the environment of the design process. The work-context of the performers will be improved and, when the project manager will be able to create effective working group according to the design objectives, human resources allocation will be more efficient.

Knowledge of the actors refers to all their expertises in one or several given domains and could be defined as being at the crossroads of in-depth knowledge and collaborative knowledge. Rose et al. [9] proposed to structure this knowledge in four different types (Figure 3):

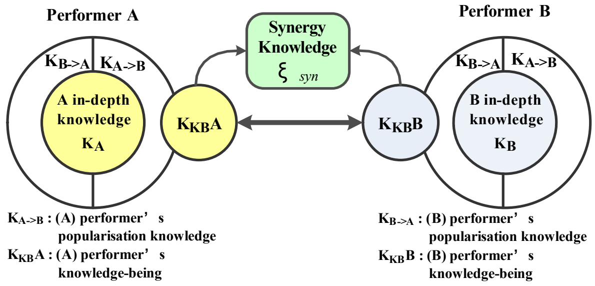

Fig. 3. Knowledge shared during collaborative design process [9]

- Popularization knowledge is acquired by the performer, coming from the other members of the design team.
- Popularisation knowledge is distributed to the other performers of the design project. It is a support of the problem solving.
- Knowledge is used by each performer when he or she has to initiate communication with the other performers. It can be seen as interface ports to reach other performers of the surrounding context.
- Synergy knowledge, implemented to carry out and maintain the intra-team knowledge exchanges. It's a support of communication.

2.3 QFD with functional analysis

By employing the QFD method, the consumer needs are systematically matched with the product attributes, which can help MPC team members to improve the product development quality. For this purpose, QFD has been widely studied and applied to transfer the consumer needs and wants into the design process and product attributes by systematically letting the wishes are reflected at every stage of the product development process.

In the QFD analysis, a matrix is used, called the relationship matrix, where the analysis is carried under the mapping from requirement attributes into design components. In order to get this information for the MPC approach, the user needs and their rankings are determined through the MEC-analysis and interviewing survey, in which the values 9, 5, 3, 1, and 0 indicate the mapping relationships ranging from very strong, strong, ordinary, weak, and none, respectively. Finally the overall weights of the product attributes are calculated and then the product attributes corresponding to the user needs' differentiations are listed and the relationships between user needs and product attributes are established. The result obtained from QFD is incorporated into the HVM graph to identify the PCD component to be developed with the morphological analysis, deriving new products that satisfy user needs by designing finite components.

The QFD used in this study is modified in the way that the technical analysis and competitor analysis are not carried out, thus the relationship matrix only lists the importance of the differential product attributes.

2.4 Morphological analysis with MAEM

Morphological analysis (MA) was developed by Fritz Zwicky as a method for structuring and investigating the total set of relationships contained in multi-dimensional, non-quantifiable, problem where causal modeling and simulation do not function well or at all. [10]. More recently, MA has been applied by a number of researchers in the fields of policy analysis and futures studies. Owing to the advanced computer support system for MA was developed that has made it possible to create non-quantified inference models, which significantly extends MA's functionality and areas of application [11].

For promoting the innovative design, a morphological chart is presented as a visual way to acquire the necessary product functionality and explore alternative means and combinations of achieving that functionality. It is one of the formal design tools enabling collaborative product development and is also an effective technique for conceptual design of products, processes, and systems [12]. In practice and in academia, the product development team can use the morphological chart to identify sub-systems and their alternative components, implementation techniques etc. for examining and figuring out systematically a number of variant but equivalent design entities and to help widen the search for solutions of the original PCD.

As a result of generating a lot of solutions from morphological chart, designer has to verify and sieve out the relevant or practical combinations of product functionality from the solution pool. In order to evaluate the alternative concepts presented in the previous section, it is necessary to define a number of variables (cost, ease of implement, functionality etc.) that will be used in the MAEM process.

Simple multi-attribute rating technique (SMART) is an extension of direct rating technique, one of the MAEM methods, and is suitable to be applied to verify the alternative PCD solutions which were generated by MA. In a basic design of SMART, there is a rank-ordering of alternatives for each attribute setting the best to 100 and the worst to zero and interpolating in between. By refining the performance values with relative weights, a utility value for each alternative is calculated. In SMART, the formula for a weighted average is simply given as follows: $U_i = \sum_j w_j u_{ij}$,subject to $\sum_j w_j = 1$, where U_i is the aggregate utility for the ith alternative, $\boldsymbol{w_j}$ is the normalised importance weight of the jth attribute of value and $\boldsymbol{u_{ij}}$ is the normalised value of the ith alternative on the jth attribute. In general, the U_i for the ith alternative is provided with the highest weighted average ranking value will be defined as the optimal solution. It means that the goal is Max $U_i = \sum_j w_j u_{ij}$.

3 Modeling the MPC-enabled PCD paradigm

The MPC approach presented in this paper, focuses on the user centred design side and the concept development phase, where consumer needs and product attributes have to be defined and interpreted for PCD. In Figure 4 the authors illustrate a framework which is integrated with multiple modules in pursuit of the study goal.

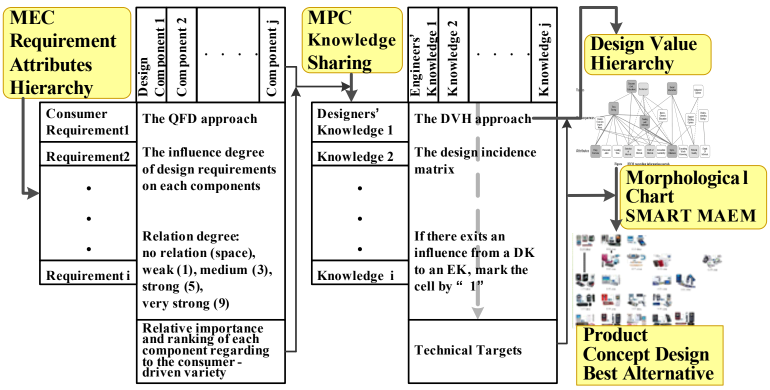

Fig. 4. Framework of the MPC-enabled product conceptualization paradigm

From a multi-professional knowledge-integrating viewpoint, the proposed model comprises four correlated modules and four main stages. The first stage begins with consumer needs elicitation using MEC technique, which clarifies the variant attributes and values of users. The second stage consists of the knowledge sharing model and QFD analysis, during which the variant attributes with involved knowledge are related to design components with specific values to identify relationship degree, thus yielding the relative importance of each component towards the differential product attributes. In the third stage, the solution pool of PCD is produced from MA and the optimal solution is verified with SMART of MAEM. Finally, the result obtained from the MPC approach is incorporated into the product usability experiment to derive the satisfaction with finite revision.

4 Use of MPC for PDC of assistive device

This investigation involved the development of eating assistive device for patients with cervical cord injuries, which was based on the collaboration of physiatrists, designers, marketers and heavy disabled persons.

A depth-interviews was conducted with 28 subjects, C4 to C6 cord injuries, between 20 to 56 years of age who had been hospitalized rehabilitation and been served with eating assistive devices. Subjects were asked to express the degree of importance of attributes and indicated the most important one and then multiple chains were acquired per respondent for the evaluation variables of the concerned phases-functions, explicit features, operating method, technology and esthetic sensibility about the product. Using laddering method answers were divided into attributes, consequences, and values and categorized further using with summary implication matrix (Table 1). The absolute number of concepts and the number of linkages between concepts was counted to construct the HVM (Figure 5).

Table 1 Summary implication matrix

Code	01	02	03	04	05	06	07	08	09	10	11	12
01	3.0 0			4 00		0.0 1	0.0 1		0.0 1	0.0 1	0.0 1	0.0 1
02						2.0 0	1.0 0				0.0 1	0.0 1
03				1. 00		0.0 1					0.0 1	
04				2. 00		0.0 1	0.0 1		0.0 1	0.0 1	0.0 1	0.0 1
05						3.0 1	0.0 1		0.0 1	0.0 1	0.0 1	0.0 3
06									5.0 0	0.0 3		
07							5.0 0				0.0 4	0.0 4
08											5.0 4	0.0 4
09										2.0 0		
10										10 5		
11												
12												5.0 0

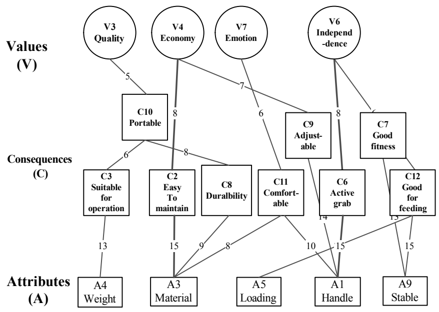

Fig. 5. HVM of eating assistive device

5 Conclusions

Table 2 demostrates that the differential importances of components for the PCD of eating assistive device which must satisfy the need of feeding independently.

Table 2 QFD matrix for mapping the differential needs of manipulation into components

Usability differentiation need	Component											
	Linkage	Handle frame	Handle	Spoon	Fork	Tray	Bowl	Bowl cover	Cup	Cup frame	mat	Box
Feeding independent	5	9	3	5	3	3	9	3	3	5	5	1

According to the results of MEC and QFD analyses, MPC team members used the MC technique with CAD system and collaborative communication environment to perform the PCD which was transferred to prototype and then verified by the subjects.

The best alternative of PCD is finalized from MC with SMART process and presented as following (Figure 6) :

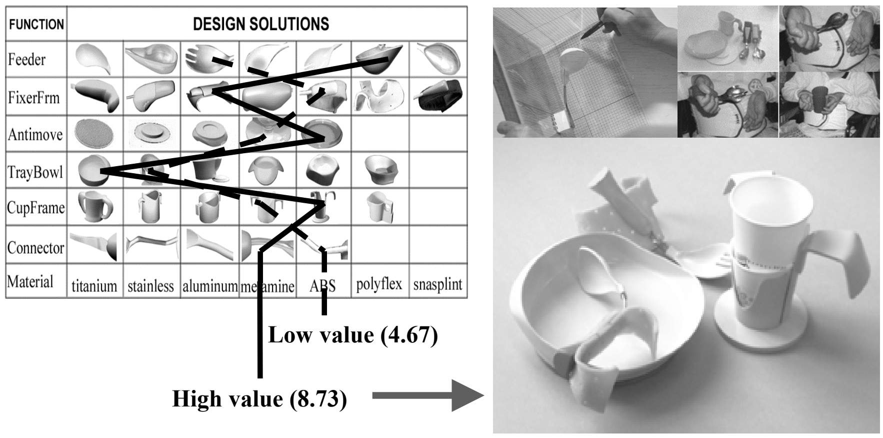

Fig. 6 The optimal PCD of eating assistive device

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DFX Platform for life-cycle aspects analysis

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Abstract. "Design for X" is commonly regarded as a systematic and proactive designing of products to optimize total benefits over the whole product life span (fabrication, assembly, test, procurement, shipment, delivery, operation, service, disposal), and meet target quality, cost, performance and time-to-market. DFX involves different methodologies for product design and optimization (like Design for: Manufacturing, Assembly, Variety, Serviceability, Environment, Reliability, Utilization, etc.), which provide useful results, however, they address only specific aspects of product life-cycle. In addition, various perspectives for business economics can often drive to contradicted conclusions, what makes the evaluation of both technical feasibility and product profitability more difficult. In this paper the framework for DFX analysis was proposed. In the described solution, the various product life-cycle analysis strategies are integrated, and profit calculations relay on common denominator – the present value of net benefit. This approach allows covering of all phases of a product life cycle not excluding e.g. complex environmental aspects. Based on the proposed framework, the DFX Platform was developed and implemented as a web service. The application of the system to a few product developments carried out within cross-bordered manufacturing company showed its big positive impact on projects and their results.

Keywords. DFX, measures of DFX, life cycle, cost/benefit model

1 Introduction

Today's highly competitive global manufacturing environment requires continous improvement of producers efficiency. One way to achieve it is to increase an efficiency of individual engineering activities, e.g., through the introduction of IT technologies. Another way is to improve the coordination between development activities by application of Concurrent Engineering (CE) methodology and its means for supporting teamwork. Typical objectives of CE are to (1) optimize product quality, (2) minimize manufacturing cost, and (3) shorten delivery time.

In this context, the application of the "Design for X" philosophy, which is commonly regarded as a systematic and proactive designing of products to optimize total benefits over the whole product life-cycle, seems to be appropriate.

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DFX involves, by definition, different methodologies for product design and optimization (like Design for: Manufacturing, Assembly, Variety, Testability, Serviceability, Environment, Reliability, Utilization, Recycling, etc.), which provide useful results however, they address only specific aspects of product life-cycle.

Since different approaches use different measures for concept design evaluation (e.g. Design for Quality minimizes cost of poor quality, while Design for Assembly cuts assembly time) it is not clear how those diverse results can be judged and compared. In this context, the need for general, but unified view on design concepts evaluation is evident. As an answer, the "DFX Platform" - a holistic approach for design trade-offs analysis is proposed.

2 Problem Definition

2.1 Approaches to DFX methodologies integration

DFX is usually carried out today in following ways:

- by cross-functional teams (multi-discipline team involved as early and often as possible)
  - using specialized design manuals (which contain do's/don'ts rules for common processes)

6. applying software tools (particular commercial software packages exist in the market), [1]

Each of these methods for implementing the DFX has certain advantages, but also drawbacks. Generally, all three mentioned above ways do not offer quantitative measure of the total profitability analysis. Payoffs and profits are difficult to model and quantify, but if the design alternatives are not measured correctly, the evaluation process can lead to wrong decisions. Therefore, in recent years, more and more design researches see engineering design as a decision-making process, which requires rigorous evaluation of design alternatives [4], [16].

Gupta, Regli and Nau [3] proposed the solution, which evaluates different aspects of product manufacturability using multiple critiquing modules (e.g. machining, fixturing, assembly, inspection) and calculates total manufacturing cost and time. In their approach, the system is able to detect for example a design, that is inexpensive to machine, but difficult to assembly, or vice-versa. Furthermore, the multiple critiquing tools balance their individual recommendations to provide an integrated feedback to the designer.

Maropouleos [7] described an approach, in which process selection tools, design-for-X methods and process planning systems are integrated into one solution. In so-called AMD architecture (aggregate, management and detailed) an evaluation of the early manufacturability of individual jobs can be executed by relating the feature geometry to knowledge about processes and resource operating parameters, and process quality cost and delivery can be calculated.

Similarly, Vliet and co-workers stated that an integrated system for continues DFX design support should offer (i) coordination of the design process, and (ii) generic estimators to adequately evaluate and quantify life-cycle aspects [15], [14]. For quantification of life-cycle properties they proposed: cost, quality, flexibility, risk, lead-time, efficiency and environmental hazard.

The generalized framework (shell) for manufacturability analysis is proposed in [13]. Unlike previous approaches, in this solution the user is able to choose the criterion to evaluate the manufacturability and thus is able to ensure that the most appropriate measure is selected.

But, as concluded by Hazelrigg in his book [5]: the true objective of engineering design is to make money. The other design targets to (1) optimize product quality, (2) minimize cost, and (3) to be available sooner just describe how the company maximizes its profits.

2.2 DFX and product life cycle phases

Today's integrated DFX tools consider mainly production phase of a product life span. However there are other aspects, which need to be covered. Design for environment (DFE), together with Life Cycle Assessment (LCA) - its most powerful instrument, is one of the most difficult to integrate with other DFX tools, which are much more related to economic benefits [8]. Life time environmental impact can be expressed in terms of price of pollutions treatment (Tellus and EPS methods) [12], [11], however these costs would not be covered directly by a producer. Nevertheless LCA can be easily integrated into the DFX framework by taking into account customer willingness to pay for "green product" [6]. More and more producers are forced (WEEE, Waste Electrical and Electronic Equipment - EU Directive) to take back their product at the "end of life" therefore Design for Recycling is the most important part of the DFE.

Rising warranty costs focus attention on the issue of Design for Serviceability [2]. Service Mode Analysis and probabilities of failure modes will be the key issues in warranty cost evaluations.

Design for Performance and Design for Compliance would complete other required design aspects related to operational and "end of life" life cycle phases.

2.3 The research goal

The key issue of this research was to develop the means to reliably estimate and verify the costs/benefits of different design concepts at different stages of product development. Various design approaches, X-s, are collected and offered in harmonized way via DFX Platform. The role of this framework is to provide a structured workflow specifying how and when the different X methodologies can be applied, and also to unify DFX measures (to combine different DFX metrics, like direct material cost, number of articles, assembly times, failures probability, etc.).

3 DFX Framework

3.1 System architecture

In the proposed DFX framework, a typical phase model is extended by functional domain – according to the project schedule different life-cycle analyses are performed in parallel. The role of this solution is (1) to provide a structured workflow specifying how and when the given X methodologies can be applied, and (2) to unify DFX and convert them into one, quantitative measure.

The framework consists of three basic architecture layers: Information layer, Domain evaluation layer and Profit analysis layer, Fig. 1.

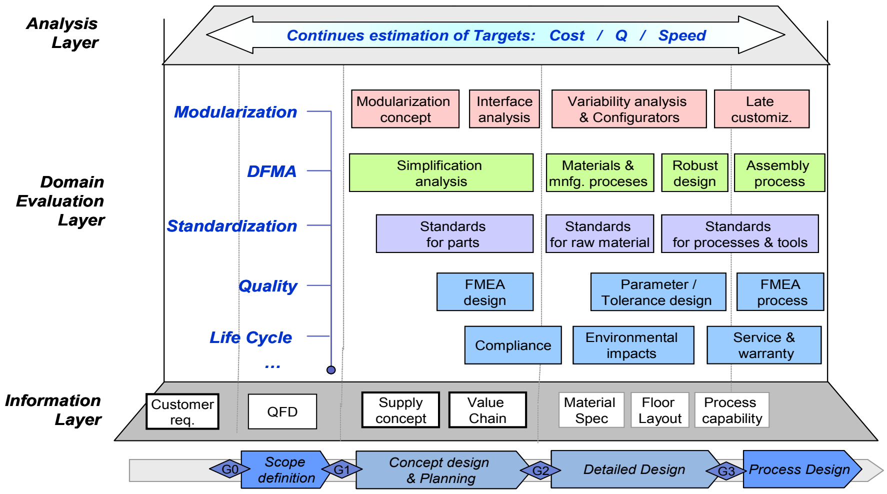

Figure 1. The general concept of DFX Platform

The **Information layer** stores the input data required by given engineering task and output information created in following project phases. By this module the intermediate technical results and design proposals are also transmitted between different DFX tools.

The **Domain evaluation layer** is designed to manage DFX approaches – the specialized methods evaluating the design concept from given product life-cycle perspective. The most common DFX approaches are:

- Modularization (maximizes external product variety),
  - Standardization (minimizes the number of different article types and mnfg. processes & tools),
  - Manufacturability (assigns suitable manufacturing process and materials),
  - Assemblability (optimizes assembly process),
  - Late Customization (differentiates product variants by application of supplementary manufacturing steps or optional module),

- Quality (ensures product reliability and minimizes defect costs).
- Life Cycle – operation & “end of life” (minimizes service/warranty costs, minimizes take-back obligations costs)

Application of the dedicated design approach is controlled by the Information layer of DFX framework, which invokes given tools or software packages, depending on the stage of product development. It also ensures that said approaches evaluate the design concepts in terms of cost, time and quality. The particular economic estimations and measures are transferred to Analysis layer.

In **Profit analysis Layer** the total cost/benefit model is constructed. In analysis module the present value of net benefit is calculated - as the main, quantitative measure of the total profitability analysis. The Net Present Value (NPV) shows the difference between present value of cash inflows and present value of cash outflows.

$$NPV = \sum_{t=0}^{n} \frac{C_t}{(1+r)^t} = \sum_{t=1}^{n} \frac{C_t}{(1+r)^t} - C_0 \qquad (1)$$

where:
t - time of the cash flow
n - total time of the project
r - interest rate
C_t - net cash flow (the amount of cash) at that point in time
C_0 - capital outlay at the beginning of the investment time (t = 0)

The typical application scenario covers: log-in to the DFX platform web side; selection of adequate DFX approach and related tool; execution of domain analysis; evaluation of the results in terms of the domain-specific measures (e.g. material cost, assembly time) and finally the total profit calculation.

3.2 System implementation

Technically, the proposed solution called DFX Platform is implemented as a web server, which manages the different DFX approaches, controls the application of specific tools according to the phase of the development process, transfers information between and within domains, and ensures consistency of cost/benefit estimations. The user invokes the web page of the DFX Platform, and follows the sequence of the analysis recommended by the system. The tools for specific DFX analyses are developed mainly as web services, which can be launched from the server. However, the solution allows also for off-line work.

4 System Validation – a Case Study

In order to illustrate the practical application of the implemented system, a case study is presented. The DFX analysis of spring mechanism powering the high voltage circuit breaker is shortly described.

Different circuit breaker applications require variety of spring mechanisms, therefore it was necessary to: (1) harmonize the designs and develop a new unified product, covering different applications and energy levels, (2) reduce the production and assembly costs, (3) improve product quality and reliability, as well as (4) minimize warranty and “take back” costs.

The first target was achieved with application of Modularization approach. For second goal – the DFA and DFM tools were applied. Third objective was fulfilled by in-depth analysis of tolerance chain, while the last one with use of Life Cycle Cost (LCC) tool. All the proposed modifications to the product design were verified by NPV calculator offered in profitability analysis layer.

4.1 Modularization analysis

To find out the most profitable product design variants the “Cost of Variety” calculation method was applied, as described in [9]. The goal was to find the optimal production volume per variant, minimizing the total manufacturing costs. It was calculated, that best profitable modularization scenario is to manufacture two variants only, out of four, what gives more than 25% of savings in comparison to original production costs.

4.2 DFMA analysis

In second analysis stage, the manufacturing and assembly aspects of new product design were taken into account. Each component in the assembly was examined with support of dedicated DFA and DFM tools. This study started with simplification analysis aiming to reduce the number of product parts. As a result one could state, that potentially about 37% of components might be eliminated.

Next, the manufacturing aspects for all product components were further studied, and the most cost efficient manufacturing technologies were assigned based on the production scale.

4.3 Quality approach

In order to improve the quality of analyzed product as well as increase its robustness, the Quality tools offered by DFX Platform were involved. In particular Tolerance analysis was run for the selected geometry and shape tolerances stated on drawings. The study allowed significant increasing of production yield, by optimizing components dimension tolerances.

4.4 Operation & “end of life” analysis

Product design optimization related to life phases after “factory gate” were limited to warranty and “take back” obligations.

Failure costs were calculated according to following formula [10]:

$$Cost_{failure} = (C_{Repair} * f_{nonstop} + C_{Consequence})\, f_{stop} \qquad (2)$$

where:
$Cost_{failure}$ = Total costs of failures
C_{Repair} = Repair and/or replacement cost
$C_{Consequence}$ = Consequence costs i.e. standstill cost from failure
f_{stop} = Number of Stopping failures in life time
$f_{nonstop}$ = Number of Non-stopping failures in life time

LCC tool supports failures modes calculation as well as recycling and disposal options. Average service time and cost can be reduced 25% due to proposed greasing system modifications.

Decommissioning cost can be minimized due to reduced number of parts and use of recyclable material eliminating disposal alternative.

4.5 Total profitability analysis

One of the key advantages of the DFX Platform is the possibility to reliably estimate the profit of analyzed product concept. The business impact coming from different DFX analyses is summed up and total cost/benefit figure is calculated, In this way, different product concepts can be compared over total life-cycle.

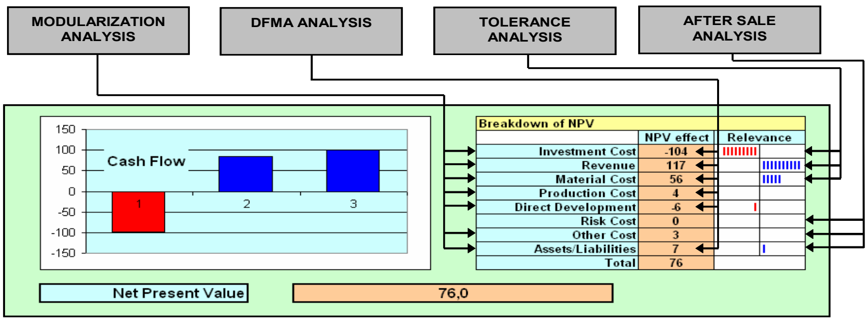

Figure 2. Total cost/benefit analysis

5 Summary

Most of today's DFX methods and tools (software packages, manufacturing guidelines, check lists, etc.) consider product and process design in unilateral way mainly, e.g. manufacture- or assembly centric. This research proposed the framework, which manages the different design approaches from whole life-cycle (including "end of life") perpective, and involves trade-offs between different design objectives and business profitability measured by present value of net benefit. Based on the proposed framework, the DFX Platform was developed. The solution was designed as a web service, which manages the different design approaches, controls the application of specific tools according to the phase of the development process, transfers the information between and within engineering domains and ensures consistency of cost/benefit estimations. The practical solution supporting proactive, profit oriented design, was implemented and successfully applied to a few product development projects carried out within cross-bordered manufacturing company, and showed its big positive impact on projects and their results. It was especially noticed, that design concepts generated “under auspices” of DFX Platform incorporated equally a vast spectrum of product life-cycle aspects, what resulted in higher product quality, lower production and after sell costs.

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Design For Lean Systematization Through Simultaneous Engineering

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Abstract. Lean Manufacturing philosophy has had an important role in productivity improvement in first rate industries. It came from the best practices applied by the Japanese automotive industry, targeting high quality, low cost, lower lead time and enhanced flexibility. Due to high competitiveness, there has been a great effort in its wider application. While product concept has had an important role on the efficacy of manufacturing, it must be said that there is still a shortage of elements for a proper product development with focus on Lean Manufacturing philosophy. Concern to design products that maximize specific characteristics by way of Simultaneous Engineering gave birth to DFX tools such as DFM. To this date no DFX tool has come up with enough subsidies to generate products that will support implementation of Lean as a whole. On the other hand, Simultaneous Engineering has not been used so as to involve Product Design with Lean Manufacturing. Present article proposes a set of guidelines, called Design for Lean, to systematize best practices for product development with focus on Lean Manufacturing through Simultaneous Engineering. They will target conceptual and detailed design phases.
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Keywords. design for lean, lean manufacturing, DFX, systematization, simultaneous engineering

1 Introduction

High competitiveness has triggered a wide usage of Lean in production. As its application has been so far generally restricted to manufacturing, losses still occur, mainly due to the fact that product concept has not been in line with that philosophy.

It is otherwise known that DFM has an important role in product design, to impact on the feasibility and the productivity of the manufacturing process.

Perhaps due to the fact that design teams are not so well acquainted with Lean, they have met difficulties in developing products that will effectively contribute with it.

In order to help enable a full implementation of Lean philosophy all the way from product design through its final delivery out of production, present tool is presented. This tool comes in a form of guidelines or wastes to be avoided as in the stamping case resulted from interviews with experts of the main automotive industry processes: stamping, welding and assembly. These guidelines are related to one or the other of the seven main wastes encountered in running production.

2 Lean Manufacturing

It is understood by Lean Manufacturing everything which refers to having the right things at the right place at the right moment and in the right quantities thus eliminating wastes in a flexible and open to changes manner.

According to Womack [8], Lean thinking is a way of specifying value, establishing the best sequence of actions which add value and developing these activities continually every time it is so required and ever more effectively. So, according to the author, Lean thinking is a way of doing more with less, increasing efficiency. Liker [5] lists seven wastes identified through Lean thinking:

1. Overproduction: manufacture of items not yet demanded, creating the need of storage and transport more often than necessary.
2. Wait: workers merely watching an automated machine or waiting for the next step of a process, requests for parts in delay, production bottlenecks, etc.
3. Unnecessary transportation: need of long distance moving of a product in process between one step and the other or between unnecessary steps.
4. Over or incorrect processing: unnecessary manufacturing steps: inefficient process due to poor tools and production design requiring unnecessary movements which may cause low quality. Wastes when excess quality demanded.
5. Excess inventory: excess of raw material, product in process or finished product, causing long delivery times, obsolescence, damaged items, storage and transportation cost.
6. Unnecessary movements: whatever movements made by workers, be it to search or reach for parts.
7. Defects: production of bad parts. Any kind of rework, loss of products, inspection, does nor add value.

3 The Role of Product Development in the Implementation of Lean Manufacturing

3.1 Product Development Process

Once the purpose of this study is to propose a DFX tool to be inserted in the product development environment, it is necessary to choose a PDP model among the various available. Figure 1 shows the Rozenfeld, *et al.* model, which will serve as a base to have us understand in which development phases the tool will be applied.

With DFX, proposed tool will have its application in Conceptual and Detailed Design phases, with its requisites already defined in the informative phase.

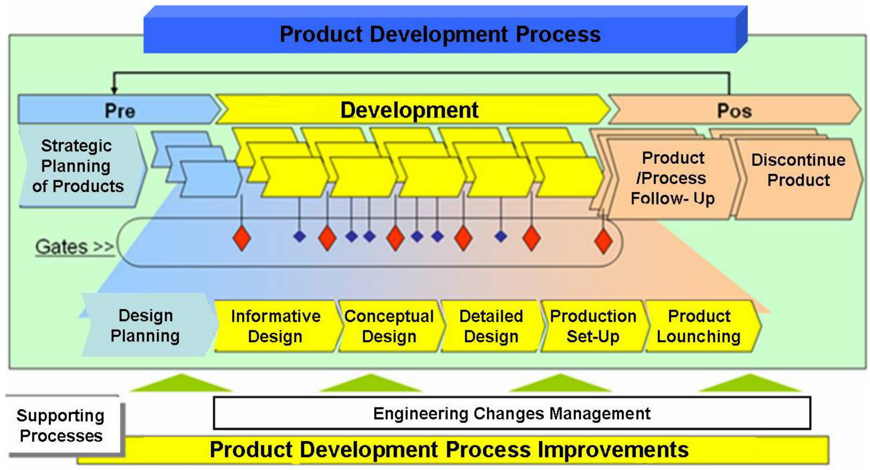

Figure 1. Model PDP adapted from Rozenfeld et al. [6]

3.2 Design for Manufacturing

Product concept has a considerable impact on final cost. It is during the production phase that design change costs are highest. To help the designer evaluate the impact of his decisions on the product's life cycle, auxiliary methods for design decisions called DFX (Design for X) were developed. Among most applied DFX is Design for Manufacturability.

For better results, this tool must be used the earliest possible in the PDP process, within Simultaneous Engineering environment.

3.3 Design for Lean Manufacturing – A New DFX Tool

At present the guidelines contained in DFM tool have supplied subsidies so that product development teams contribute, although modestly, with the implementation of Lean Manufacturing philosophy, mainly in what regards standardization. There is to be noticed, however, a strong absence of tools to support product development teams specifically in the task of contributing with the implementation of Lean Manufacturing in its entirety.

According to Rozenfeld [6 apud Womack 8], in order to promote opportunities that will cause impact on manufacturing efficiency, cost and product quality, Lean Production must be aligned with product not only in its manufacture, but also in its concept in PDP.

But, then, what new approach would this tool bring with regards to the already known DFM? The answer is a set of specific guidelines for the development of products that is focused on the implementation of Lean Manufacturing philosophy in the manufacturing phase.

The development of products with focus on Lean Manufacturing must intrinsically think not just in the product manufacturing phase, but yes in all the concept cycle. According to Womack [7], one must search to utilize value engineering techniques in order to break down the costs of each production step, identifying every possible factor to reduce cost of each part. Afterwards, value analysis techniques are applied in order to reduce additional costs. In this phase, each step of the manufacturing process is analyzed in order to identify critical points which will get more attention so as to reduce costs even more.

Womack [7] makes an analogy between mass versus lean product development, in which, among other differences, resources needed for the development of the design are temporarily placed under a Design Manager, with no ties to their routine, or series, activities for the entire duration of the design. Whereas in mass production, resources needed for the design are placed in simultaneous development programs and under a functional department. As in the Lean system the available resources dedicate exclusively to their design and do not report to other departments during its lifetime, design duration is consequently shorter than in mass concept.

Through this development technique products can be produced quicker, with less work and fewer errors, which significantly contribute to Lean manufacturing. Following prerequisites have been identified to enable this concept:

- a team leader, responsible for design and engineering;
- a synergic work team under one single design leader;
- Simultaneous engineering – as the engineering department can not have enough knowledge of all relevant design areas, experts from other areas are to be brought in. Full benefits from simultaneous engineering to be harvested.

4 Simultaneous Engineering

The term simultaneous engineering can denote both a parallel cooperation and work discipline towards a set of common objectives in the development step or a form of design time reduction through the accomplishment of independent activities which can be made simultaneously.

According to Rozenfeld [6], one of the first attempts was to increase the degree of parallelism among development activities, seeking the simultaneous accomplishment of design and process planning activities. In this way, activities that were previously started after the former activity had been finished and approved, can be made in parallel.

Following benefits can be attained through simultaneous engineering:

- reduction of time for development of new products
- reduction of cost in the development of new products
- better quality of new products as per customer needs

So, through Simultaneous Engineering, one can make the product concept changes in the initial development process steps.

Our object is not exactly the reduction of product development time, but yes the assurance that the developed product meets essential requisites for the implementation of Lean Manufacturing philosophy. For that purpose it is necessary to determine what is its application that exactly corresponds to the goal market, which in our case is Lean manufacture.

Many authors like Bralla [1], defend that DFX tools can be implemented without the help of Simultaneous Engineering, once good designers should be able to consult their direct and indirect customers and apply design guidelines by themselves. That may be one reason why even today there is so much difficulty developing products focused on their internal customers and not just on the expectations of the final customer.

In order to assure the good result of its application, Simultaneous Engineering must be backed up by product development supporting tools, such as QFD, DFX, among other which are not exactly the focus of this work.

In the same way it is utilized to process and translate the needs of the final customer, QFD should be used as a coordination element of the information process, dictating the rhythm of product development and the sequence of activities of this process. This means that each phase of the development process should have the elaboration of the respective QFD matrix as its conductive element.

To our interest, Simultaneous Engineering is an important tool in what concerns bringing the customer needs to the implementation of Lean Manufacturing philosophy. In other words, through Simultaneous Engineering the product development teams work together with Lean Manufacturing implementation teams.

In order to render the utilization of Simultaneous Engineering effective in the phase of product development, of importance is the support given by the Informational phase supported by the QFD tool, to ensure consensus of the different definitions on the product. Through QFD, translation is made of the Lean Manufacturing goal specifications into product requisites, so that they do not negatively interfere with other important product requisites. This is easy to observe as Lean Manufacturing philosophy asks, among other things, less robust products and whenever possible with not so tight tolerances. Well, this requisite may very well work against some of the final customer’s requisites, as for example efficiency, or product quality, or even against Lean principles themselves, once a stamped part with loose tolerance may generate the need of further adjusting operations in the welding steps.

5 Recommendations to the Product Development Team

Once the environment of this study is mainly the automotive industry it is only natural that study focus shall be on it.

As explained in the initial stages, the objective of this work is to supply directives which will enable a wider penetration of Lean Manufacturing philosophy through strong contribution of the product development team as well as other DFX tools.

Therefore it has been decided to stratify the main steps of automotive production so as to supply orientation to each of them. Whenever possible, these orientations will be directly related to the seven main wastes mentioned in the Lean Manufacturing definition.

The following recommendations where extracted from experiences taken place in daily production, and from interviews with specialists in the respective areas. It is expected that these recommendations will allow a leaner and more efficient production system all the way from its conception to the final delivery of the good.

First step – stamping: if the manufacturing process of an automobile is analyzed as a whole we will notice that, what concerns product design, the higher the quality of a stamped part the lower is the investment needed. Higher productivity gains in stamping have been obtained through improvements by way of high flexibility equipment. Less complex geometry, right choice and adequate thickness of materials will allow following benefits, shown in table 1, according to the seven main wastes previously mentioned:

Table 1. Relation between benefit and avoided waste during stamping process

Benefit	Waste
Less complex geometry bringing lower tool adjusting time;	Over and incorrect processing;
Adequate raw material and thickness, bringing lower template numbers;	Defects;
Less complex geometry meaning less time spent on measuring and rework;	Over and incorrect processing;
Adequate raw material and thickness reducing stamping stages;	Over processing;

A stamped part of higher complexity along with robustness of the stamping process is however preferred over a lower complexity part. Reason is stamped parts must be welded and assembled giving thus shape to the vehicle. Therefore, design of stamped parts give indeed a great contribution to the reduction of manufacturing steps to follow.

Second step – welding: table 2 relates the main potential wastes encountered in the welding process as well as its consequences when they are not avoided, according do the seven main wastes previously mentioned:

Table 2. Relation between waste causes and consequences during welding process

Causes	Waste
Necessary process checkings to ensure good product quality to be delivered to assembly due to low design robustness;	Over processing and incorrect processing;
Amount/complexity of gadgets to ensure welding geometry;	Over processing and incorrect processing;
Number of welding spots to ensure product rigidity;	Over processing and incorrect processing;
Part degradation in storage due to high degree of ductibility and thickness;	Defects; over production;

Welding is the direct client of stamping, therefore quality of stamped product has a direct impact on the requirements of a robust welding process.

The environment in which the study was carried out is responsible for the production of two distinctive vehicle brands, to be called brand A and brand B. Each of them demands a specific production line, which allows a direct comparison as to the robustness of both processes involved.

Brand A, due to its more robust part design, needs a leaner manufacturing process. As an example, a hinge to be welded to the car body has a rather complex design, thus requiring a more complex stamping tool. Stamping time as well as number of tools and their stages are however not necessarily higher and the welding operation to the car body can be performed through a simple gadget as it was designed so to have its positioning on the body ensured.

Brand B on the other hand has a simpler design, but demands a much more robust and complex assembling process as it not capable to ensure needed positioning by itself.

Third step – painting: Not to be dealt with in this study as it is a distinct process from the others.

Fourth step – final assembly: At this stage the vehicle has already had its body welded and painted, and is ready to receive up to a thousand components. This is the phase where the highest optimization potential has been identified for both brands. First, design decisions on large stamped parts (sides, doors and stringer) have an amplified impact during assembly as the welded components, here including car body, present geometric variations that will require a great number of adjustments in this manufacturing stage.

Table 3 shows the relation between waste causes and their consequences in final assembly, according to the seven main wastes mentioned earlier.

As happens with body welding, final assembly spends even more time and money with the attempt to geometrically position large components, mainly mobile parts. Due to the low design robustness of their primary components they do not feature many rigid points and thus must undergo a flexible positioning for assembling purposes. On top of this there are the process variations.

In order to facilitate the parts design and absorb variations along the process due to the addition of tolerances, it is a practice that the designer resorts to “fitting facilitators”, commonly known as oblongs and keyways. These artifices have an enormous contribution for us to have an unstable process, therefore creating a dependency on operator sensitivity (which so far cannot be measured) and on devices, patterns that eliminate this variable, creating tools and operations that do not add value. It is desirable an effort from the designer so that any and every subjective operation which depends on “the common sense of the operator” be brought to a minimum, for there is no way to standardize this requisite.

Another point observed was the amount of similar items, in special screws which in many cases could have their usage unified, therefore reducing the number of inventoried items, number of screws and also the amount of assembly failures by means of mistakes.

An important point to be considered when designing a stamped part is that it should come with tolerances such that when added to the tolerances of the other components there is no further difficulty put to the final assembly process.

Table 3. Relation between waste causes and its consequences during final assembly process

Causes	Wastes
Components with geometric variations received from internal suppliers;	Waiting time; over and incorrect processing; unnecessary moving;
Component with undefined positions in assembly operation (oblongs, keyways), requiring many adjustments at assembly;	Over processing and incorrect processing; unnecessary moving;
Parts that could have their assembly through fitting instead of screws, decreasing number of components, inventory, number of components and operations;	Unnecessary moving, excess inventory; defects; over processing and incorrect processing;
Lack of standardization of components that have very similar functions (screws, nuts), meaning high inventory, process faults, excessive equipment needed;	Unnecessary moving, excess inventory; defects; over processing and incorrect processing;
Inadequate raw material which deforms during process, requiring adjustments steps;	Defects; excess inventory; over and incorrect processing; unnecessary moving;

6 Conclusion

Through this study we can observe that the integrated development of products has an important contribution for the implementation of Lean Manufacturing philosophy in its entirety. The DFX tools available to this date like DFM are not sufficient, there being room for the creation of a new tool – DFL.

Simultaneous Engineering has an important role in the search for the development of products with focus on Lean Manufacturing, still underutilized, not only in the reduction of product development time, but mainly in the development teams interaction with their client areas.

Much has been done in the search for a Lean manufacturing, with contributions from product in a punctual manner and in isolated steps of the manufacturing process. Isolated changes of the product in search of cost reductions in the production process can bring as a consequence an excess of operations that do not add value along the production chain.

Present study has shown that the product development can present a positive contribution for the implementation of Lean Manufacturing philosophy, mainly if the guidelines here outlined are applied in the initial steps of the manufacturing process.

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Postponement planning and implementation from CE perspective

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Abstract. Nowadays manufacturing companies are facing the challenge of meeting increasing specific customer needs and even so, to offer short delivery times and low price products. Companies must have flexibility to customize products in a rapid way. A product customization strategy, named "Postponement", has been adopted by a growing number of companies to address the products' differentiation requirements, demanded by the new global market. This paper aims to contrast and compare a proposed postponement strategy definition method with existing postponement approaches found in the literature. The paper reviews various approaches from different authors, to identify how postponement is described in terms of its benefits, implementation barriers, factors that enable or make difficult its practice and the relationship with other theories and techniques. The paper then highlights the contribution given by a proposed method to plan and implement the postponement strategy in a company, using a concurrent engineering perspective.

Keywords. Postponement; Concurrent Engineering; Product customization strategy.

1 Introduction

The markets for mass production low cost standard goods, actually, are a hostile environment and of decreasing profitability. The wide scale production is still a requirement, however a new market characteristic emerges: to customize products according to specific customer needs. The current economic scenario is characterized by uncertainty and high competition level.

As a consequence, companies are facing difficulties to forecast the product demand. For many companies, a bad demand forecast means changes in the schedule of customer orders generating product's reconfiguration down to the assembly line [10]. The high competition level in the market creates a more stringent customer profile, who asks for more customized products, shorter delivery times and lower prices [14]. Then, the following conflict is generated: the

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higher the level of product customization, the higher the probability of reconfiguring the product at the assembly line.

In order to easy this conflict, nothing can be done to change the market characteristics or the customer profile. Thus, the unique way left to reduce the product price and delivery time is to tackle the product customization processes within the company, trying to make it more flexible.

Many companies are adopting a strategy that postpones the product configuration to as late as possible in the production phase [5].

This strategy is named postponement: an operational concept that consists of delaying the product configuration until the actual customer demand is known [23].

Postponement is not a recent concept; there is information about its preliminary practices since 1920's [3]. The concept was originally developed in the marketing literature by Wroe Alderson in 1950 [23] as an approach to reduce risk and costs related to the product differentiation uncertainty. Today it can be identified more than 2500 published papers on this matter, and their number grows rapidly [19]. However, a great part of this literature focuses in high-tech and mass production industries, such as HP and Dell [3].

This paper aims to contrast and compare a proposed postponement strategy definition method with existing postponement approaches found in the literature. Reviewing various approaches from different authors, it is intended to identify how the postponement is described in terms of its benefits, implementation barriers, factors that enable or make difficult its practice and the relationship with other theories and techniques. The paper then highlights the contribution given by a proposed method to plan and implement the postponement strategy in a company, using a concurrent engineering perspective.

2 Existing postponement approaches

This section discusss different postponement approaches, and identify factors that impact their implementation.

2.1 Factors that impairs the postponement implementation

The main challenges observed in the literature that impairs the postponement implementation are: little knowledge about the benefits and associated costs, technology limitation, difficulties to estimate gains and weak alignment among departments in the organisation [21].

Other factors such as inefficient transportation, manufacturing and information technology systems also raise difficulties to postponement implementation [29].

There are no quotations in the literature that refer to the lack of Concurrent Engineering (CE) culture in the company as a factor that turns difficult the postponement implementation. In this paper it is shown that the CE practice is primordial to have success in the postponement strategy implementation, specially when an enterprise develops complex products .

2.2 Types of operational strategies

According Bullock [3], there are two main kinds of postponement referred to in the literature: *form* and *time* postponement.

Form postponement aims at delaying certain stages of the product manufacturing process until a customer order has been received.

Time postponement refers to the situation where the distribution or the actual delivery of a product is delayed until customer demand is known.

Iyer *et al* [10] presented a postponement strategy ,where the customer order is postponed, thus establishing a trade-off between the payment of contractual penalties and operational costs reduction. There are some authors which propose to mix postponement and speculation strategies [23][25].

The present paper proposes to use a different strategy from those just mentioned. It consists of applying CE concepts, to define some manufacturing strategies during the preliminary design phase. Manufacturing and market teams work together to define optional items kits, using analysis tools which cope with uncertainty [2]. Then, the company builds up buffers of these kits that might be applied in the product assembly line to increase the flexibility and agility of the customization process.

2.3 The influence of postponement on industrial costs

Zinn and Bowersox [28] classify the postponement costs as: inventory, process, transportation and cost with lost sales.

One can observe that there is no agreement among the authors about postponement costs. It is also found that higher postponement levels lead to lower inventory holding costs [28], there is also a literature quotation [7] which claims that in some cases, customized components must be on the shelf (stock) to keep the production line flexible and agile.

The transportation costs and the cost with lost sales are not well elaborated, because of the uncertanties shipments size and the unknown balancing between customization levels *versus* product delivery time.

Some authors say that the manufacturing costs increase with postponement implementation because of the new technology requirements [3][12], however this viewpoint is questioned by Waller [28].

. The kind of relationships among postponement and its associated costs can change from one case to another. This evidences that the current formulations for postponement cost are not yet mature.

This paper takes into account a cost-postponement relation that has not been found in the literature so far: the product reconfiguration cost.

2.4 The relationship between postponement with other theories

There are authors that relate postponement to other theories, pointing out cases where one theory can help the other, for example Just in Time (JIT). Some authors say that JIT often results in postponement [28].

Shihua [13] and Yang [30] relate postponement to modular design. Shihua says that through commonality, it can be possible to reduce risk and uncertainties associated with lead-times. This might help to reduce stock in a safe way, improve the wide scale production, simplify the planning task and improve the product development process. However, the commonality brings in higher costs per unit due to excess of performance, greater workload and work-in-process variability [13]. Other consequence of the modular design is that components tend to be weightier, what is extremely bad for aerospace industries.

As can be observed, just few authors relate postponement to product design, and an even lower number mention the importance of Concurrent Engineering as a enabling factor to postponement. When this does happen, usually it is presented in a superficial, ad hoc manner, without practical examples to support it [26][23][3].

This gap in the literature is partially fulfilled by Tseng [4], Du [25] and Jiao [26]. They propose a certain relationship between postponement and concurrent engineering, bringing the customer close to product development, to help the creation of a Product Family Architecture (PFA) that enable the postponement and generates value to customer.

2.5 Benefits

Most authors say that the advantages of postponement are: customer satisfaction improvement, inventory costs reduction and uncertainty reduction of demand forecast [21] [3].

However, there are other authors that, in particular cases, relate postponement to the investment reduction [10], by delaying customer orders when there are unpredicted demands, to avoid production capacity overloads as well as investments in new equipments, as a consequence. Then, they propose the following trade-off: either pay contractual penalties or invest in production capacity. In the next section, it becomes evident yet another benefit brought through the postponement utilization: the product reconfiguration cost reduction.

3 Proposed method

The detailed presentation of the proposed method, including case study applications, is described in previous papers [7][8]. Its main characteristic, is the utilization of CE tools to:

- identify, during the product development phase, the best way and level of postponement that should be adopted in an aerospace company;
  - map the relationships among the functional and physical characteristics with the customer needs and, at the same time, assure that the costs comply with the product development limitations;

  7. determine the best moment to take the main decisions related to postponement during the product development phase.

Figure 1 provides an overview of the referred postponement method:

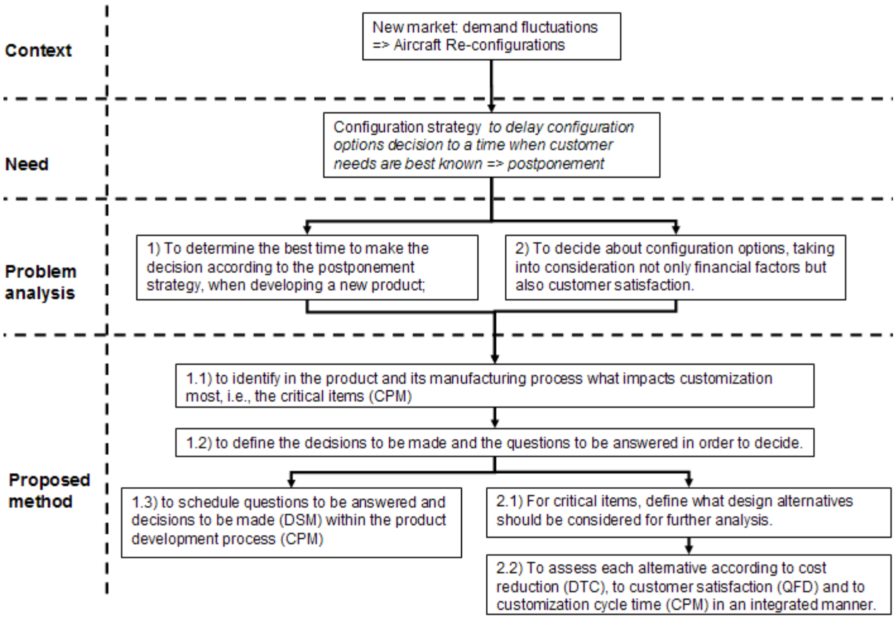

Figure 1. Method overview

The Critical Path Method (CPM) is used to identify the most critical processes to the customization cycle time [6][17][20][24]. Then, through a technical analysis, design alternatives are created for customized product components and manufacturing processes. After that, the Quality Function Deployment (QFD) [11] and Design to Cost (DTC) tools help to determine the best product design and manufacturing alternative according to cost constraints and customer needs. The customer needs are related to the company's engineering and manufacturing requirements through the QFD matrices; they also help to weight the relationship between the requirements and the product's parts and manufacturing processes. The DTC technique, by its turn, is used to compare the target costs with the estimated costs, singling out the product part or process that must be redesigned to meet the target cost. All the CE tools mentioned are combined to perform the postponement strategy definition process. Then, the activities which compose this decision process are classified as questions, decisions and milestones [15], to be scheduled through Design Structure Matrix (DSM) [9][15][18][22], generating the postponement strategy definition process planning.

4 Comparison: proposed method *versus* current methods

Nowadays the literature about postponement keep focus on its utilization in high-tech and mass production industries [3], mainly because these industries have serious problems with inventory costs (risk of obsolescence and great product volumes).

This paper proposes to study postponement in an aerospace company, where the production rate is not so high, but other characteristics as high value added per unit, long production lead-times and high product customization justify the postponement utilization.

Basically, the current work consider as main benefits of the postponement utilization the inventory costs reduction, demand forecast uncertainty reduction and even investments reductions. In this paper, is proposed the postponement strategy utilization to provide a new kind of benefit, the product reconfiguration cost reduction.

Literature provides various postponement operational strategies to reach these benefits, as form, time, logistic as well as customer order postponement. But there is not a model to define the best postponement strategy from a CE viewpoint.

This is the main goal of the method proposed herein, that, based on CE tools, such as QFD, DTC and DSM, defines the best postponement strategy that should be adopted by an aerospace company, which complies with customer needs and product development cost constraints.

There are some shy attempts in the literature that relate postponement feasibility to product design concepts. Just few authors establish a direct relationship between postponement and Concurrent Engineering [4],[25],[26], They developed methods that use CE approaches to create product family architectures according customer perspectives, enabling to assess the impacts on the customer needs by the process and product changes. However their methods are but simple and can be applied only for simple products, like a power supply.

Thus, the literature lacks of a method to evaluate the feasibility of postponement implementation for complex products from the CE perspective. This is fulfilled by the proposed method.

5 Conclusions

After comparing the proposed postponement strategy definition method with existing postponement approaches found in the literature, it can be formulated its main contribution: it helps to define the best postponement strategy that should be adopted to develop a complex product, from a CE perspective.

There were found some works which propose product customization strategies aligned with customer needs, but due to their non-pragmatic approach, they can not be used for complex products. The main contribution of this paper is to provide a method, based on CE concepts and supported by tools as QFD, DTC, DSM and CPM, to create systematic links from customers needs to product functional requirements and product physical characteristics, and at the same time, assuring that the costs comply with the product development constraints, to determine the best postponement level. The method also assures that any change in the functional or physical characteristics in the product or its manufacturing process will be evaluated according to the customer needs, product development costs limitations and postponement level.

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Neural Network and Model-Predictive Control for Continuous Neutralization Reactor Operation

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Abstract. This paper outlines neural network non-linear models to predict moisture in real time as a virtual on line analyzer (VOA). The objective is to reduce the moisture variability in a continuous neutralization reactor by implementing a model-predictive control (MPC) to manipulate the water addition. The acid-base reaction takes place in right balance of raw materials. The moisture control is essential to the reaction yield and avoids downstream process constraints. The first modeling step was to define variables that have statistical correlation and high effect on the predictable one (moisture). Then, it was selected enough historical data that represents the plant operation in long term. Outliers like plant shutdowns, downtimes or non-usual events were removed from the database. The VOA model was built by training the digital control system neural block using those historical data. The MPC was implemented considering constraints and disturbances variables to establish the process control strategy. Constraints were configured to avoid damages in equipments. Disturbances were defined to cause feed forward action. The MPC receives the predictable moisture from VOA and anticipates the water addition control. This process is monitored via computer graphic displays. The project achieved a significant reduction in moisture variability and eliminated off-grade products.

Keywords. Model-predictive control, Neural networks, Virtual on-line analyzers, Moisture, Process variability.

1 Introduction

A neural network, also known as a parallel distributed processing network, is a [28]computing solution that is loosely modeled after cortical structures of the brain. It consists of interconnected processing elements called nodes or neurons that work together to produce an output function. The output of a neural network relies on the cooperation of the individual neurons within the network to operate. Processing of information by neural networks is characteristically done in parallel. Since it relies on its member neurons collectively to perform its function, a unique property of a

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neural network is that it can still perform its overall function even if some of the neurons are not functioning. It is robust to tolerate error or failure, as described by Mandic[1].

Neural network theory is sometimes used to refer to a branch of computational science that uses neural networks as models to simulate or analyze complex phenomena and/or study the principles of operation of neural networks analytically. It addresses problems similar to artificial intelligence (AI) except that AI uses traditional computational algorithms to solve problems whereas neural networks use software or hardware entities linked together as the computational architecture to solve problems, Saint-Donat[2]. Neural networks are trainable systems that can "learn" to solve complex problems from a set of exemplars and generalize the "acquired knowledge" to solve unforeseen problems as in stock market and environmental prediction. They are self-adaptive systems as shown in figure 1, according to Wikipedia[3].

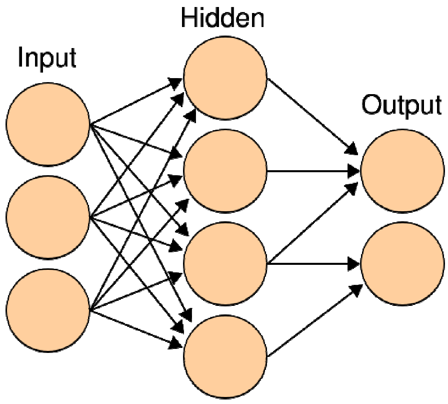

Figure 1. Neural network

Predictive process control involves the ability to monitor and control a continuous materials process in real time. This allows the conditions of the process to be adjusted quickly and responsively, and avoids the delay associated with only monitoring the final product. The potential of this technology sub-area is great, as it can improve the yields and productivity of a wide range of industrial processes. It can also contribute to the reduction in unwanted or polluting side processes.

Advancing the state of the art in predictive process control requires advances in sensor capability, in data communications and data processing, and in modeling. Improved interfaces with operators, usually via graphic displays, will also provide improved control system performance. The most important class of sensors for this sub-area is non-imaging sensors which can be used to measure a vast range of phenomenology such as temperature, pressure, humidity, radiation, voltage, current, or presence of a particular chemical or biological material. Specialized micro sensors can be used to detect particular chemical or biological agents. The information generated by the sensors must be combined and processed using data processing and models specific to the process being monitored.

The United States is a major player in all of the technologies which make up predictive process control. For example, historically Honeywell has had a major presence, having introduced the first distributed control system (the Honeywell TDC 2000) in 1975. Many other countries are also players in this area, however. In the UK, BNFL has developed advanced control system. In Germany, Siemens Industrial Automation has been leader in designing control systems with open architecture. The Japanese company, Yokogawa, is active in the International Fieldbus Consortium.

Model Predictive Control (MPC) is widely adopted in industry as an effective means to deal with large multivariable constrained control problems. The main idea of MPC is to choose the control action by repeatedly solving on line an optimal control problem. This aims at minimizing a performance criterion over a future horizon, possibly subject to constraints on the manipulated inputs and outputs, where the future behavior is computed according to a model of the plant, as showed in figure2. Issues arise for guaranteeing closed-loop stability, to handle model uncertainty, and to reduce on-line computations, according to Bemporad [4].

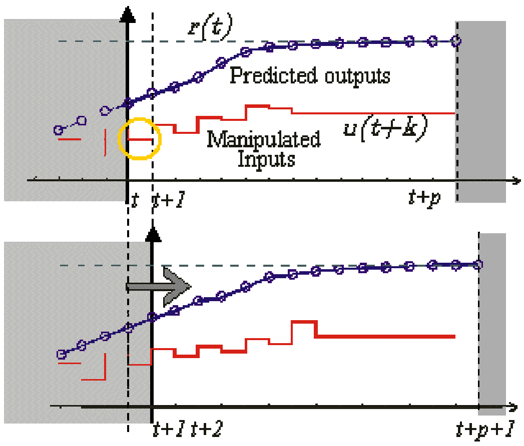

Figure 2. Model predictive control

MPC is an advanced method of process control that has also been in use in the process industries such as chemical plants and oil refineries since the 1980s. Model predictive controllers rely on dynamic models of the process, most often linear empirical models obtained by system identification. The models are used to predict the behavior of dependent variables (outputs) of a dynamical system with respect to changes in the process independent variables (inputs). In chemical processes, independent variables are most often set points of regulatory controllers that govern valve movement (e.g. valve positioners with or without flow, temperature or pressure controller cascades), while dependent variables are most often constraints in the process (e.g., product purity, equipment safe operating limits). The model predictive controller uses the models and current plant measurements to calculate future moves in the independent variables that will result in operation that honors all independent and dependent variable constraints. The MPC then sends this set of independent variable moves to the corresponding regulatory controller set points to be implemented in the process, Patwardhan[5].

Despite the fact that most real processes are approximately linear within only a limited operating window, linear MPC approaches are used in the majority of applications with the feedback mechanism of the MPC compensating for prediction errors due to structural mismatch between the model and the plant. In model predictive controllers that consist only of linear models, the superposition principle of linear algebra enables the effect of changes in multiple independent variables to be added together to predict the response of the dependent variables. This simplifies the control problem to a series of direct matrix algebra calculations that are fast and robust, according to Garcia [6].

2 Baseline Process

Monsanto has implemented a manufacturing unit in Sao Jose dos Campos city using as concept a continuous process to make a specific salt through a continuous acid-base reaction. The basic process consists in a continuous addition of an acid to be stoichiometrically neutralized with a base, in presence of water according to figure 3. Since the start-up of the plant several operating constraints were observed regarding the high variability in moisture control. Moisture is an important parameter to ensure that the acid-base reaction takes place properly. The control is done by feeding water into the continuous reactor, creating product dough. It is done automatically via a closed-loop configured in the Distributed Control System (DCS). The set-point for water feed rate is determined by the operators through a previews visual analysis of the product in the reactor outlet pipeline.

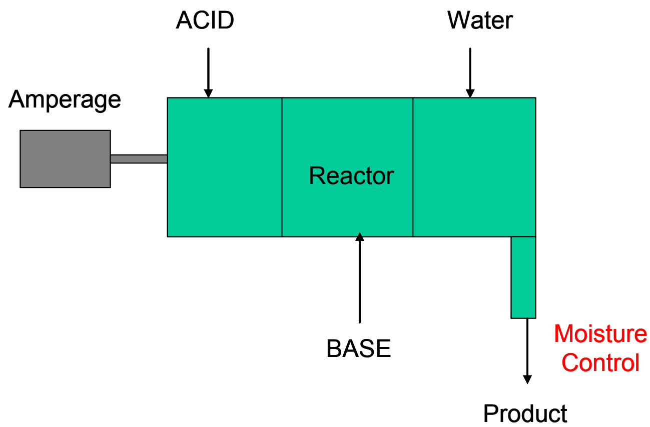

Figure 3. Continuous neutralization reactor

The ideal moisture operating range is within 4 – 6%. Working off the range many plant shutdowns is observed due to pluggages in the equipments located in the downstream process. It can also impact the product quality once the higher moisture causes lump formation and lower moisture creates dust in the further process steps.

In order to establish the process baseline many six sigma statistical tools were applied to the historical data of the manufacturing unit. MINITAB® software was used for calculating the indexes and supports the technical evaluation. According to Hayashi[7], the capability tool was applied and the result showed a process cpk of 0.29 for moisture control. This value is much lower than 1.32 that is the reasonable number for a capable process, see figure 4.

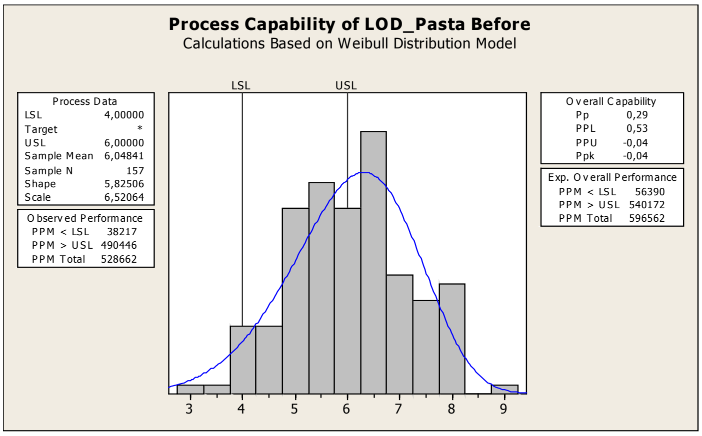

Figure 4. Baseline process capability analysis

Prior to implement advanced process control concepts, it was configured in the DCS a linear modeling created by MINITAB®. The main objective was to correlate the water feed rate as a function of the reactor amperage, acid feed rate and acid moisture. The linear regression equation, as described below, did not work properly due to a cyclical variation in the closed control loop, causing many plant upsets.

$$\text{Water\_feed\_rate} = \frac{\text{Reactor\_amp} + 310 + \text{Acid\_rate}*0.023 + \text{Moisture}*31}{(248 + \text{Moisture}*21)}$$

3 Project Implementation

In order to implement a more reliable system this project outlines neural network models to predict the moisture in the continuous reactor in real time as a virtual on-line analyzer. The project considered also a model-predictive control to manipulate the water feed rate based on the predicted moisture in the continuous reactor.

A benchmarking was done to find out potential softwares to be used for implementing the VOA and MPC applications. The marketing search considered the restrictions of the current plant DCS. A versatile software was defined to be the platform to run the neural network and MPC applications, Emerson [8].

The neural network was trained using 6-month period of historical data with the objective to establish a control block system in order to replace the linear regression equation, previously used in the DCS. The amount of data used represented the plant operation for long term, excluding the outliers that in fact, are non-usual events, plant shutdowns, downtimes or experiments. The model is expected to predict the moisture in the continuous process.

The first step of modeling was to calculate the correlation between chosen variables and select those ones which statistically had the main effects with predictable variable (moisture). Based on the engineering flow diagram, the reactor temperature, amperage and raw material feed rates, assays and moistures were selected as potential variables to obtain the model correlation. The selected variables were the acid feed rate, acid assay and the water feed rate which have demonstrated correlations higher than 0.80. Virtual on-line analyzer was obtained by training the digital control system neural block through historical data of the unit, as showed in figure 5.

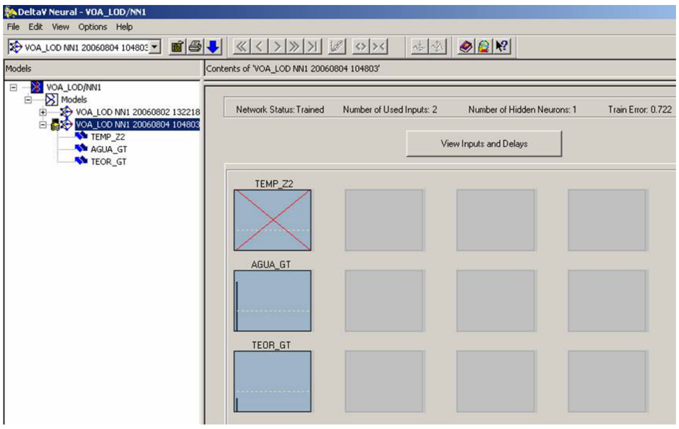

Figure 5. Neural network model

The predictive model gains were obtained by providing steps in the process, collecting and treating the data through the software. In figure 6 is shown the software template. To establish the process control strategy for MPC it was considered the following variables:

- Constraint variable: Reactor amperage that can not exceed a certain value to avoid damages in the reactor mechanical structure.
- Disturbance variables: Acid feed rate and acid assay have a direct correlation to the reactor moisture and influenciate the predictable parameter by the VOA.
- Controlled variable: Moisture predicted by the VOA. The operators insert the moisture set point in the DCS and based on that the MPC manipulates the water feed rate set point.
- Manipulated variable: Water feed rate, is the variable adjusted by MPC automatically in remote operation mode.

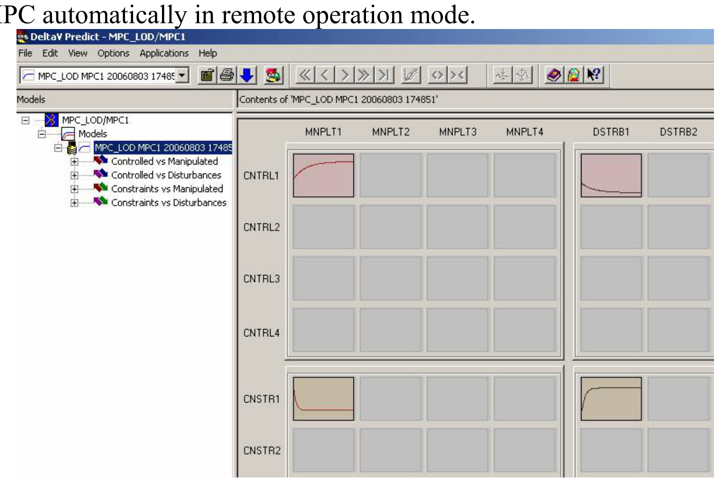

Figure 6. Model-Predictive Control

4 Results and Discussion

The process constraints were minimized by reducing the moisture variability throughout better water feed rate control. The achieved process capability (cpk) is 2.22, as demonstrated in figure 7. The related off-grade product was eliminated and the continuous reactor operation became more reliable. No plant downtimes occurred, increasing the plant productivity.

The most important part of the modeling process is to get reliable historical data as well as planning the plant trials and parameters adjustments. Besides the software tools, the process control strategy should be evaluated by an expert technical group prior its implementation to avoid future problems.

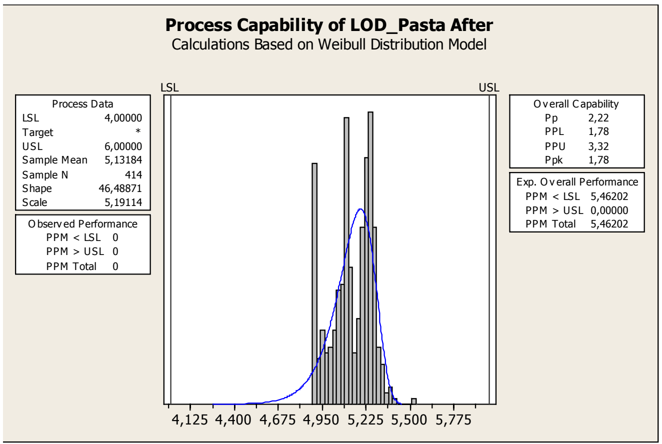

Figure 7. MPC capability analysis

5 Conclusions

The project was implemented accomplishing the goals and was recognized as a breakthrough solution. Technology innovation and business strategies were focused on this project by searching modern ways for manufacturing process control and management. Smart tools, new control strategies, process modeling and teamwork were the key to achieve success in this implementation. The engineering approach in this work allowed the process to be anticipated avoiding waste of resources in the manufacturing organization and working in a proactive vision. The technology innovation provided a friendly user tool for the operators and knowledge exchange among the team. Being so, by applying intelligent control, it was possible to increase overall productivity of the manufacturing unit. The collaboration among all the individuals involved from different areas of knowledge was essential to get the results in an integrated manner. The overall results lead the company to a sustainable business strategy due to the large potential to increase the instantaneous plant capacity. This project opens also new opportunities to reduce costs in the manufacturing units by applying smart control system.

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Manufacturing processes and environmental requirements for sustainability

Modelling and Management of Manufacturing Requirements in Design Automation Systems

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Abstract. Initially, when implementing a design automation system the focus is on successfully developing a system that generates design variants based on different customer specifications, i.e. the execution of system embedded knowledge and system output. However, in the long run two important aspects are the modelling and management of the knowledge that govern the designs. The increasing emphasis to deploy a holistic view on the products properties and functions implies an increasing number of life-cycle requirements. These requirements should all be used to enhance the knowledge-base allowing for correct decisions to be made. In a system for automated variant design these life-cycle requirements have to be expressed as algorithms and/or computational statements to be intertwined with the design calculations. The number of requirements can be significantly large and they are scattered over different systems. The aim of the presented work is to provide an approach for modelling of manufacturing requirements, supporting both knowledge execution and information management, in systems for automated variant design.

Keywords. Design automation, requirement management, requirement modelling, manufacturing requirements, producibility

1 Introduction

Today, many companies have adopted the strategy of product customization. To be able to reduce the workload and handle the large amount of information that this strategy entails, companies have to make use of appropriate methods and tools. Further, companies have to capture the knowledge behind a design for internal reuse and/or to be able to provide design history documentation as requested by customers and authorities. This implies that they have to consider the modelling and management of the knowledge that govern the designs. This includes the core elements of the knowledge, the range of the knowledge, its origin, its structure, and its relations to other systems and life-cycle aspects.

The purpose with this work is to integrate the properties and the functions for knowledge execution and information management into one system. The work is

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based on two previously developed systems: one system for automated variant design [1] and one system for management of manufacturing requirements [2]. Both systems can be used as analysis or synthesis tools concerning producibility aspects [3]. The systems have different functionalities and properties, e.g. regarding knowledge execution and information management, and it would be fruitful to combine these in one system. The aim of the work is to provide an approach for modelling of manufacturing requirements in systems for automated variant design, supporting both knowledge execution and information management.

One strong reason for using IT-support to manage requirements is the need for traceability. This implies that changes should propagate to the product definition guided by traceability links. According to [4], a requirement is traceable if one can detect:

- the source that suggested the requirement,
- the reason why the requirement exists,
- what other requirements are related to it,
- how the requirement is related to other information such as function structures, parts, analyses, test results and user documents,
- the decision-making process that led to derivation of the requirement, and
- the status of the requirement.

To support traceability between customer requirements and systems/parts the employments of three additional structures: *functions*, *solutions*, and *concepts* has been proposed [5]. A similar approach is to enhance traceability using additional structures for *functions* and *function-carriers* [6]. Both approaches are based on the chromosome model [7], which is a further development of the theory of technical systems [8,9].

The introduction of a *process function domain*, with process requirements, in the four domains of the design world, [10], has also been proposed [11]. The purpose is to enable manufacturing requirements for the physical product to be the mapped. However, the approach focuses on the management of process requirements set by the product. This is intended for a company strategy where the design of the manufacturing system is subordinated to the design of the product and a new manufacturing system is developed for every new product. Another approach argues for the structuring of manufacturing requirements in accordance to the product and manufacturing domain [12]. It is suggest that the manufacturing structures (*processes*, *functions*, *functional solutions*, and *resources*) could be used for the structuring of manufacturing requirements. However, it is not describe how to support the conceptual phases where different manufacturing alternatives are to be evaluated or how to model requirements arising from the combination of resources. The approach is applicable for product documentation and configuration systems. Although, the approach's applicability for systems supporting evaluation of different courses of action or for generative process based systems is considered to be limited.

2 Modelling of Manufacturing Requirements in Design Automation

From an engineering design view, the origin of manufacturing requirements is the coupled relationship between the product design, the material, and the manufacturing process. The main objectives of manufacturing requirements are to ensure the product's conformability with the manufacturing system, i.e. prevent problems in manufacturing from occurring, and to enhance producibility. From a modelling perspective, some of the manufacturing requirements can be considered to arise in the interfaces as depicted in Figure 1 [2].

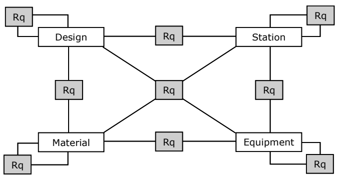

Figure 1. From a modelling perspective, the manufacturing requirements are considered to arise in the interfaces between objects, e.g. design, material, station, and equipment [2].

The requirements have to be collected and structured in a systematic way. A number of properties need to be defined in order to ensure that they fulfil the needs of the different interested parties. This can be achieved by looking at how the requirements relate to the other concepts. The requirements can have different ranges, be applicable at different company levels, be of different types, be expressed and illustrated in different formats, and have a number of links to other concepts and instances. Different concepts and their links are depicted in Figure 2.

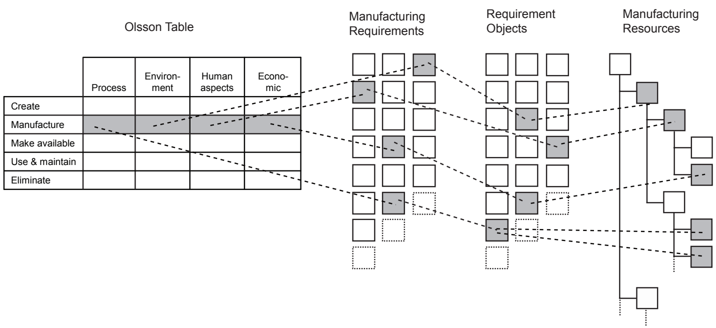

Figure 2. Different concepts for modelling of manufacturing requirements. The Olsson table [13] supports the definition of requirements.

The manufacturing requirements are defined by applying different views from the Olsson table [13] on the manufacturing resources to ensure that all important aspects are considered. Individual manufacturing resources as well as their combinations can constitute a base for a manufacturing requirement. This is supported with the concept of requirements objects by which different resources, together or individually, can be related to a specific manufacturing requirement. The manufacturing requirements contain the statements of the requirements. Additional information can be provided as attributes or relations to other objects.

2.1 Manufacturing Knowledge and Producibility Rules

The initial steps in the system development procedure [3] are to define: the variables and requirements origin from the customers within a Customer space, the resources within a Company design space, the product variables within a Product design space, and finally to formulate the design algorithms, rules, and relations that transform customer and company variables to product variables (Figure 3).

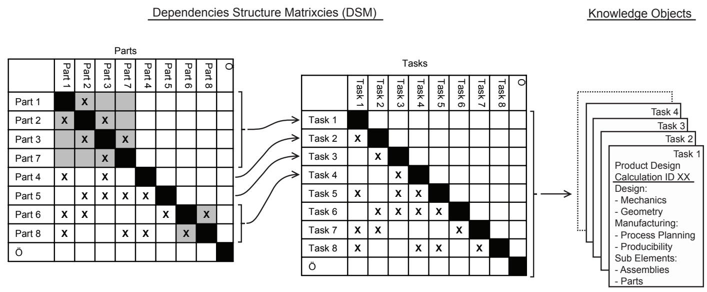

Figure 3. An analysis and a modelling of design algorithms, rules, and relations that transforms customer and company variables to product model variables results in a generic product structure. The items in this structure have to be clustered in executable knowledge objects by deploying a process view to resolve the bidirectional dependencies and/or the recursive dependencies.

The gathered knowledge of manufacturing requirements that are expressed in text has to be transformed into to executable producibility rules, i.e. numerical values, computational statements or production rules (If–Then-Else) to be incorporated in the system. The requirement can be expressed as, for example:

- a constraint that must not be violated,
  - a boundary for a search space where the most optimal solution is desired,

  8. a parameter, working as an input to the design calculations.

The resulting statements have to be incorporated as a number of checks in an analysis system (executed to control the products´ conformance with the manufacturing requirements) or intertwined with the product design calculations in a synthesis system.

2.2 Mapping of Concepts to Support Traceability

The mapping of manufacturing requirements, manufacturing resources, and knowledge objects is done with the concept of requirement objects. This is completed when setting up the system for a specific product, Figure 4.

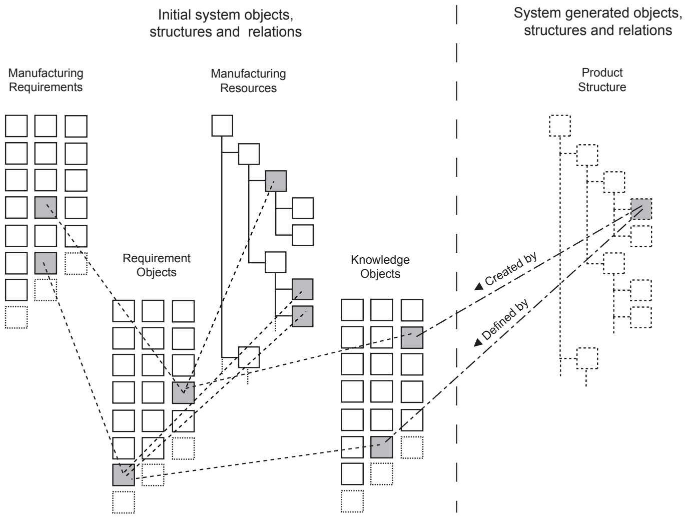

Figure 4. Initial and generated system objects, structures, and relations. For the mapping of the knowledge objects to the product structure there are two solutions: explicit mappings of individual knowledge objects to related item(s), or implicit relations that are realised when the knowledge objects are executed. At system execution two relations are created; one for the creation and one for the definition of the product items.

3 System Example – Car Seat Heater

The case example is taken from an ongoing research project. The project aims at setting up the principles of a system for automated layout of heating elements, Figure 5. The proposed approach, Section 2 *Modelling of Manufacturing Requirements in Design Automation*, for modelling of manufacturing requirements has been adopted when planning and setting up a first initial solution for a design automation system.

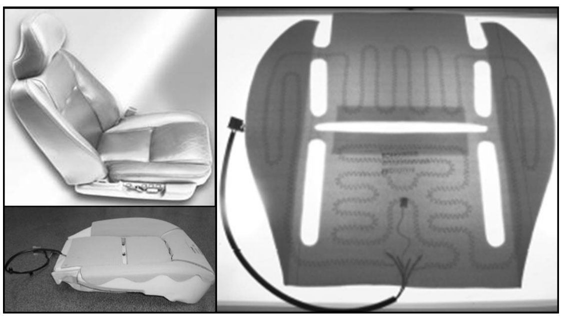

Figure 5. Upper left: a car seat with heating elements in the cushion and backrest. Lower left: a cushion element glued to the seat foam. On the right: a cushion element on a lighting table showing the heating wire with sinus formed loops, the thermostat. and the connection cable beween two layers of carrier material.

3.1 Manufacturing Requirements in Case Example

The design of a heating element must conform to the manufacturing system. Examples of manufacturing requirements classified according to the types in Section 2.1 *Manufacturing knowledge and producibility rules*, are:

- No centre line radii of less than 10 mm are allowed due to the winding machine. This is a constraint that must not be violated.
- The number of turns should be minimized. The winding machine has to slow down in the turns and the processing time will increase with the number of turns. This is a boundary for a search space where the most optimal solution is desired.
- There must be a clearance of 5 mm between the element's outer boundary and the outer boundary of the heating area. The reason for this is the gluing of the lower carrier with the upper carrier. The calculation of the heated area must be based on this offset. This is a parameter working as an input to the design calculation of the heated area.

3.2 System Principles

In Figure 6, a principle system architecture for an automated system generating varant designs of the car seat heater is depicted. The purpose is to combine properties of, and functions for, knowledge execution and information management into one system.

The system is based on commercial software applications (Access and Visual Basic, by Microsoft; Mathcad, by Mathsoft; and Catia, by Dassault Systems). The scope of the system is to generate variant designs of heating elements based on different customer specifications and seat geometries. The deployment of the proposed approach will ensure access to company know-how and know-why. The objectives with the system implementation are to: cut quotation lead time, allow for evaluation of different design alternatives, quality assure the design process, capture design knowledge, and provide design documentation. The system ensures the products' producibility in existing facilities by the incorporation of producibility rules. It also supports traceability between the production system and the product system. The automated system for variant designs will be a vital part of the company business process regarding heat elements. To ensure system longevity, maintainability, and expandability it is important to incorporate meta-knowledge about the origin of the system's embedded knowledge.

4 Conclusion

The presented work provides an approach for modelling manufacturing requirements in design automation. The approach promotes the integration of properties and functions for knowledge execution and information management into one system, i.e. integration of design know-how with life-cycle related know-why. The focus in this work has been on requirements originating from manufacturing, although the presented principles are perceived as applicable to other life-cycle requirements. An expanded support for requirements modelling and mapping will support different stakeholders' needs of requirement traceability and system maintenance.

The proposed approach has been adopted during the planning and setting up of a first solution for a design automation system. The system provides the company with opportunity to work with producibility issues in a systematic way. It can also serve as a tool that enables the evaluation of different courses of action in the early stages in the development of product variants. Future work includes further system development, user tests, and evaluations. Issues to be studied can be: the relation between Knowledge Objects and Product Elements, the scope and re-execution of the Knowledge Objects, how general the Knowledge Objects shall be, how to include process planning and cost estimation, how to handle implications on the knowledge base resulting from system generated product structures and process plans, and suitable execution principle (depth-first or breath-first) to be deployed.

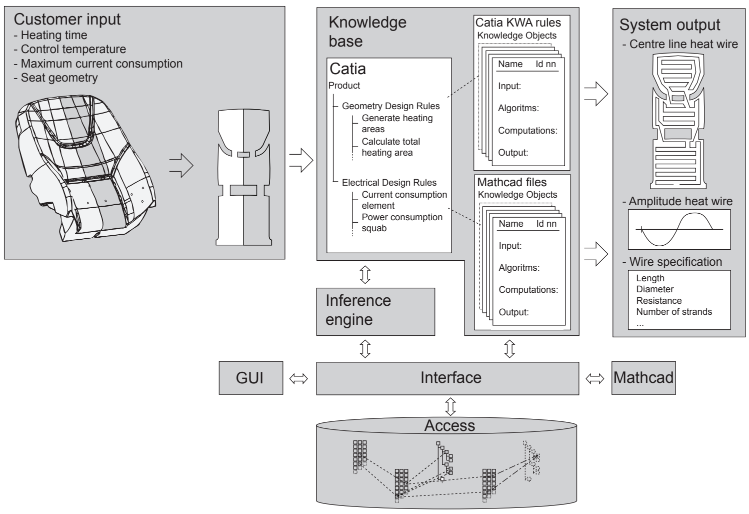

Figure 6. System architecture. The graphical user interface (GUI) and the interfaces to different software applications and databases are programmed with Visual Basic. The knowledge base comprises rules in Catia Knowledge Ware Advisor (KWA). The rules are linked (through an Access database) to different Knowledge Objects. A Knowledge Object is a database object that has a number of input parameters and output parameters. The Knowledge Objects can be of different types (e.g. Catia KWA rules, Mathcad worksheets) in which the methods of the different Knowledge Object are implemented. The rule firing, invoking the Knowledge Objects, is controlled by an inference engine, Catia KWA. The company resources with associated manufacturing requirements are stored in an Access database together with the Knowledge Objects. The product items and structure together with the two relations, *Created by* and *Definied by*, are created at runtime. The system is fed with customer specific input (parameter with associated values together with a 2D outline of the heated seat areas). The main output is the pattern for the heating wire's centre line, an amplitude factor for the sinus formed loops, and the wire specification.

5 Acknowledgements

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Integrating Manufacturing Process Planning with Scheduling via Operation-Based Time-Extended Negotiation Protocols

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Abstract. It is proposed in this paper the on-line adaptation of process plan with alternatives, through the application of an operation-based time-extended negotiation protocol for decision-making about real-time routing of job orders of parts composed of machining operations in a job-shop environment. The protocol is modified from the contract net protocol to cater for the multiple tasks and many-to-many negotiations. The grouping of the machining operations enables reduction of setup times, resulting from the reduction of machines changes. For each part, all feasible routings are considered as alternative process plans, provided the different manufacturing times in each machine are taken into account. The time-extended negotiation period allows the visualization of all of the times involved in the manufacture of each part, including those times that are not considered in systems of this nature, such as the negotiation times among agents. Extensive experiments have been conducted in the system, and the performance measures, including routings, makespan and flow time, are compared with those obtained by the search technique based on the co-evolutionary algorithm.

Keywords. Negotiation protocol, Agent technology, Planning and scheduling

1 Introduction

A large obstacle for the integration between process planning and production scheduling, in dynamic manufacturing environments, is the lack of flexibility for the analysis of alternate resources when allocating the jobs in the shop floor.

According to Shen et al. [4], the integration problem of manufacturing process planning and scheduling becomes even more complex when both process planning and manufacturing scheduling are to be done at the same time. This paper will describe a multiagent system with a heterarchical structure for making decisions

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about the manufacture of parts composed of machining op-erations in a job shop layout, or similar kind of flexible manufacturing environments. The negotiation between the many agents present in the system is based on the grouping of machining operations with an extended period. Each job is announced, subdivided into operations, and later treated as the total sum of groups of machining operations that compose the process plan of the part. In the proposed method, it is also allowed the use of alternative resources for the manufacture of part to increase flexibility in scheduling, but considering their different manufacturing times in each machine. The constraints related to the precedence between the machining operations are taken into account in this model, as well as the machine and fixturing setup times.

2 Related Research

The problem of integrating process planning and production scheduling has been under investigation in the last years, and many different approaches have been applied to accomplish that. More recently many authors have suggested the multiagent systems (MAS) as an adequate approach for solving this problem.

In spite of the advances in this area, it is observed that in many works that use the multiagent approach, a greater emphasis is on production scheduling, both predictive and reactive, while process planning is treated in a static way, i.e. it is determined before the part is released into production. It is also noticed that despite some authors use dynamic process planning in their approaches, there is a recurring problem related to the researches that study the integration of process planning and production scheduling, which is the consideration of the activities that compose the scheduling of an order or a part. In [3], the features that compose each of the parts are treated in an independent way from each other, i.e. a single feature is negotiated at a time between the part and the resources. This kind of treatment may lead to an increase in the setup and queue times, resulting in a longer makespan and flow times. This increase in the manufacturing times results from the many changes machines on which the parts are manufactured, but if the features or operations are grouped based on the setup, this may improve the manufacturing and transport times. These possible gains are investigated in this paper.

3 Characteristics of the Adopted Model

The problem domain in this paper is specific to a job shop environment, or similar kind of flexible manufacturing environments, like open shop, for the production of n parts with m machines. The shop scheduling problem addressed in this paper, there are a given number of jobs on order, with each job having a large number of process plans, which is due to operation, sequencing, and processing flexibilities. Two types of objectives are considered: minimizing makespan and minimizing mean flow time over all the jobs.

3.1 Operation-Based Time-Extended Negotiation Protocol

The operation-based time-extended negotiation protocol is an adaptation of the protocol utilized by Usher [3]. Contrary to the typical duration of a negotiation process used in agent-based systems defined by how long it takes for the messages exchanged between the participating agents to be constructed, sent, and responses received, in the operation-based time-extended negotiation protocol the deadline corresponds to a fixed percentage of the expected time that will be required to setup and process the job on the current resource. According to [3], by considering a definite time interval from the onset of negotiation to the response deadline, each resource can negotiate with multiple part agents simultaneously.

However, the protocol suggested by Usher [3] has as limitations two equally important factors: (a) it does not provide any mechanism for grouping operations that compose a job, and although in that system multiple part agents are coordinated concurrently, each part agent can announce only one single task (or operation) at a time; (b) it considers the setup times independent of operation sequence.

For a better understanding of the setup, the nomenclature used in this paper is presented below. This representation of the variables was adapted from Conway et al. [2], and is used to describe both the sequencing problem and the proposed solution:

- i: index of the jobs to be processed by the shop; $1 \leq i \leq n$;
- j: index of the sequence of operations on a job; $1 \leq j \leq g_i$;
- g_i: the total number of operations on job i;
- $p_{i,m}$: amount of time required for resource m to perform the job i;
- $s_{i,m}$: total setup time of job i on resource m;
- $sp_{i,m}$: total machine setup time of job i on resource m. This value is independent of batch size;
- $sf_{i,m}$: represents the total fixture time of job i on resource m. This value is dependent of batch size.

The proposal time is the sum of all the times considered by a resource agent for the elaboration of a proposal in response to a request made by a part agent. This proposal time indicates the time predicted to start manufacturing the job on the resource. Equations (1) to (4) represent the times that compose the proposal time:

(1) $$\text{Proposal time} = Tq_m + \left(\frac{\sum_{j=1}^{g_i} p_{i,m} + s_{i,m}}{g_i} \right)$$

(2) $$Tq_m = \sum_{i=1}^{n} (q_i + c_i + w_i)$$

(3) $$s_{i,m} = sp_{i,m} + sf_{i,m} * batch\_size$$

$$\text{(4) Proposal time} = \sum_{i=1}^{n}(q_i + c_i + w_i) + \left(\frac{\sum_{j=1}^{g_i} p_{i,m} + sp_{i,m} + sf_{i,m} * batch\_size}{g_i} \right)$$

Where:

- Tq_m: queue time to carry out all manufacturable jobs on a resource. These jobs are already in the resource processing queue, but they have not yet started manufacturing at the instant of negotiation. If there are no jobs in the resource processing queue at the negotiation instant, then Tqm = 0;
- q_i: resource queue time of job i;
- c_i: contract time. These orders have already contracted a resource, but have not yet arrived at the resource processing queue (for instance, they are still being manufactured at a previous resource);
- w_i: waiting time. It is the interval between the sending of the proposal for job execution by a resource agent, and the acceptance of the proposal by the part agent that is negotiating with the resource. If no jobs are in the waiting interval at the negotiation instant, then wi = 0.

For a better understanding of the contract time (c_i), waiting time (w_i), and resource queue time (q_i), which compose Equations 2 and 4, figure 1 presents an example illustrating the exchange of messages between three part agents *i1*, *i2* and *i3*, and three resource agents *R1*, *R2* and *Rn*. Each of the resource agents has an internal counter of the total queue time, *Tq1, Tq2* and *Tqn*, responsible for adding the total queue time (*Tqm*) that will later be used in the proposal.

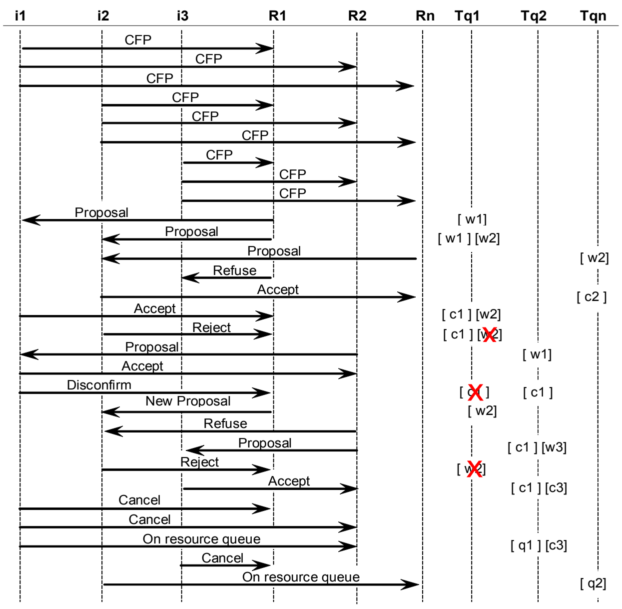

Figure 1. Negotiation between part agents and resource agents

The negotiation starts with part agents *i1, i2* and *i3*, which send a call for proposal (*CFP*), requesting a proposal time to resource agents *R1, R2* and *Rn*. As soon as resource *R1* sends a proposal to *i1*, the counting of the waiting time starts (w_i). This time is calculated in column *Tq1* until resource *R1* receives an “accept” or “reject” by *i1* referring to its proposal. In the case of a positive response (“accept”) by i1, the time will not be calculated as waiting time (w_i), and instead it will be considered as contract time (*c1*), remaining that way until job i1 is moved to the resource processing queue. At this instant job *i1* sends to resource *R1* the message informing that it arrived at the resource queue. When resource *R1* receives this message, it considers the time related to i1 as a portion of the resource queue time (*q1*). If the resource proposal is rejected, as it occurs in the negotiation between *i2* and *R1*, where *R1* receives a “reject” of a proposal made to job *i2*, the waiting time (*w2*) is not considered as part of the resource negotiation time, and it is discarded.

3.2 Mechanism to Compare the Proposals

In order to characterize the dynamic scheduling environment, a mechanism that allows the renegotiation between resource agents and part agents even after a “reject” message by the part agent was created. This mechanism is triggered whenever an alteration occurs in the queue of jobs of the resource agent involved in the negotiation. The steps that compose this renegotiation are shown in figure 2.

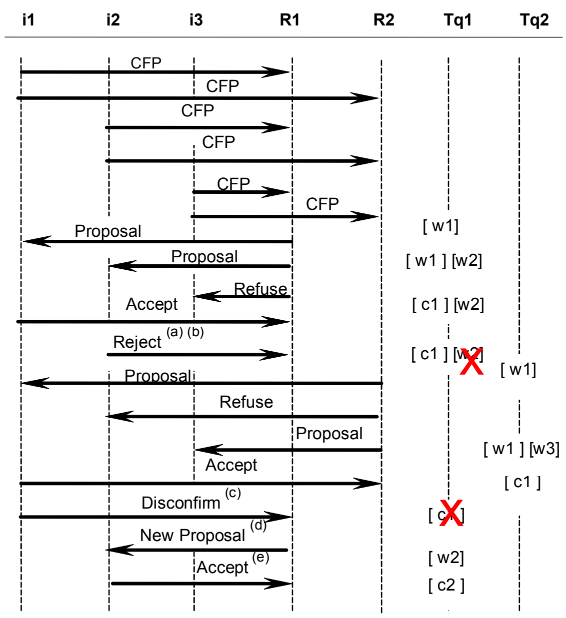

Figure 2. Mechanism to Compare the Proposals

(a) When sending a "reject" proposal, the part agent also needs to send the best proposal that it received until that moment of negotiation, i.e., the proposal that motivated its refusal;
(b) This proposal, which includes the information about the part that originated it, is stored temporarily by the resource agent;
(c) If an alteration occurs in the queue of jobs of the resource agent, such as an order cancellation, this resource will calculate new queue times, updating the proposal time of all of the jobs that are in its physical queue or negotiation queue;
(d) After calculating all the new times, the resource agent will analyze the proposals stored in item (b), comparing them with its new availability. In case the new proposal is better than the stored proposal, the new proposal is sent again to the part agent;
(e) Finally the part agent will analyze this new proposal, verifying if it will accept it or not.

4. Implementation and experiments

In this paper, the performance of the proposed operation-based time-extended negotiation protocol is compared with a symbiotic evolutionary algorithm (SEA) [2]. SEA is a co-evolutionary algorithm that can simultaneously deal with process planning and job shop scheduling in a flexible manufacturing environment. In the hierarchical approach, the process planning is first solved, and then the scheduling problem is considered under the constraint of the solution.

In order to evaluate the performance of operation-based time-extended negotiation protocol, a number of experiments is conducted based on the test-bed problems provided in Kim et. Al [1]. They generated 18 parts with various combinations of flexibility levels. Each job consists of a minimum of 8 and a maximum of 22 operations. They constructed 24 test-bed problems with the 18 jobs. The number of jobs, the number of operations, and the job composition involved in each problem are listed in table 1. The complete set of data for all 24 test-bed problems and 18 parts, including the alternative process plans and the related data, is available in [2] and not repeated here.

Table 1. Test-bed problems

Problem	Number of jobs	Job Number	Problem	Number of jobs	Job Number
1	6	1, 2, 3, 10, 11, 12	13	9	2, 3, 6, 9, 11, 12, 15, 17, 18
2	6	4, 5, 6, 13, 14, 15	14	9	1, 2, 4, 7, 8, 12, 15, 17, 18
3	6	7, 8, 9, 16, 17, 18	15	9	3, 5, 6, 9, 10, 11, 13, 14, 16
4	6	1, 4, 7, 10, 13, 16	16	12	1, 2, 3, 4, 5, 6, 10, 11, 12, 13, 14, 15
5	6	2, 5, 8, 11, 14, 17	17	12	4, 5, 6, 7, 8, 9, 13, 14, 15, 16, 17, 18
6	6	3, 6, 9, 12, 15, 18	18	12	1, 2, 4, 5, 7, 8, 10, 11, 13, 14, 16, 17
7	6	1, 4, 8, 12, 15, 17	19	12	2, 3, 5, 6, 8, 9, 11, 12, 14, 15, 17, 18
8	6	2, 6, 7, 10, 14, 18	20	12	1, 2, 4, 6, 7, 8, 10, 12, 14, 15, 17, 18
9	6	3, 5, 9, 11, 13, 16	21	12	2, 3, 5, 6, 7, 9, 10, 11, 13, 14, 16, 18
10	9	1, 2, 3, 5, 6, 10, 11, 12, 15	22	15	2, 3, 4, 5, 6, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18
11	9	4, 7, 8, 9, 13, 14, 16, 17, 18	23	15	1, 4, 5, 6, 7, 8, 9, 11, 12, 13, 14, 15, 16, 17, 18
12	9	1, 4, 5, 7, 8, 10, 13, 14, 16	24	18	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18

4.1 Performance Comparison

The performance of the proposed operation-based time-extended negotiation protocol is compared with those three algorithms mentioned above. The experiment for each problem is repeated 10 times for every test-bed problem. The average of this is reported in the tables. The improved rate is computed by the Equation 5.

(5) Improved rate ={mean of SEA approach – mean of proposed protocol/ mean of SEA approach} x 100%.

Table 2 shows the experimental results for mean makespan and flow time, respectively. Since the test-bed proposed by Kim [1] does nor consider the setup times of the operations, it is necessary to carry out two performance comparisons in order to better characterize the nature o this investigation. Column Setup_0 in table 2 refers to the same conditions presented by Kim, i.e., the setup time is not considered. On the other hand, in column Setup_10_10, the total operation time used by Kim was divided in three parts: 80% processing time in the machine (pi,m); 10% machine setup (spi,m); 10% fixturing setup (sfj,m).

Table 2. Comparison of overall Flow time and Makespan

	Makespan								**Flow time**							
Problem Set	**SEA** Mean	s.d	**Setup_0** Mean	s.d	**Improved rate (%)**	**Setup_10_10** Mean	s.d	**Improved rate (%)**	**SEA** Mean	s.d	**Setup_0** Mean	s.d	**Improved rate (%)**	**Setup_10_10** Mean	s.d	**Improved rate (%)**
1	437.6	10.9	458.28	10.16	-4.7	432.7	13.2	1.1	318.9	3.7	302.39	5.97	5.2	300.5	5.6	5.8
2	349.7	5.9	334.88	10.60	4.2	331.0	10.1	5.4	287.7	4.7	273.23	2.93	5.0	266.0	3.2	7.5
3	355.2	7.4	329.89	6.15	7.1	318.4	11.7	10.4	304.8	4.3	285.54	5.71	6.3	278.9	5.3	8.5
4	306.2	0.4	301.63	8.83	1.5	297.7	7.5	2.8	251.3	4.8	246.84	1.84	1.8	245.4	4.4	2.4
5	323.7	3.6	306.22	14.81	5.4	320.6	15.6	1.0	280.3	3.2	259.31	5.58	7.5	261.5	6.1	6.7
6	443.8	5.0	455.88	11.35	-2.7	434.5	11.3	2.1	384.7	5.7	353.02	6.55	8.2	343.5	4.8	10.7
7	372.4	1.3	348.54	8.82	6.4	352.8	18.4	5.3	314.1	2.6	297.37	4.21	5.3	291.6	7.6	7.2
8	348.3	5.7	337.68	8.01	3.0	327.3	10.0	6.0	295.2	5.0	281.22	5.13	4.7	278.3	7.1	5.7
9	434.9	9.8	463.47	9.01	-6.6	446.1	4.2	-2.6	298.9	7.0	286.58	2.75	4.1	282.8	7.4	5.4
10	456.5	10.8	467.42	13.43	-2.4	434.6	8.5	4.8	349.2	6.1	313.20	5.07	10.3	309.1	6.9	11.5
11	378.9	5.1	349.38	13.99	7.8	344.7	10.4	9.0	312.9	7.6	288.18	5.47	7.9	285.2	5.1	8.8
12	332.8	3.4	340.01	11.46	-2.2	336.1	29.0	-1.0	279.6	4.7	267.84	4.42	4.2	261.9	6.1	6.3
13	469.0	10.7	456.23	15.21	2.7	436.9	13.2	6.8	387.0	7.1	335.63	5.50	13.3	324.8	4.9	16.1
14	402.4	10.6	367.40	14.83	8.7	369.9	21.2	8.1	346.9	8.5	317.62	5.63	8.4	317.9	4.8	8.3
15	445.2	11.0	471.32	12.71	-5.9	457.3	8.2	-2.7	316.1	6.2	292.66	3.54	7.4	286.7	7.1	9.3
16	478.8	12.0	471.35	34.06	1.6	461.9	27.0	3.5	359.7	4.3	318.60	7.42	11.4	316.8	5.0	11.9
17	448.9	8.7	387.86	28.46	13.6	403.6	36.9	10.1	364.7	4.7	313.46	4.99	14.1	306.2	4.7	16.0
18	389.6	7.5	375.47	9.18	3.6	383.5	23.6	1.6	322.5	6.4	286.44	9.15	11.2	284.8	7.8	11.7
19	508.1	10.0	480.06	18.75	5.5	444.5	14.1	12.5	406.4	4.6	336.41	6.41	17.2	339.4	5.5	16.5
20	453.8	5.2	404.08	14.12	11.0	394.3	18.5	13.1	372.0	5.7	324.78	4.79	12.7	323.1	8.5	13.1
21	483.2	6.8	482.09	17.50	0.2	457.1	13.6	5.4	365.4	8.2	323.23	6.47	11.5	305.2	7.4	16.5
22	548.3	6.9	504.31	36.35	8.0	474.5	12.3	13.5	417.8	5.8	360.68	9.48	13.7	352.2	11.9	15.7
23	507.5	8.3	458.28	33.74	9.7	434.0	21.9	14.5	404.7	5.1	347.28	12.86	14.2	334.4	11.5	17.4
24	602.2	7.1	529.58	27.35	12.1	495.9	26.4	17.6	452.9	7.5	391.77	12.54	13.5	387.4	12.7	14.5
			Mean Improved rate (%) =		3.66	**Mean Improved rate (%) =**		6.18			**Mean Improved rate (%) =**		9.13	**Mean Improved rate (%) =**		10.56

Table 2 reveals that, for several test-bed problems, the proposed operation-based time-extended negotiation protocol provides the best makespan performance among the compared algorithms. The global average obtained is also better than those generated by the other SEA algorithm used in the comparison. The cases in which the results for the makespan are worse than those attained by the SEA algorithm will be investigated in greater detail in the future, since in a preliminary analysis no dominant characteristic was found that could lead to a worse result.

With regard to the flow time for all the given examples, the proposed operation-based time-extended negotiation protocol provides the best performance among the compared algorithms.

5. Conclusion

The system proposed in this paper uses a heterarchical multiagent model that allows the dynamic process planning while reducing makespan and flow time through the reduction of the setup time between the jobs. In order to reach this objective, an operation-based time-extended negotiation protocol was used.

One of the most significant contributions to the efficacy of the proposed operation-based time-extended negotiation protocol is the use of flexible process plans that can be verified step by step during the sequencing and routing of jobs, which allows the resources group the operations that they are capable of manufacturing, reducing the machine setup time. This grouping allows the reduction of both the makespan and the flow time, and this is due to the reduction in the number of machine changes on which the jobs are manufactured. This shows that the simplification of the scheduling problem in a job shop layout through the inclusion of setup times in the total processing time of the machines may result in an incorrect analysis of the problem.

As a future work, an analysis of the influence of the setup times in the reduction of makespan and flow time will be carried out. This analysis will be based on the gradual increase of the contribution of the machine setup time. A mechanism will also be created for the analysis of the effects caused by disturbances on the flow time. At first two types of disturbances will be analyzed: machine failures, and the cancelling of orders that have already been released for manufacture. Also, solutions that minimize the effects of these disturbances will be investigated through the re-dynamic scheduling of the orders.

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Using Differing Classification Methodologies to Identify a Full Compliment of Potential Changeover Improvement Opportunities

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Abstract. In recent decades industry has focussed a lot of attention on changeover performance, recognising it has to reduce changeover losses in multi-product manufacturing environments in order to remain competitive.

This paper seeks to analyse the complexity of the changeover problem and the scope of the diverse improvement opportunities which typically are present. It does so by investigating widely variable changeover classification methodologies which have been developed to date. The paper discusses how suitable elements of these existing methodologies might be combined, thereby guiding the changeover practitioner in a structured fashion to consider a full compliment of potential improvements.

Keywords. Changeover classification, changeover improvement framework, changeover improvement rules

1 Introduction

From the end of the 1970's and into the 1980's and beyond, western volume manufacturers were confronted with an ever worsening competitive position relative, particularly, to leading Japanese manufacturers [11]. With the emergence of new manufacturing paradigms such as *lean* and *mass customisation* awareness has grown that competitive criteria extend considerably beyond those simply of high product quality and low unit cost which traditionally dominated in *mass production* [17]. A leading changeover capability greatly assists manufacturers to be more responsive and is widely identified to be at the heart of modern small-lot multi-product manufacturing practice [14].

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1.1 Changeover complexity and the use of indices

Changeover is assessed within the current paper as a complex, multi-dimensional activity, wherein very many opportunities are potentially available to improve how changeovers are completed. Notwithstanding the availability of various improvement methodologies, most notably the SMED (Single Minute Exchange of Die) methodology [12], changeover of equipment to enable the manufacture of a new product is in many circumstances both difficult and time consuming.

Whereas there are many different ways that complexity might be observed, complexity is usually only measured in practice in terms of time and, perhaps, the number of personnel employed. In both instances complexity is assessed by assigning indices to changeover activity, determining performance according to predetermined criteria (here, a simple time index and a personnel count index). Consequently improvement is often crudely sought only in these terms, where other performance indices are rarely pursued. Moreover, normally only internal time is measured, rather than the total time required to complete all tasks, including those which are concluded externally [12].

That other indices can be very beneficially employed is apparent in the early results of applying the University of Bath's Design for Changeover (DfC) tool [9-10], which seeks to guide the way OEM design in particular might be undertaken, and to determine what its impact might be. DfC particularly concentrates upon indicators of machine design complexity, and targets changeover improvement by redesign which will alter appropriate design-based indices.

2 Different classifications give different improvement awareness

Elsewhere [6] the authors have described the dominance of the SMED methodology and in turn the dominance when using it of pursuing organisation-led improvement. The authors further argue [6-7] that this situation is a reflection of the prominence of the prime objective of Shingo's methodology – of seeking to externalise changeover tasks – in the mind of those employing it [12]. If improvement is only sought by externalising tasks then those tasks will normally remain exactly as before (only being undertaken at a different time). The total amount of work which has to be completed logically remains the same.

2.1 Seeking a wider perspective of potential improvement opportunities

The premise above is that the prominent classification within SMED of a changeover comprising internal and external tasks substantially guides what improvement options are pursued. If so, alternative changeover classifications may cast new light on where gains can be found.

2.2 Classifications employed in changeover research at the University of Bath

The University of Bath has supported an extensive changeover research program for more than 15 years. In this time well in excess of 100 industrial partners have become involved in the research, based throughout the UK and mainland Europe. Many highly diverse industrial situations have been investigated.

The difficulty of understanding changeover in all its complexity and of understanding all the myriad potential improvement opportunities which can be available is reflected in the number of classifications University researchers alone have adopted. Many of these classifications have been modeled from others' work, sometimes being adopted unchanged. Conversely some novel working classifications have also been developed.

Recognizing that an overall changeover is typically interwoven with aspects of technical, personnel and behavioral issues (both in the immediate confines of the tasks being undertaken and beyond) the paper now investigates some selected key global classifications – which are later collated together into a new improvement framework.

2.3 Organization and design

For many years University researchers have drawn a distinction between design-led and organization-led improvement [7]. Any chosen improvement lies on a spectrum between being 100% design based and 100% organization based (where only what people do is altered). Whereas retrospective improvement can be undertaken with either a design or an organizational bias, OEMs (Original Equipment Manufacturers) can only realistically pursue better equipment design. It is for such personnel in particular that the University team has been developing its DfC tool.

2.4 Changing when tasks occur and changing what tasks occur

The authors have explained that a useful alternative perspective of changeover improvement to that of SMED is to recognize that individual tasks can either be conducted at an alternative time, or tasks can be revised such that the same tasks as before are no longer conducted [8].

In seeking to alter when tasks can occur the authors' approach is to seek improved allocation between the tasks and the resources necessary to complete those tasks. No distinction is made between 'separating' and 'converting' when tasks can occur [12], noting as well that useful improvement can often still be found even when tasks are not externalized [8].

2.5 The 4P's

Illustrated by figure 1, the separate 'P's' of People, Practice, Processes and Products have each been identified as a global influence on changeover activities and hence on measured changeover performance [9]. They are all available to be amended to support the required goal of faster and higher quality changeovers.

Hence, to gain improvement, the motivation of people might be addressed, or better training provided. Or the work practices which are adopted might be revised. Similarly, the products themselves might be redesigned to enable better changeovers, and physical revision to process hardware can be contemplated.

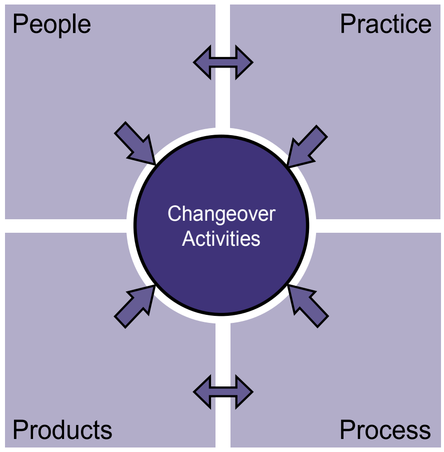

Figure 1. The '4-P' influences on changeover activities [9]

3 Discussion: diverse improvement opportunities

The desirability of enhancing manufacturing capability in changeover terms in the context of an environment of constant uncertainty and constant change is widely described [16]. Alongside better organisation of a changeover, as championed in many improvement programs, both product design and manufacturing process design also potentially have a key role to play [7, 3]. Each presents opportunities to more rapidly and precisely adapt production processes for the manufacture of an alternative product. Reik *et al*. [9-10] describe specifically how better design can enable fewer, faster, simpler changeover tasks to be completed, yielding sustainable gains, and significantly contributing to lean and competitive processes.

Whether by concentrating on design or concentrating on better organization, a generic approach to improvement can be proposed which is informed by the foregoing classifications. As will be further discussed, the approach is to seek one or both of a reduction in changeover complexity and change as to when tasks are conducted. Reducing variability (seeking standardization) represents one specific way that complexity can be reduced and is deliberately isolated in the proposed improvement framework as a sub-set of complexity reduction.

3.1 Reducing complexity

Whether seen as a series of tasks, activities, events or actions (or any other similar terms), all changeovers take a time to complete and represent a level of complexity. Reducing complexity by reducing the difficulty of individual tasks (or activities or events or actions) and/or their number should result in an easier and more rapid changeover being completed. Organizational and design-led approaches may both be employed. Complexity can be determined by whatever indices might locally be deemed appropriate, including combining them as ratios. Some very simple indices might be the number of hand tools used, the number of change parts or the distance that an operative moves.

3.2 Reducing variability (a sub-set of reducing complexity)

Improvement opportunities which include enhancing maintenance [13], repeatable good communication [2] and the adoption of best-practice standard procedures [15] have been reported in the literature.

These opportunities are all concerned with variability, which can add significant complexity to a changeover by necessitating non-standard tasks or procedures to be conducted (over and above the most efficient procedure possible within the constraint of given product and manufacturing process designs). It may be impossible to predict what these unnecessary additional tasks are as the changeover starts, and variability can sensibly be seen in its own right to be a major contributor to lengthy and inconsistent changeovers [5]. For example in the authors' experience, and supported in the literature [13], the condition of change items can often be critical. The need is for these change items all to be in a repeatable, known, standard condition. For example replacement ink in a print changeover requires to be mixed to the right color – if it is not then many iterative (and often highly time-consuming) adjustment or compensatory steps may have to be undertaken, usually whilst the production facility remains static [7].

Variability does not only relate to physical entities: human performance in particular is also likely to be important [5].

3.3 Changing when tasks occur

Importantly, despite the scope of the above options, it needs to be recognized that reducing complexity *per se* (including doing so by reducing variety) is not the only potential way that quicker changeovers may ensue.

An alternative strategy in many industrial circumstances is to change when tasks occur [8] – for example externalizing them, prior to production being halted [12]. The time at which tasks commence is changed, rather than the tasks themselves intrinsically being changed.

Changing when tasks take place has been argued elsewhere [8] to be strongly influenced to the ability to match tasks to the resources needed to complete them, most notably labor (which is the reason externalizing tasks is often particularly attractive). In other words task re-sequencing is potentially possible if a resource is not being used at any given time. Normally the task start time would be altered to minimize the period when production is interrupted by the changeover ('internal time' in SMED nomenclature).

Conversely, better matching of resources to the tasks which need to be completed can also be beneficial, for example adding more skilled labor or providing pre-setting jigs [8]. Once more the effect is potentially to allow change to the time when tasks can be undertaken, hence again reducing production losses.

4 Unravelling opportunities: a new framework

Illustrated by figure 1, the ‘4P’s’ of People, Practice, Processes and Products are each influential on changeover performance. They are all available to be amended to support the required goal of faster and higher quality changeovers. Standing alone however, the 4P categorisation still provides little detailed guidance as to how improvement might be undertaken. This situation changes when other perspectives are brought to bear, and more particularly if some sufficiently focussed working rules (or improvement directives) can be structured as a clear part of this fuller view. A candidate framework is presented as figure 2, which combines elements of the classifications previously outlined in section 3 with the generic approach discussed in section 4. Figure 3 articulates simple yet searching high level questions to be used within the proposed framework – outlining improvement opportunities in a similar manner to that done for example by DFMA (Design for Manufacture and Assembly) methodologies [1].

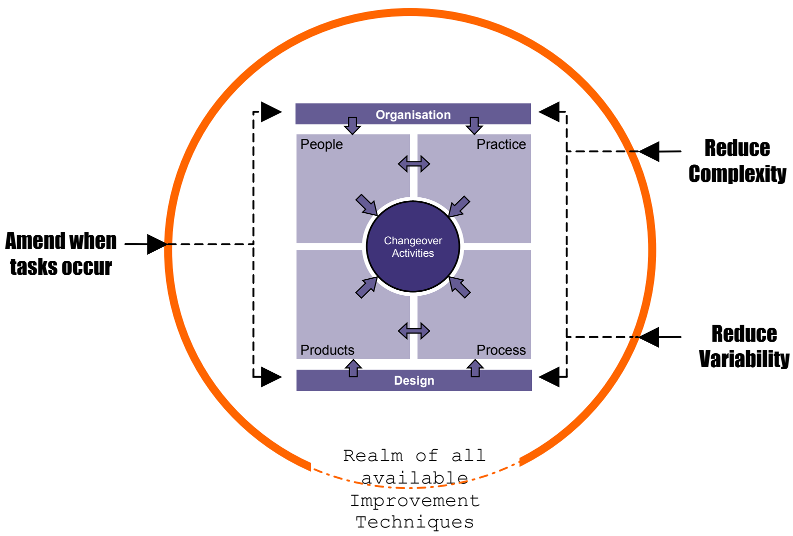

Figure 2. Integrating classifications (part 1): an improvement framework

Thus, first considering figure 2, a global objective of reducing complexity might be pursued. This objective might be pursued by using any relevant improvement technique, such as (but not limited by) those described by Shingo [12], where the chosen technique can be either organization-biased or design-biased [7]. The two rules which guide a focus on complexity, shown in figure 3, are those which respectively seek a reduction in any sensible locally defined activity count index and/or a reduction in any sensible activity difficulty index – where a net reduction is sought across all the complexity indices which are being employed.

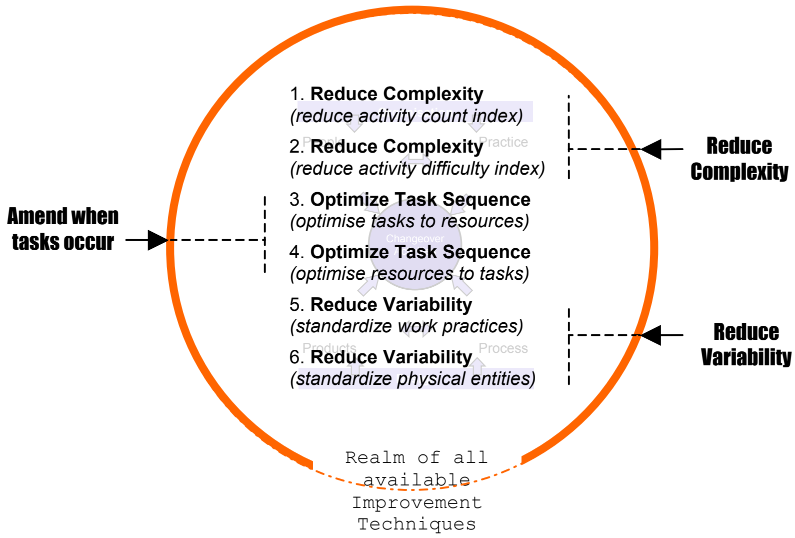

Figure 3. Integrating classifications (part 2): working rules for improvement

Similarly, amending when tasks occur – for which once again any relevant techniques can be used, with either an organization or design emphasis – involves better matching tasks to resources and/or better matching resources to tasks [8]. A design-led opportunity might be to provide specialist jigs and an organization-led opportunity might be to provide additional manpower. It is being sought in either case to optimize the task sequence and thereby reduce production downtime. A particularly potent technique can be that of externalizing tasks.

The final option of variability reduction equally guides improvement by use of any potentially relevant technique, once again with either an organization or a design bias. Variability of work practices relates to what people do. Variability of entities relates to physical hardware entities such as change parts, physical product entities such as surface finish and operational entities such as temperature.

5 Conclusions

Flexibility and responsiveness are watchwords of modern manufacturing, driven by a desire to reduce non-value-added activity and better respond to customer demands. Rapid changeover between products is paramount if genuine manufacturing flexibility and efficiency are to be achieved.

To date the quest for better changeover performance has been substantially guided by the pioneering work of the late Japanese engineer-consultant, Dr Shigeo Shingo. However it is becoming clear that his SMED methodology does not readily embrace all potential improvement opportunities, not least those which are available to an OEM (who in any case will realistically never be involved in retrospective improvement programs for which the methodology is intended).

This paper discusses how suitable elements of disparate classifications employed at the University of Bath during the past 15 years can usefully be combined, obliging a changeover practitioner to consider a full compliment of potential improvement possibilities in a much more structured fashion than hitherto. The proposed framework is applicable to all potential improvement opportunities where, dependent on the specific situation, some will be favored above others. It is applicable across all of a changeover's phases, including the run-up phase, once production has been restarted but has yet to stabilize.

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Museum Visitor Routing Problem with the Balancing of Concurrent Visitors

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Abstract. In the museum visitor routing problem, each visitor has some exhibits of interest. The visiting route requires going through all the locations of the exhibits that he/she wants to visit. Routes need to be scheduled based on certain criteria to avoid congestion and/or prolonged touring time. In this study, museum visitor routing problems (MVRPs) are formulated by mixed integer programming and can be solved as open shop scheduling (OSS) problems. While visitors can be viewed as jobs, exhibits are like machines. Each visitor would view an exhibit for a certain amount of time, which is analogous to the processing time required for each job at a particular machine. The traveling distance from one exhibit to another can be modeled as the setup time at a machine. It is clear that such setup time is sequence dependent which are not considered in OSS problems. Therefore, this kind of routing problem is an extension of OSS problems. Due to the intrinsic complexity of this kind of problems, that is NP-hard, a simulated annealing approach is proposed to solve MVRPs. The computational results show that the proposed approach solves the MVRPS with a reasonable amount of computational time.

Keywords. Museum Visitor Routing Problem, Open Shop Scheduling, Vehicle Routing, Simulated Annealing, Sequence-dependence Setup Times

1 Introduction

Museums provide people a physical environment for leisure sight-seeing and knowledge acquisition. By enhancing museum collection and services, countries all over the world are able to use museums as a core facility to facilitate the elevation of culture, art and tourism industry. Due to the advent of IT and networking technologies, museum services can be strengthened by providing context-aware guidance systems for visitors with different background, interests and/or time constraints.

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In order to establish a prototype tour guide system for the National Palace Museum of Taiwan, a context-aware framework where visitors in different contexts can obtain information customized to their needs is established. Visitors provide their personal data, special needs and constraints to the guidance system. The system in turn extracts suitable information from the structured museum contents for the visitors to utilize during the visit. Such context data are classified by demographic data, preferences and interests such as ages, genders, education, professions, languages, media type preferred, time available, special subject of interest, specific assignment, device used, and the location.

This research implements a route guidance function to automatically provide real-time information to visitors. Routes need to be scheduled based on certain criteria to avoid congestion and/or prolonged touring time. In a museum visitor routing problem, each visitor has some locations to visit; the visiting sequence is not restricted as long as visitors trip all the stations that they want to visit. Visitors are like jobs, display locations are like machines. Each visitor stays at a display in a certain amount of time, which is analogous to the processing time required for each job being processed at a particular machine. This routing problem can therefore be solved as an open shop scheduling (OSS) problem. In an OSS, the processing jobs follow no definite sequence of operations. As long as all the operations needed for a job are done, the processing for the job is considered done. The open shop formulation allows much flexibility in scheduling, but is more difficult to develop rules that give an optimum sequence for the problem.

The objective of the museum visitor routing problem can therefore be modeled as (1) minimizing the makespan, that is minimizing the visiting completion time of the last visitor; (2) minimizing the variation of flow time, that is, each visitor is required to spend as close amount of time in visiting as possible; and (3) minimizing the maximum lateness, that is, if an expected visiting time is pre-determined, the visiting completion time of each visitor is scheduled as close to the expected visiting time as possible. In this study, the objective is to minimize the makespan.

Yet, the visitor's travelling distance between two display locations depends on the physical distance between them, indicating that there exists a sequence-dependent setup time in OSS. In addition, each display has a maximum space where visitors can stay and browse. The museum visitor routing problem is therefore more complicated than the OSS. This study applied the simulated annealing (SA) approach for solving the museum visitor routing problem to find a solution which is a (near) global optimization based on the objective function of the problem.

This research takes into account of the potential congestion problem that may occur with a great number of concurrent visitors having the same set of interests on the exhibits. To provide smoother visiting experiences for the visitors, museums can adopt the concept of concurrent engineering to avoid congestion by recommending different routes for different visitors subject to the total visiting time of all visitors can be minimized. The reminder of this paper includes the following sections. The problem formulation and literature is mentioned in Section 2. Section 3 elaborates the proposed approach. Experimental are made in Section 4. The conclusion is made in the last Section.

2 Problem Formulation and Literature Review

The museum visitor routing problems (MVRPs) are similar to the open shop scheduling problems in industrial engineering. Open job scheduling problems can be defined as follows. There are *m* machines and *n* jobs to be scheduled. Each job has to be processed again on each one of the m machines. However, some of these processing times may be zero. There are no restrictions with regard to the routing of each job through the machine environment. The scheduler is allowed to determine the route for each job, and different jobs may have different routes. The museum visitor routing problems can be stated as follows. There are *m* exhibits to be visited and there are *n* visitors in the museum. Each visitor needs to visit each exhibit once. There are no restrictions with regard to the routing of each visitor through the museum environment. The main difference between museum visitor routing problems and open shop scheduling problem is that the sequence dependent setup time will be incurred because visitor are required to walk some distance between exhibits in museum visitor routing problems. Thus, the different routing has different travelling time (distance). This requirement is not imposed in open shop scheduling problems when job is moved from one machine to another machine. That is, the MVRPs are the extension of open shop scheduling problems.

As usual, let c_{ik} denote the completion time of any visitor on exhibition *k*. In order to simplify the mathematical model, we assume the travelling speed is the same for all visitors. Let t_{ij} denote the visiting time of visitor *i* on exhibition *j*. Let s_{hk} denote the travelling time from for exhibition *h* to exhibition *k* of all visitors, and denote s_{0k} the travelling time of any visitor which is travels to exhibition *k* from the indoor directly. s_{k0} denotes the travelling time of visitor who travels to outdoor from the exhibition *k* directly.

Assuming the objective function of the museum visitor routing problem is to minimize the makespan which is the time beginning of the leaving of indoor until the end of last visitor arrive at the outdoor. It is easy to establish a lower bound for the makespan with *m* exhibitions when non-preemptions are allowed:

$$c_{\max} \geq \max\left(\max_{j\in\{1,\ldots,m\}} \sum_{i=1}^{n} t_{ij}, \max_{i\in\{1,\ldots,n\}} \sum_{j=1}^{m} t_{ij} \right) + \min_{j\in\{1,\ldots,m\}} s_{0j} + \min_{j\in\{1,\ldots,m\}} s_{j0} + \min_{i,j\in\{1,\ldots,m\};i\neq j} s_{ij}(m-1).$$

That is, the makespan is at least as large as the maximum visiting time of each of the *m* exhibitions plus the minimum travelling time and at least as large as the total amount time of visiting plus the minimum travelling time to be done on each of the *n* visitors. Because only the minimum sequence dependent setup times are included, the results obtained can not be better than the lower bound.

For a visitor *i*, if the visit on exhibition *h* precedes that on exhibition *k*, we need the constraint $c_{ik} - t_{ik} - s_{hk} \geq c_{ih}$. Otherwise, the visit on exhibition *k* comes first, then we need the constraint $c_{ih} - t_{ih} - s_{hk} \geq c_{ik}$. An indicator variable a_{ihk} can be defined. $a_{ijk} = 1,$ if visit on exhibition *h* precedes that on exhibition *k* for visitor *i*; otherwise, $a_{ijk} = 0.$ Now we consider the visit un-overlapping constraint for a given exhibition. For two visitors *i* and *j*, both need to visit exhibition *k*. If visitor *i* comes before visitor *j*, we need the following constraint: $c_{jk} - c_{ik} \geq t_{jk}$. If, on the other hand, job *j* comes first, then we need the following constraint $c_{ik} - c_{jk} \geq t_{ik}$. An indicator variable x_{ijk} can be used. $x_{ijk} = 1$, if visitor i precedes visitor j on exhibition k; otherwise, $x_{ijk} = 0$.

The MVRPs with a makespan objective can be formulated as follows:

$$\min \max_{i \leq i \leq n} \{c_{i0}\}$$

$$c_{ik} - t_{ik} - s_{hk} + M(1 \text{-} a_{ihk}) \geq c_{ih}, \; i = 1,2,\ldots,n; h = 1,2,\ldots,m-1; k{=}h{+}1,\ldots,m \quad (1)$$

$$c_{ih} - t_{ih} - s_{kh} + Ma_{ihk} \geq c_{ik}, \; i = 1,2,\ldots,n; h = 1,\ldots,m-1; k = h+1,2,\ldots,m \quad (2)$$

$$c_{jk} - c_{ik} + M(1 \text{-} x_{ijk}) \geq t_{jk}, \; i = 1,2,\ldots,n-1; j = j+1,\ldots,n; \; k = 1,2,\ldots,m \quad (3)$$

$$c_{ik} - c_{jk} + Mx_{ijk} \geq t_{ik}, \; i = 1,2,\ldots,n-1; j = j+1,\ldots,n; \; k = 1,2,\ldots,m \quad (4)$$

$$c_{ik} \geq s_{0k} + t_{ik}, \quad i = 1,2,\ldots.,n; \; k = 1,2,\ldots,m \quad (5)$$

$$c_{i0} \geq c_{ik} + s_{k0}, \quad i = 1,2,\ldots.,n; \; k = 1,2,\ldots,m \quad (6)$$

$$a_{ihk} = (0,1), \quad i,h = 1,2,\ldots,n; k = 1,2,\ldots,m \quad (7)$$

$$x_{ihk} = (0,1), \quad i,h = 1,2,\ldots,n; k = 1,2,\ldots,m \quad (8)$$

The objective is to minimize the makespan, constraint (1) and (2) ensure each visitor can visit on only exhibition at a time. Constraint (3) and (4) ensure that exhibition can be visited only one visitor at a time. Constraint (5) ensures that the traveling distance from indoor any exhibition is included in the model. Constraint (6) ensures that the traveling distance from any exhibition to the outdoor is considered in the model.

Notably, the scale of the problem is primarily determined by the number of constraints. Owing to the complexity of the problem, global optimal solutions are difficult to obtain when the problem size is large. Optimization algorithm such as branch bound algorithm [5][6] reported good quality solutions, but with high cost in time and are limited to smaller-sized problems. Therefore researchers apply polynomially or pseudo-polynomially solvable algorithms for solving for special cases on open shop scheduling without considering the sequence-dependent costs.

For the case where m=2, Gonzalez and Sahni [9] proposed a polynomial time algorithm to solve this problem. A simple rule called "the Longest Alternate Processing Time first" (LAPT) has proven to give optimal schedules [11], also solves this problem in polynomial time. Even though it is shown that for $m \geq 3$, the open shop scheduling problem is NP-complete [9], some open shop problems with special structures are polynomially solvable. For example, Fiala [8] proposed a polynomial time algorithm which solves the problem for arbitrary m, whenever the sum of processing times for one machine is large enough with respect to the maximal processing time. Adiri and Aizikowitz [1] developed a linear time algorithm for the three-machine open shop scheduling problems, provided that there is a machine dominating one of the other two. Algorithms for arbitrary m-machine problems with one or two dominating machines are proposed by Strusevich and summarized in Tanaev et al. [18].

As far as heuristics are concerned, there are only few heuristic procedures for the general m-machine open shop problem published in the literature. Rock and

Schmidt [16] introduced a machine aggregation algorithm based on the result that the two-machine cases are polynomially solvable. Gueret and Prins [10] proposed a simple list scheduling heuristics based on priority dispatching rules. The shifting bottleneck procedure, originally designed for the JSP, has been adapted by Ramudhin and Marier [15] to the OSP. Bräsel et al. [4] proposed efficient constructive insertion algorithms based on an analysis of the structure of a feasible combination of job and machine orders.

Recently, meta-heuristic approaches have been developed to solve the open shop problem, including tabu search (TS) [2][12], genetic algorithm (GA) [7] and simulated annealing [13]. Liao [14] developed a powerful hybrid genetic algorithm (HGA) that incorporates TS as a local improvement procedure into a basic GA. Furthermore, Blum [3] proposed a hybrid ant colony optimization with bean search to open shop scheduling, and obtain better solution in existing benchmark instances. Meta-heuristic approach can obtain (near) optimal solution at the expense of large computing resource. To the best we know, there are seldom literature to deal with museum visitor routing problems which is the extension of OSS with sequence-dependence setup times.

3 The Proposed Approach

Annealing is the process through which slow cooling of metal produces good and low energy state crystallization, whereas fast cooling produces poor crystallization. The optimization procedure of simulated annealing reaching a (near) global minimum mimics the crystallization cooling procedure. For the application of the SA approach to the MVRPs, the solution representation, the neighbourhood, procedure and the parameters used are discussed as follows.

Solution representation: For an *n*-visitors *m*-exhibitions problem, a solution can be represented as a string of $n*m$ entry (p_1, p_2, …, p_{nm}). An entry p_i represents one visit and the value of p_i ranges from 1 to $n*m$. Thus, the solution representation is the permutation of $n*m$ number. The lookup table can be constructed to identify which visit is taken into consideration decoded from the solution representation. For example, if there is a 3-visitor and 4-exhibition museum visitor routing problem, each visit can be coded by a unique index value as shown in Table 1. Given a solution representation, the routes are derived by the following way. The value of entry p_i is used to determine the i^{th} visit. Suppose that the value of entry p_3 is 6, it means that the third visit to be considered is the one that visitor 2 visits the exhibition 2. The value of entry p_7 is 9, it means that the 7^{th} visit to be considered is the one that visitor 3 visits the exhibition 1.

Table 1. Visit encoding example of 3-visitors and 4-exhibitions.

	Exhibition 1	Exhibition 2	Exhibition 3	Exhibition 4
Visitor 1	1	2	3	4
Visitor 2	5	6	7	8
Visitor 3	9	10	11	12

Consider the 3-visitors and 4-exhibitions problem given in Tables 2, 3 and 4. Suppose a solution representation is given as [2 5 11 12 1 4 6 10 8 3 7 9]. Generate the schedule by a one-pass heuristic based on the list. The resulting active visitor routing schedule is shown in Figure 1.

Table 2. Example of 3-visitor and 4-exhibit museum visitor routing problem.

Visiting time	Exhibition 1	Exhibition 2	Exhibition 3	Exhibition 4
Visitor 1	4	5	5	4
Visitor 2	4	5	5	4
Visitor 3	4	5	5	4

Table 3. Travelling time (setup time) required from exhibition *i* to exhibition *j*.

Travelling time	Exhibition 1	Exhibition 2	Exhibition 3	Exhibition 4
Exhibition 1	□	2	1	2
Exhibition 2	2	□	2	2
Exhibition 3	1	2	□	2
Exhibition 4	2	2	2	□

Table 4. The travelling time required from indoor to exhibition and the exhibition to outdoor.

Travelling time (setup time)	Exhibition 1	Exhibition 2	Exhibition 3	Exhibition 4
Travelling time from indoor to exhibition	2	2	1	2
Travelling time from exhibition to outdoor	2	2	1	2

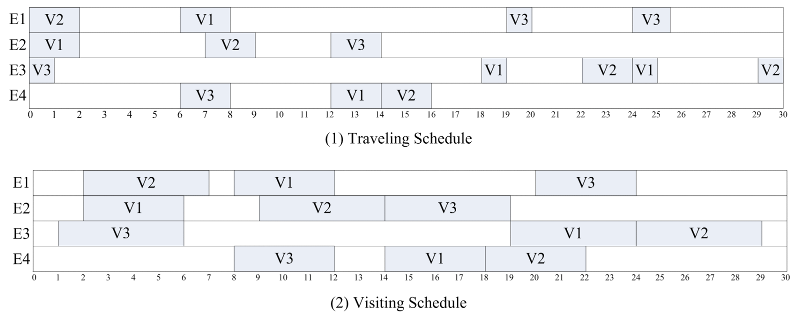

Figure 1. Decode active visitor routing schedule.

Neighbourhood: Neighborhood is sampled either by insertion or swap at random. The insertion is carried out by randomly selecting the i^{th} number of X and inserting it into the position immediately preceding the randomly selected j^{th} number of X. The swap is performed by randomly selecting both the i^{th} and j^{th} number of X, and then swapping the values of these two numbers directly. A 50 percent probability exists of carrying out an insertion, and there is a 50 percent probability exists of carrying out a swap in obtaining the neighbourhood solution of X.

SA procedure and parameter used: In the beginning the current temperature T is set to be the same as T_0. Next, an initial solution X is randomly generated. The current best solution X_{best} is set to be equal to X, and the best objective function value F_{best} is set to be equal to the objective function value of X. For each iteration, the next solution Y is generated from $N(X)$ and its objective function values are evaluated. T is decreased after running I_{iter} iterations from the previous decrease, according to a formula $T \leftarrow \alpha T$, where $0 < \alpha < 1$. Let obj(X) denote the calculation of the objective function value of X, and Δ denote the difference between obj(X) and obj(Y); that is $\Delta = \text{obj}(Y)\text{-obj}(X)$. The probability of replacing

X with Y, where X is the current solution and Y is the next solution, given that $\Delta > 0$, is $\exp(-\Delta / T)$, is accomplished by generating a random number $r \in [0, 1]$ and replacing the solution X with Y if $r < \exp(-\Delta / T)$. Meanwhile, if $\Delta \leq 0$, the probability of replacing X with Y is 1. If the solution X is replaced by Y. If T is lower than T_F, the algorithm is terminated. The X_{best} records the best solution as the algorithm progresses.

4 Computation results

The problem set from Taillard [17] is used to verify the developed approach. This set consists of six different problem types and 10 instances of each problem type, for a total of 60 different problems. However, only 3 instances of each problem type are tested. These problems are all square problem, i.e., n=m, and range form small ones with 16 visits to problem with 400 visits (Taillard observed that open shop problems with n=m are harder to solve than those with n>>m). The problem set from Taillard is originally used in open shop scheduling; therefore, we add the sequence-dependence setup times in problems. The sequence-dependent setup times for problems are generated by the similar way of Taillard's problems set. The setup times are generated uniformly distributed over the interval [1, 5], with $\overline{s} = 3$. The proposed SA approach is implemented in c language and run on a Pentium-IV 2.4 GHz PC with 512 MB Memory. After running a few problems with several combinations of parameters, the parameter values for SA were I_{iter}=m*n*500, T_0=100, T_F=1, α=0.965 where n is the number of visitors and m is the number of exhibitions to be visited. Each problem is solved 10 times. The worst, average, and best objective function value among 10 runs are shown in Table 5.

Table 5. Results for benchmarks.

Problem	Time seed	Time seed	n	m	Lower bound	Worst obj. value	Avg. obj. value	Best obj. value	Avg. running time (s)
4×4_1	1166510396	164000672	4	4	203*	203	203.0	203	1.66
4×4_2	1624514147	1076870026	4	4	247*	247	247.0	247	1.66
4×4_3	1116611914	1729673136	4	4	280*	280	280.0	280	1.66
5×5_1	527556884	1343124817	5	5	313*	315	313.6	313	3.85
5×5_2	1046824493	1973406531	5	5	271*	273	271.7	271	3.85
5×5_3	1165033492	86711717	5	5	342*	347	344.7	342	3.87
7×7_1	1840686215	1827454623	7	7	443	460	456.3	451	14.95
7×7_2	1026771938	1312166461	7	7	451	474	469.2	465	14.86
7×7_3	609471574	670843185	7	7	478	505	500.3	494	14.90
10×10_1	1344106948	1868311537	10	10	648	695	691.1	686	67.88
10×10_2	425990073	1111853152	10	10	599	628	624.5	620	67.96
10×10_3	666128954	1750328066	10	10	609	649	644.0	634	67.83
15×15_1	1561423441	1787167667	15	15	953	1015	1006.3	1000	416.64
15×15_2	204120997	213027331	15	15	934	1019	1011.4	1002	430.53
15×15_3	801158374	1812110433	15	15	887	966	953.6	939	419.80
20×20_1	957638	9237185	20	20	1176	1319	1309.7	1296	1581.62
20×20_2	162587311	1489531109	20	20	1262	1438	1417.4	1404	1583.44
20×20_3	965299017	1054695706	20	20	1278	1392	1388.4	1378	1579.48

*optimal solution obtained by CPLEX.

The lower bound of objective function values are also shown in the Table. It can be found in Table 5, for small-scaled problems (4×4 and 5×5), the solutions obtained by proposed SA approach is same as the optimal solutions obtained by CPLEX. For larger-scaled problems, the range of the solution obtained among 5 times for each problem is smaller, which means the proposed SA approach is stable. Thus, the proposed SA approach is suitable for the MVRPs.

5. Conclusions

In this study, museum visitor routing problems (MVRPs) is formulated as a mixed integer programming**.** While the problem can be formulated as a mixed integer programming problem, solving this problem using mathematical methods is not feasible when problem scale is large. A simulated annealing approach is proposed to solve the MVRPs. The effectiveness of the proposed SA approach is demonstrated in experiments with encouraging results. The SA approach presented in this paper provides an effective method to generate very good solutions to this problem with computer technology that is well within the reach of museum.

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Improving Environmental Performance of Products by Integrating Ecodesign Methods and Tools into a Reference Model for New Product Development

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Abstract. New product development (NPD) is a critical process to improve a company's competitiveness. As environmental impacts generated throughout the product lifecycle are significantly determined during the early phase of its development, NPD plays a crucial role in enhancing the environmental performance of new products. Ecodesign may be defined as the systematic introduction of environmental concerns during product development. Despite the fact that several opportunities for competitive advantage have been associated to ecodesign the implementation of this concept has not reached companies worldwide mainly due to the gap between eco-oriented and product-oriented research. Thus both points of view must come together in order to achieve ecodesign benefits. This paper aims at proposing a systematic approach to do it by introducing some selected ecodesign methods and tools into the early phases of a reference model for NPD. The expected result is a set of structured activities that can successfully combine ecological and business perspectives. This paper presents some preliminary results on the field of sustainable product development (SPD) conducted by the authors.

Keywords. New product development, reference model, ecodesign.

1 Introduction

The increasing consumption of products is at the origin of most pollution and depletion of resources caused by our society [10]. Environmental impacts observed throughout a product lifecycle are, to a large extent, determined during its development phase [9]. Hence, taking environmental aspects into consideration during the new product development (NPD) phase can play an essential role in the reduction of environmental impacts related to product lifecycle. Ecodesign can be

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defined as the systematic introduction of environmental concerns into NPD through the application of specific methods and tools. Despite the fact that the number of available methods and tools has increased in the last decade, ecodesign has not been implemented by companies worldwide mainly due to the gap between eco-oriented and product-oriented researchers [2, 12]. Eco-oriented researchers fail to see NPD as a business process crucial to competitiveness, which leads to partial or poor integration of ecodesign methods and tools into NPD, failing to generate the expected ecodesign competitive advantages [1, 11]. On the other hand, product-oriented researchers pay too little attention to environmental aspects, focusing on legal compliance and 'end-of-pipe' solutions due to little knowledge of ecodesign methods. This gap generates a lack of systematic use of ecodesign methods and tools in NPD, contributing to low levels of environmental performance. The goal of this paper is to propose a systematic approach to bridge the aforementioned gap, through the introduction of ecodesign methods and tools into the early phases of a reference model for NPD, as a way to structure activities in a business process. The ecodesign methods to be integrated have been selected through literature review using a structured classification method. The reference model, used as the integration baseline, resulted from experiences accumulated since 1990. The expected result is a set of structured NPD-oriented activities that can successfully combine environmental and business perspectives to help companies worldwide to achieve sustainability by making new and "green" products that are also successful in the market. This paper presents some preliminary results conducted by the authors.

2 Literature Review

2.1 New Product Development and Ecodesign

According to [21] new product development (NPD) is "The overall process of strategy, organization, concept generation, product and marketing plan creation and evaluation, and commercialization of a new product". It is also frequently referred to as just "product development." Clark and Fujimoto [7] state that "Product development process is the resulting process when market information is transformed into information and necessary sources to manufacture a product with the aim of commercializing it." For Pugh [23], "Product development process is the necessary systematic activity from the identification of the market/customer needs until the product sale, an activity that includes product, processes, people and organization". It is not a new notion that product development has become one of the key processes for competitiveness in manufacturing. One of the well-known factors of product development is that the degree of uncertainty in the beginning of the process is very high, decreasing over time. The decisions in the beginning of the development cycle are responsible for 70% of the cost of the final product [3]. As regards environmental impacts related to products, if environmental requirements are taken into account at the beginning of the development phase environment impacts may be reduced by an estimated 70% [9]. Hence, taking environmental aspects into consideration during the new product development (NPD) phase plays an essential role in reducing environmental impacts related to the product lifecycle.

Ecodesign (Europe) or Design for Environment (US) implies a new way of developing products where environmental aspects are given the same status as functionality, durability, costs, time-to-market, aesthetics, ergonomics and quality. Ecodesign aims at improving the product's environmental performance and may be seen as a way of developing products in accordance with the sustainable development concept [4,6,13,16,28].

Baumann et al [1] identify more than 150 existing ecodesign methods and tools to implement what they call Environmental Product Development (EPD). In the ecodesign research field the terms "tool" and "methods" are often interchangeable. In this paper we selected four methods/tools: Life Cycle Assessment (LCA), Quality Function Deployment for Environment (QFDE), The Ten Golden Rules and Environment Effect Analysis (EEA). Those methods and tools were selected because there is more available information about them, addressing definitions and usage, as compared to other methods. LCA assesses environmental aspects and potential impacts associated with a product by compiling, evaluating and interpreting an inventory of relevant inputs and outputs. In reality, LCA constitutes a class of methods, since there is no single method for conducting LCAs [8,17]. QFDE analyzes functions required for a product or its structure to promote these functions, helping design engineers to select the best plan among design improvement alternatives while concurrently meeting consumers' needs [21, 26]. The Ten Golden Rules are a summary of guidelines gathered from the company's guidelines and in different handbooks [5,19]. EEA systematically identifies and evaluates potential environmental impacts in all product lifecycle phases, by assessing each activity in the product lifecycle. EEA should be carried out together with Design-FMEAs [18]. Table 1 shows the systematization of methods/tools according to input and output data.

However, in order to ensure concrete results with the selected methods and tools, it is necessary—as a preliminary measure—to introduce the topic of sustainability into the company's business core. Porter [22] indicates that the environmental aspects should be integrated with the company's strategic and operational activities, should be specific to each company and be seen as source of opportunity, innovation and competitive advantage. To put in practice this win-win principle, companies have to identify the intersection aspects between environmental impacts of the product lifecycle and stakeholders' demands; to define the environmental aspects to be dealt with and to incorporate the environmental dimension and goals into the company's strategy. In agreement with IISD [14] the following seven steps are required to manage enterprises according to sustainable development principles: (1) Perform a stakeholder analysis; (2) Set sustainable development policies and objectives; (3) Design and carry out an implementation plan; (4) Develop a supportive corporate culture; (5) Develop measures and standards of performance; (6) Prepare reports; and (7) Enhance internal monitoring processes. This may be a prerequisite task to all NPD-related activities. Baumann's organizational tools are also suitable for this propose [1].

Table 1. Methods/tools input and output data

Methods/Tools	Input Data		Output Data	
	Description	Nature	Description	Nature
Life Cycle Assessment (LCA)	Used materials and energy	Qualitative and Quantitative	Analysis of contribution of lifecycle stages	Qualitative and Quantitative
	Lifecycle inventory		Exposure of up- and downstream impacts	
	Product characterization		Ideas to reduce environmental impact	
QFDE	Customers' voice	Semi-Quantitative	Important attributes and function units	Semi-Quantitative
	Engineering metrics		Possibility of design improvements	
	Product requirements			
	Energy			
	Chemicals used			
	Energy Use			
	Solid Residues			
	Liquid Residues			
	Gaseous Residues			
The Ten Golden Rules	Product concept	Qualitative	Product evaluation	Qualitative
Environment Effect Analysis (EEA)	Earlier LCA	Qualitative	Identification of the LCA focus of specific areas	Qualitative
	Environmental function requirements			
	Legal and other external requirements		Verification of legal compliances	
	QFD for customers demand		EEA on detailed design	
	Internal objectives and targets		Design requirements	

3 Integrating ecodesign methods and tools into a reference model for NPD

When systematizing a NPD for a company, a pattern should be established to define projects for the development of products, thus contributing to the standardization of some practices, use of a common language, repeatability among projects and quality. The NPD process used as a reference to define the scope of product development projects is normally represented by a reference model, also known as standard process [25]. The reference model presented in this work was created through a joint project of three research institutions based on a community of practice [24] on the Internet, created to promote knowledge sharing about product development among universities and companies. Standard processes have been derived from this model for some companies, which helped the researchers to improve it [25]. A general view of the reference model, divided into macro-phases, is presented in Figure 1.

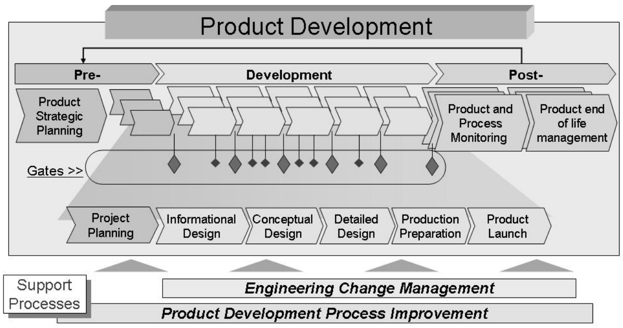

Figure 1. The reference model for product development [25]

The product strategic planning phase includes product portfolio management in accordance with the business strategic plan, taking into consideration market and technological innovations. This phase deals with the whole product portfolio whereas the following phases are related to a specific product, i.e., a sole project. During the project planning phase, the project scope, resources, people in charge, effort, duration and costs are defined. PMBOK best practices are considered during this phase. If the project plan is approved by means of a formal gate process [27], the project begins and will come to an end at the product launch phase. The product lifecycle, the stakeholders and their requirements are determined at the informational design phase. The product requirements, which must be quantified in measurable variables with target values, derive from the stakeholders' requirements. This is not the first time the requirements have been defined, since their definition begins in product strategic planning, when marketing supplies information about the market, which is now detailed in the informational design for a specific product. The product functions (physical, quality, interface, etc.) are established in the conceptual design phase so as to meet the product requirements. Technological solutions and product architecture are also determined at this point. Creativity methods may be applied in this phase. Innovations may emerge based on new technologies developed by the R&D process (complemented by NPD). Nevertheless, not all of the projects go through the conceptual design phase, as product architecture does not usually change into derivative projects. The next phase is the detailed design, which consists of three integrated cycles: detailing, acquiring and improving cycles. Calculations, simulations, product modeling, drafting, bill of materials, process plans, failure analyses, prototypes, evaluations and tests are carried out in this phase. All the manufacturing resources are specified—even a new factory when necessary. Product handbooks and instructions for technical assistance are also produced, as well as sales support information systems. The supply chain is defined at the beginning of the product development process, when arrangements are made with main strategic partners and co-developers. The last supplier contracts must be signed at the detailed design phase. Based on prototypes, the product is then certified. In the next phase—production preparation— additional equipment defined as necessary in the previous phase is installed and tested. A pilot production process is run to certify the production facilities and products being manufactured with the definitive resources, since during the detailed phase prototypes might, for instance, be built with non mass production equipment. In this phase, a new production business process (or even the whole supply chain process, including logistics) can be mapped out and established in order to define, for instance, whether production should be controlled by means of orders or Kanban. The product launch phase takes place in parallel to production preparation. Other business processes are mapped out in this phase, such as technical assistance and customer service, when, for instance, a new help desk script for the new product must be created. In short, production preparation aims at defining the supply chain from an internal standpoint and the product launch phase from an external standpoint (market and customers). After the product is launched, production and sales business processes become the responsibility of other areas of the company. Then the project phase (development macro-phase—see the Figure 1) is concluded, the team is disbanded, and its members are assigned to other projects or return to their original functional areas. Nevertheless, product life cycle management continues, since efforts must now focus on monitoring the product and its manufacturing process. Ongoing customer support and engineering change management (ECM) must be provided to eliminate failures or improve product performance. At this time, configuration management ensures product information integrity throughout the product lifecycle. ECM manages product changes, whereas other supporting processes carry out improvements in NPD. At the end of its lifecycle, the product is discontinued and could be reused, remanufactured, recycled, disposed of according to the end-of-life (EOL) plan, which is usually developed during the development macro-phase.

This brief description of the process provides only a functional overview of NPD, since only chief activities have been mentioned. Other complementary views have not been addressed here.

The proposed integration focuses on the Strategic Product Planning, Informational Design, Conceptual Design and Detailed Design phases. This is due to the fact that the entire product life cycle environmental impacts are, to a large extend determined during these phases. Table 2 shows the tools/methods selected by the NPD reference model phases in which their use is suggested.

Each phase of the model presented in this paper comprises several activities. Thus, one has should explore the influences of the suggested ecodesign methods and tools on these activities in order to make ecodesign come about. This can be done by developing templates in which the usage of one method or tool is described. The process of selecting ecodesign methods and tools and deciding at which NPD phase they should be used has to be carried out by the design team members, who in turn should take into account the dynamics of their activities and their ecodesign maturity level. This selection may be assisted by a specialist.

Table 2. Integration of ecodesign methods and tools into NPD reference model

Phases	Methods/Tools
Strategic Product Planning	Porter's guidelines, the seven steps for managing an enterprise according to sustainable development principles and Baumann's organizing tools
Informational Design	The Ten Golden Rules, QFDE (Phase I), LCA
Conceptual Design	QFDE (Phase II and III), EEA, LCA
Detailed Design	QFDE (Phase IV), LCA

The use of selected methods and tool depends mainly on the stage of the product development process, i.e., how detailed the available information is. Time and cost may be reduced and a more environment-friendly product may be produced if ecodesign methods and tools are used early in the design process. Since ecodesign factors of success are, to a large extend, similar to NPD factors of success [15], the task of integrating the ecodesign concept as a whole will be easier to those companies that have high NPD maturity levels.

4 Conclusion

NPD plays an important role in reducing the environment impacts of a product lifecycle. The use of a reference model for NPD may contribute to the standardization of some practices, the use of a common language, the repeatability of projects and to its quality, thus increasing the probability of making successful products by means of structuring this business process. Despite the existence of many ecodesign methods and tools, a systematic way to use them in NPD is lacking. Introducing ecodesign methods and tools into designers' daily activities through a reference model for NPD may bridge this gap. The task of selecting ecodesign methods and tools and deciding at which NPD phase they should be used is something companies have to perform internally. However, in order to ensure concrete results with the implementation of ecodesign methods and tools, it is also necessary to introduce the topic of sustainability into the company's business core as a preliminary measure. The proposed integration is a set of NPD-oriented structured activities that can successfully combine environmental and business perspectives.

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Sustainable Packaging Design Model

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Abstract. For many consumer products the packaging is as important as the product itself. This means that one does not exist without the other. The product development process, in this in case, is only complete when the packaging is also developed. This work aims to consider an integrated Sustainable Packaging Design Model(SPkDM) .Therefore, in view of the imperious necessity and concurrence of PDP (Product Development Process) and PkDP (Packaging Development Process) and its interdependence and the resulted solutions, a model that also integrates the environmental aspects was established upon their initial phases. The strategies of eco-design and tools must be incorporated in each phase of the development process, as well as the assessment of the impacts, before going to the next phase.. They also provide the designers with data that will enable them to refine the packaging and the product. The model will instrument the packaging designers of the companies, guaranteeing that the process has a better ecological efficiency. The regular use of the model will bring as benefits time, cost and environmental impact reductions of the packaging.

Keywords. Concurrent engineering, Product Development, Packaging development, Ecodesign, SPkDM.

1 Introduction

The packaging development process is an activity becoming more important every day in the economic context. It has its coverage and direct relation with practically all the productive sectors. The packaging industry has a structural role in the capitalist society. Through packaging millions of people in the whole world have access to all types of consumer products. For the consumer, the packaging represents the symbol of the modern world, the consumerism, the practicality, the

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convenience, the comfort, the facility to conserve food and the desire of ownership [1].

Being also a product, packaging generates environmental impacts throughout its life cycle. Packaging developing has become a great challenging task and of enormous responsibility for the companies and the professionals involved. The reality has shown that most of the companies have their product development process totally independent from the PkP. As a result, they face losses in competitiveness, costs increases, and longer lead time. In addition, it also brings an unfavorable environmental performance for both the product and the packaging.

Currently, the companies have focused their concerns in the environmental performance of the products. Thus, both product and packaging development have become of great importance, since their environmental performance is determined mainly during the PDP. The PDP is the key to develop environmental friendly products. Ecodesign is a proposal that incorporates environmental aspects in the traditional product development process, also known as Design for Environment (DfE) [5]. It incorporates a systematic examination, during the PDP, of the aspects related to the environment protection and to the health of the human being. This systematic examination is performed throughout all the phases of the life cycle process of the product. It allows that the development team includes the environmental considerations since the initial phases and during the development, taking also into account the traditional aspects as function, production costs, aesthetic, ergonomics, etc. However “Charter and Tischner” [5] also consider the sustainability in the product development. The development of sustainable products for them is more than just ecodesign, since there is also a concern in balancing economic, social and environmental aspects in the PDP.

The objective of this article is to propose a Sustainable Packaging Design Model (SPkDM), integrating Product Development Process (PDP) and Packaging Development Process (PkDP) as well as the environmental aspects since the initial phases of the process.

2 Packaging

The packaging throughout its history has represented an important tool for the trade development and the growth of the cities. It guarantees that the product reaches the final consumer in safe conditions and quality. It can be defined as an industrial and marketing technique to contain, to protect, to identify and to facilitate sales and distribution of consumption, industrial and agriculture products [15]. “Saghir” [17] defines packaging as a coordinated system of preparation of goods for safety, efficiency and effective handling, transportation, distribution, storage, retail, consumption and recovery, reuses or disposal combined with the maximum value to the consumer, sales and consequent profit.

2.4 Product and Packaging Development Process

2.4.1 Product Development Process (PDP)

PDP involves a flow of activities and information. According to "Rozenfeld *et al*" [16] it allows to understand the critical relations between areas of the company, PDP, market, suppliers, technological information and institutions of product regulations. Thus, PDP has its relation with internal and external processes of the company.

There is a vast literature in terms of product development process models like Back [2], Ulrich&Eppinger ,[19], Pahl[11], Rozenfeld *et al* [16]. However these models do not consider packaging, and when there is a reference, it is very limited. In the case of "Rozenfeld *et al*" [16], they only make reference to it at the detailed phase of the project.

Another important aspect to be considered is that these models do not incorporate environmental issues since the initial phases of the design, but just as end of pipe solutions.

2.4.2 Packaging Development Process

The existing models for the packaging development process available in the current literature are limited and scarce and do not include environmental issues since the initial phases of the design.

It was also noted that the existing processes are related to more specific areas for example, food product development like Fuller [7]; Brody and Lord, [4]. There are not much authors with publication in the area of packaging development process which can be cited like Griffin [8]; Paine [12]; Romano [13]; DeMaria [6]; and ten Klooster [18].

Bramklev[3]model's however integrates product and packaging but environmental issues are not considered, therefore this model is not complete for the demands of eco efficient products.

3. Sustainable Packaging Design Model

A Sustainable Packaging Design (SPkD) model was developed, having in mind the relevant necessity and simultaneity of Product Development Process (PDP) and Packaging Development Process (PkDP). It also includes environmental aspects since the initial phases. It is based upon "Rozenfeld *et al*" [16] an updated and generic model. It is integrated with the product and the ecodesign strategies and tools are incorporated in each phase of the development process. The mentioned model is shown on Figure 1.

The interdependency of each one, the product and the packaging processes, will be represented by arrows. Each phase of the model will be described in a generic form. It performs the macro phases of Pre-Development, Development and Post-Development. It includes the various phases of the Packaging Strategic Planning(macro phase of pre-development), Packaging Planning, Concept Design, Detail Design, Proving Functionality, Packaging Launch and Packaging Review (macro phase of post-development).

3.1 Pre-Development – Product and Packaging Strategic Planning Integration

The macro-phase of Pre-Development integrates the Product and Packaging Strategic Planning. It involves the company's planning and business goals related to products and packaging. Almost all the company's sections contribute with these activities, but especially areas involved with Product, Packaging and Environment.

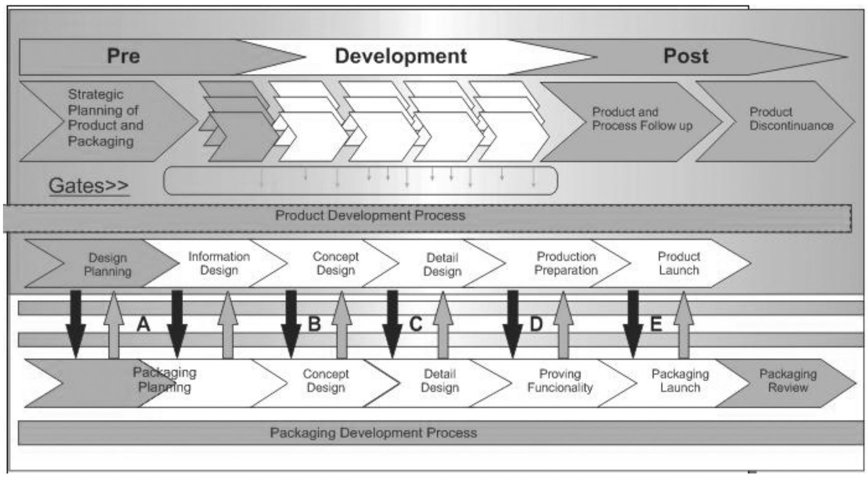

Figure 1 - Sustainable Packaging Development Process (SPkDP)
Note – Process Integration – Black arrows = product and Bordeaux arrows = packaging

Projects to be developed are then prioritized based upon technological, market, product's and packaging's environmental trends information, besides the establishment of environmental and strategic goals. For this, the company utilizes Market Research Information, Competitive Intelligence, Product and Packaging Life Cycle Assessment (LCA) of the competitors and similar products and finally, also, Environmental Impact Information of different materials and processes.

3.2 Packaging Planning

Packaging Planning integrates the macro-phase of Pre-development (Design Planning) – **Stage 1** and the macro phase of Product Development (Informational Design) – **Stage 2**.

3.2.1 Stage 1 – Product and Packaging Planning Integration
This part of the packaging planning phase integrates the Product and Packaging design planning. At the end of all the activities of this phase, the Project Plan is generated and it will be common for the two areas product and packaging.

The design team is composed of people from cross-functional areas. The members of the team, considered core members, are representatives of Product, production, Quality, Supply Chain (SC), Logistics, Packaging, Environmental Management areas, etc. There will be two teams, working in parallel – product and packaging. These two will interact when necessary, as established on the project timeline. For an environmental friendly packaging development the packaging team will have to have a strong interaction with Logistics, Supply Chain and Environmental areas. In addition, there will be exchange of information and participation of external members like packaging and raw material and packaging equipment suppliers.

In this part of the phase the project scope is also worked out in detail. It's a common guideline document for both PD and PkD. Furthermore, Stage 1 of this phase includes situational analysis, task description, establishment of responsibilities and timeline preparation. Also cost indicators, necessary resources, critical success factors and establishment of performance indicators and financial feasibility of the project cannot be ignored.

3.2.2. Stage 2 – Integration of Informational Product Design and Packaging Planning

Stage 2 of this phase has as its purpose, upon collection of information arising from different sources, to establish target-specifications of the product-packaging system. It is necessary the collection of technical and economical information and also information related to components, to the materials and to the partners and suppliers capabilities. These capabilities relate to financial, technical, quality issues, besides environmental performance. Benchmarking analysis is carried out using technical and environmental information's of a base line product-packaging, showing weakness and opportunity for improvement. Important environmental data sources are: LCA, purchase records, monitory reports, quality assurance, reports, records, publicity records *etc*.[9].

This stage also searches information, describing where the product-packaging system goes through and identifying clients and their necessities. The client requirements are obtained through the client's necessities, classifying, arranging and grouping according to the phases of the corresponding life cycle.

Furthermore this phase also includes the planning and the formulation of the product/ packaging requirements and the environmental requirements for both, taking always into consideration the timeline of the design and available budget. In the SPkD integrated model the QFD (Quality Function Development) methodology, for example, will be used as an integrated form for establishment of the target-specifications of the product-packaging system, in this case helping a better understanding of what the product-packaging system needs in order to fulfil the necessities of the consumer and also to beat the competition [14].

3.3 Conceptual Product Design Integration with Conceptual Packaging Design

In this phase the design team looks for, creates and presents solutions for the product-packaging system guided by the target-specifications of the project with environmental focus, considering environmental issues during the life cycle. By looking for solutions, the team will have to give attention to marketing and logistics requirements and adopt DfE and DFX (Design for X) where X may be any of a number of design attributes to get efficiency, improvement of materials and energy, careful soil use and cleaner production. Packaging alternatives or generated concepts must be analyzed and combined with product alternatives and concepts, evaluating them together in order to generate the concepts of the product-packaging system.

The concept that best fits the target-specification, consumer expectations, costs, technical and environmental criteria, will have to be chosen.

3.4 Detailed Product Design Integration with Detailed Packaging Design

In this phase various decisions are made like materials to be used, shapes and colours. These all cause substantial influence to the flow cycle of materials and production processes which are used. Concepts are developed to comply with the product-packaging design specification and to detail the product-packaging system, before production or introduction for use. In this phase most of the activities run simultaneously for both product and packaging. It is essential to use DfX (Design for X) considerations, including DfE (design for Environmental) ecodesign tools like strategies, matrixes, catalogues, checklists as well as LCA.

It is also very important that the Design team works close together in order to specify thoroughly the product- packaging system, sharing information and characteristics or properties of both systems in order to assure the design success.

In order to determine the primary packaging several tests are necessary. In a sequence, all levels of packaging are detailed.

3.5 Integration of the Preparation of the Product and Packaging Functionality Tests

The purpose of this phase is to assure that the company is able to produce the volume established in the project scope, complying with the client's requirements during the life cycle of the product-packaging system.

The evaluation and assay of a pilot lot of the product-packaging system will improve the detailing of the project, indicating necessary adjustments of the process conditions, and sometimes even change of suppliers. LCA revision can also be performed in this phase.

3.6 Integration between the Product Launching Phase and the Packaging Launching

The launching phase covers the activities of the logistics chain in delivering the product to the market, involving the sales and distribution processes, customer's service, technical assistance and marketing campaign. It encompasses the planning, production and packing of the product and delivery to the sales point. In order for the product launching date to perform as planned in the project time line the various activities related to the manufacturing of the product, packing and distribution will have to be properly coordinated to assure that the product reaches the sales point during the advertise period and sales promotions. This phase also includes the presentation of the information regarding the characteristics and benefits of the product and its packaging, stimulating customers to look for and to buy the product. The sales catalogue must mention information and benefits of the environmental packaging. It will help to attenuate the environmental impacts during the use and disposal phases of the product and packaging. Environmental information and communication (Environmental Labelling) can be propagated in different forms: at the sales point, on the packaging label, on the Web, on the company's customer service and on other media channels.

The company can also supply collectors for the disposal of the packaging after its use at the sales point, stimulating its recycling.

3.7 Packaging Review and its Development Process and Integration with the Phases of Follow-up and Discontinuing Products

This phase is part of the macro-phase of post-development which integrates two phases of the product project – Follow-up and Discontinuing Product.

3.7.1 Packaging Review and its Development Process and Integration with Product and Process Follow-up Phase

It is extremely important that the company reviews the packaging and its development process six months after launching it [6]. This review must encompass consumer's satisfaction, product functionability, manufacturing records, packaging, waste indicators, worker's health records, energy and water consumption, and environmental impacts.

3.7.2 Packaging Review and its Development Process and Integration with the Product Discontinuing Phase

The discontinuing of an item of the company's Product Portfolio takes place when it shows no more benefits or even importance. The final packaging use or its disposal, having a different life cycle in relation to the product, starts with the use of the product. In this case the packaging is disposed and then sent for the recycling process or to the land fields or to collecting points. It may also be returned to the manufacturer.

In reality, the correct destination of the disposed packaging depends on local authorities and laws applicable in every country, besides the people's education and awareness. This creates then an adequate structure of shared responsibilities of all interested parties. These lead to a gradual expansion of the production and consumption of products and packaging with less environmental impact.

Conclusion

The SPkD model presented complies with the current demand of competitiveness and eco-efficiency, besides fulfilling an important gap in the literature for product developments.

This model will contribute with a greater integration of knowledge within the companies as well as with the partnership commitment among different companies.

It will instrument designers and packaging developers with a complete SPkDM, including the environmental variables in all the phases, assuring a more consistent and sustainable environmental efficiency. By integrating PDP and PkDP and also including the environmental variable, since the beginning of the project there will definitely be quality gain and cost reduction, besides shorter development lead time and great benefits as a consequence of the reduction of the environmental impacts.

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Information Modelling For Innovation And Sustainability

Environmental Regulations Impose New Product Lifecycle Information Requirements

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Abstract. In a global response to increasing health and environmental concerns, there has been a trend towards governments enacting legislation to encourage sustainable manufacturing where industry creates products that minimize environmental impact. This legislative trend seeks to shift the environmental responsibility of product manufacturing to the finished goods manufacturer. To meet this new responsibility, data relevant to the material composition of a product must flow unimpeded from the raw material producers to the final producers. Unfortunately, existing systems are ill-prepared to handle the new data requirements. For example, the European Union's (EU) Energy Using Product (EuP) Directive will require that companies provide total energy used during a product's lifecycle, including manufacturing and transportation energy. To meet these new requirements, new systems must be designed and implemented, or modifications made to existing data management systems. Because every law poses its own unique requirements on industry, it is not always clear what information will need to be collected and stored. This paper seeks to provide industry with a forward-looking view at new data exchange requirements needed within the manufacturing supply chain of the future. It surveys current and forthcoming environmental legislation including EU Restriction of Hazardous Substances (RoHS), China RoHS, California RoHS, EU EuP, and the EU Registration, Evaluation and Authorization of Chemicals Directive (REACH). The paper identifies the unique data requirements that will need to be incorporated in a products supply chain in order for companies to comply with each law.

Keywords. RoHS, EuP, sustainability, product, lifecycle, supply-chain

1 Introduction

Many governments, corporations, and other regulating political bodies are seeking to address health and environmental problems through initiatives and laws.

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The prevailing idea is that legislation can be used to encourage "sustainable manufacturing" (i.e., requiring that industry create products with minimal negative health and environmental impacts). One example of this policy trend is the emergence of Extended Producer Responsibility (EPR) Directives in the European Union in the early 1990s (known in the US as Product Stewardship). These directives seek to shift the environmental responsibility of product manufacturing to the finished goods manufacturer. Encouraging manufacturers to eliminate toxic materials from a product's design is an excellent way to keep those materials from ultimately being released into the environment. Still, regardless of the origin or benefits of these new laws, the laws will certainly have a substantial impact on current manufacturing practices. Adaptation will require new materials, modified manufacturing processes, and new information systems.

This article surveys and discusses several current and forthcoming environmental laws that fall into two broad categories: Restrictive/Toxic Substances and Energy Efficiency. Within these laws and directives, the survey identifies each law's unique data requirement that will need to be incorporated in a product's supply chain in order for companies to comply with the given legislation. As such, this paper seeks to provide industry with a forward-looking view of upcoming requirements.

2 Restrictive / Toxic Substance Legislation

Restrictive / Toxic Substance Legislation focuses on banning certain known hazardous materials from the manufacturing process. While many countries are currently evaluating and developing such laws, there are four specific laws that will likely have wide ranging implications for industry.

2.1 European Restriction of Hazardous Substances (RoHS)

The European Union's Directive 2002/95/EC on the restriction of the use of certain hazardous substances in electrical and electronic equipment is the most famous of the new type of toxic substance legislation. The directive bans various substances (such as heavy metals) from being incorporated into electronic devices. In essence, the directive seeks to shift the responsibility for a product's environmental impact back to the manufacturer of the product. The directive, which went into effect July 1, 2006, has left the electronics industry scrambling to develop substitute materials [1] and new data exchange mechanisms in order to ensure compliance.

2.1.1 Key Elements of EU RoHS

The directive has several key elements that directly impact any company importing electronic products into the EU [2]:

- It bans the use of lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenl ethers (PBDE) in products above a maximum concentration value (MCV).
  - Anything that can be identified as a homogenous material within the product must meet the MCV limits.
  - It maintains the right to ban or restrict future toxic or hazardous substances.
  - The EU RoHS directive is very broad in scope (8 product categories), but excludes specific items through the use of exemptions.
  - Defines "electrical and electronic equipment" as being dependent on electric currents or electromagnetic fields in order to work.
  - Enforcement implementations are left up to the EU member countries.

2.1.2 Unique Data Requirements

Compliance with RoHS is the responsibility of the company that seeks to market the product within the EU. There is no detailed declaration requirement, simply a yes/no declaration of compliance by the manufacturer. However, since the six banned substances are tracked at the homogeneous level, it is now the responsibility of the final product producer to track those six substances through the supply chain from raw materials to the final product. The final product producer needs to ensure that their products do not exceed the MCVs[3] listed in Table 1.

Table 1. EU RoHS Allowable MCVs

Restricted Substance:	**Allowable Concentration:**
lead, mercury, hexavalent chromium	0.1 % by weight in homogeneous materials
Cadmium	0.01 % by weight in homogeneous materials
polybrominated biphenyls or polybrominated diphenyl ethers	0.1 % by weight in homogeneous materials

2.2 Administrative Measure on the Control of Pollution Caused by Electronic Information Products (China RoHS)

This proposed law is very similar to the European Union's RoHS. So much so, in fact, that it is commonly referred to as China RoHS by industry. Unfortunately, while both pieces of legislation target the same set of six substances [4], there are substantial differences between the two that could pose problems for industry.

2.2.1 Key Elements of China RoHS

The directive has several key elements that are very similar to EU's RoHS:

- It bans the same six hazardous substances (lead, mercury, cadmium, hexavalent chromium, PBB's, PBDE's) in products with specified MCVs.
  - It maintains the right to ban or restrict future toxic or hazardous substances.

However, beyond the six restricted substances and their MCVs, there are differences between the two sets of legislation in both their scope and how they are to be implemented.

- Rather than broad product categories, China's RoHS specifically lists which items are included in the legislation; no product exemptions are needed. A product catalog will be revised yearly to add additional products.
- China RoHS has a new requirement that compliant products must be properly labeled to indicate the presence of the restricted substances (as measured above the MCV at the homogenous material level).
- China RoHS, in a future phase of the law, will require that products be tested for compliance by a certified Chinese testing laboratory (or possibly some certified external laboratory).
- The new law defines a new "environmentally-friendly use period" for a product which indicates the stable shelf life of a product.
- China RoHS requires manufacturers to list on their packaging the substances contained within the packaging.
- In certain instances, China RoHS establishes different criteria for evaluating the MCVs.

2.2.2 Unique Data Requirements

Several new unique data elements stand out in the China RoHS legislation: "environmentally-friendly use period", an alternate way to calculate the maximum permitted substance concentration basis, product catalogue information, and compliance testing data. The new use-period requirement identifies the period during which toxic and hazardous substances contained within the electronic information product will not leak out or mutate. It is still undecided which substances qualify for this requirement or how the use period will be determined, but the requirement will be put in place. China RoHS also allows for reporting on the basis of the mass proportion of the entire device for devices smaller than 4mm3 (the approximate size of a surface mount transistor). This will lead to differences in reporting mechanisms for the EU and China legislations; a product could pass one but fail the other based on size. With the product catalogue subject to yearly modifications, it will be important to keep a link between the product and a specific version of the catalogue. Finally, with the products being tested for compliance it will be important to propagate the test results throughout the supply chain.

2.3 California Electronic Waste Recycling Act of 2003 (SB20/50) (California RoHS)

The California law also seeks to limit the levels of hazardous materials that appear in some electronic devices. This law is in fact so closely linked to the EU's RoHS that it seeks to prohibit an electronic device from being sold or offered for sale in California if it is also currently prohibited from being sold in the EU due to Directive 2002/95/EC. However, as the California RoHS was implemented by two sets of emergency legislation in late December 2006[5], there are noticeable differences between the pieces of legislation. Specifically, California RoHS targets fewer restricted substances and focuses on a smaller set of covered electrical devices (CED)[6].

2.3.1 Key Elements of California RoHS

- California RoHS bans only the four heavy metal substances (lead, mercury, cadmium, hexavalent chromium) and establishes an allowable MCV (Harmonized to match the MCV values in EU's RoHS).
- The law covers only CED which are enumerated in Public Resources Code section 42463 as video display devices beyond a certain size. More specifically, in 2005 eight broad categories of displays were established by the California Department of Toxic Substances Control (DTSC).
- The second legislation added portable DVD players to the list of CEDs.
- The law targets only retail products, not business to business products.
- California RoHS allows exemptions for some classes of products.

2.3.2 Unique Data Requirements

As California RoHS is clearly a subset of the EU's RoHS legislation, it contains little in the way of unique data requirements. Since the MCV values are the same, the only unique data that will need to flow through the supply chain are California-specific exemptions.

2.4 Registration, Evaluation and Authorization of Chemicals Directive *(REACH)*

REACH is a new proposed regulatory framework for the EU Chemical Industry created by the European Commission in 2003 [6]. Its stated goal is to provide a mechanism to protect human health and the environment, while maintaining the EU's Chemical Industries competitiveness and innovation. It seeks to replace the existing patchwork of laws currently in place with a single, EU-wide framework. Working on the assumption that industry is best positioned to know the properties of the substances used during the manufacturing process, REACH seeks to shift responsibility to industry to manage risks from chemicals and to provide safety information to downstream users. It requires that all substances identified as persistent, bio-accumulative, or toxic (PBT) be registered prior to being sold in the EU. The registration process itself would require producers / importers to create a dossier which would include a chemical data sheet (CDS) that covers safety information throughout the product's entire supply chain.

2.4.1 Key Elements of REACH

- "No Data, No Market" – Without registration, products can not be sold in the EU.
- A newly created European Chemicals Agency (ECA) will handle registration of the product dossiers.
- Registration limited to chemicals imported or produced by one company in excess of one ton annually.
- Beyond registration, chemical safety reports (CSR) will be required for substances produced in excess of 10 tons or are of "very high concern".
- CSR will contain information on the substance's hazards, classification, and exposure scenarios.
- Chemicals are registered for specific uses (which may result in chemicals being registered multiple times).
- Subset of substances of "very high concern" will required specific EU authorization to be sold and might be restricted in their use or marketing.
- Will treat old chemicals exactly the same as new chemicals (no grandfather clause for the over 100,000 chemicals in use).
- Due to the vast number of old chemicals on the market (of which 99% have limited safety information) the directive proposes to assess about 30,000 (leaving out ones produced in volumes less than 1 ton).
- REACH will enter into force on June 1, 2007.

2.4.2 Unique Data Requirements

REACH is unlike any existing restrictive substance legislation, and its unique data requirements will have far reaching implications for industry. First, REACH will require new data information flows: downstream to customers (chemical safety information), upstream to suppliers (chemicals' expected use) and sideways (dossiers) to the new ECA. While systems for the exchange of chemical safety data sheets (SDS) exist and work, new and expanded SDS will be required to include information such as proposed use, exposure scenarios, etc. Also, implicit with REACH is that there will likely be a need for material declarations for the substances of high concern, to avoid legal liability. It is likely that upwards of 2,000 substances will need to be declared if they appear in a product.

3.0 Energy Efficiency

This type of legislation focuses on helping industry and consumers improve their own energy efficiency in order to reduce overall energy usage. The main example of this is the upcoming European Union's Energy Using Products legislation.

3.1 EU's Energy Using Products (EuP)

The EuP is different from the other legislation in that, rather than focusing on restricting hazardous substances, it focuses on improving energy efficiency [8]. In fact, the EuP is part of the EU-wide Energy Efficiency Action Plan [9], which seeks to reduce energy consumption by improving energy efficiency. The EuP targets the negative environmental impacts of energy-using products that occur throughout the product life-cycle. These impacts arise from the extraction of raw materials, the manufacturing process, distribution, use and eventual disposal. In essence, the EuP will require manufacturers to calculate and track the energy used to produce, transport, sell, use and dispose of any non-transportation product all the way from extracting raw materials to the product's end of life disposal. The energy data collected by manufacturing companies will then be used in a variety of ways to spur energy conservation (consumer labeling, setting limits, etc.)

3.1.1 Key Elements of EuP

- EuP is a "framework" that specifies a fast-track mechanism for implementing future legislation, rather than setting any specific requirements itself.
- As its name implies, its focus is broader than just the electronics industry; it applies to any non-transportation products.
- The first set of implementing legislation will focus on energy efficiency in a vary narrow range of products, specifically those that match the following criteria:

  – High-volume market: >200,000 units are placed annually
  – Have a significant environmental impact on the EU community
  – Significant room for improved energy efficiency is already possible based on comparable products already on the market

- The energy usage data collected by manufacturers will likely be used in at least two ways: to set limits on the total allowable energy used to produce certain products, and to produce better product labeling.
- The EuP is seen as complementary to the Energy Labeling Framework Directive: it makes comparative labeling compulsory in all member countries once a product (implementing) directive has been passed.
- Future modifications to the Energy Labeling Directive (based on the EuP) could lead to new energy labels, which identify both the product's running cost and the total energy cost of production.

- The idea is that these new energy labels will allow customers to change their buying behaviors in favor of products that cost less energy to produce and use.

3.1.2 Unique Data Requirements

The EuP introduces data tracking requirements that could be an order of magnitude greater than RoHS, REACH, or any other pending environmental legislation. Most companies do not currently track this information and have no systems or processes in place to measure energy usage, let alone pass it along to customers. To make matters worse, no metrics for tracking rate of energy usage have been finalized and no specialized reporting format for energy usage has been introduced. While EuP is limited to energy, it is likely that additional data reporting requirements, such as greenhouse gases and water usage, will be added.

4 Suggested Next Steps for Industry

One primary point revealed by this survey is that many political entities (countries, states, and unions) are seeking to protect human health and the environment through implementation of new legislation. Unfortunately, each directive provides its own unique take on what to limit and protect. The result is a patchwork of confusing (and possibly conflicting) regulations with which industry cannot comply unless further steps are taken. The best option for industry is to start collecting as much material composition and energy usage information as possible about the components used to build their products. Rather than aiming for basic yes/no compliance with each new piece of legislation, industry should strive to fully describe the contents of each product's bill of materials. In the end this method would likely be cheaper since companies would not have to scramble to update their supply chain information systems with every new law. By collecting and tying all this information into a product lifecycle, companies will be able to create on-demand declaration reports for any applicable legislation. Also, by collecting all available information, companies will protect themselves from changing requirements in the future.

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Data Modeling to Support Environmental Information Exchange throughout the Supply Chain

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Abstract. With an ever-increasing awareness of the environmental impact of manufacturing, more and more political organizations (countries, states, and unions) are enacting legislation designed to protect the environment. One category of this restrictive legislation is called Extended Producer Responsibilities (EPR). EPR directives place greater responsibility on manufacturers for the environmental impact of their products. These laws shift the focus from the product's origin to the product's final destination and from the process of manufacturing to the product itself. The highest impact of these directives is the Restriction of Hazardous Substances (RoHS) directive, finalized by the European Union in 2003. The RoHS directive restricts imports of new electrical and electronic equipment containing lead and five other hazardous substances. For manufacturers to successfully comply with RoHS and similar legislation, they need the ability to exchange material content information. This information would then propagate through the supply chain from the raw material suppliers all the way to the final producer. While a solution could be generated for any single piece of legislation, the problem is that companies will need to successfully deal with potentially dozens of laws and directives. To deal with this problem, the National Institute of Standards and Technology (NIST) (a US Government Research Laboratory) developed a data model to address the underlying material declaration problem using a software development methodology. This data model was used in the development of IPC's 1752 Material Declaration standard. IPC's 1752 standard helps the electronics industry comply with RoHS by providing a data exchange mechanism by which businesses can declare the presence or absence of the restricted materials. While IPC 1752 was created to deal with EU's RoHS, the data model was designed with the intent that it would be able to support future RoHS-like legislation (China RoHS, California RoHS, etc). Even if different solutions were developed for each piece of Legislation, they can interoperate provided they are based on the same data model. This paper looks at the data model designed for the IPC1752 standard, the methodology that was used to create it, and how it can be adapted to similar RoHS-like laws and directives.

Keywords. RoHS, material composition declaration, data exchange, modeling

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1 Introduction

Countries around the world are creating legislation designed to encourage manufacturing practices that promote human health and environmental protection. Many of these laws are built around a concept called *extended producer responsibilities* (EPR). EPR shifts the responsibility of a product's negative environmental or health impact directly to the producing company. The first major regulation of this type was the EU RoHS directive [1], which went into legislative force in 2006. The RoHS directive restricts imports of new electrical and electronic equipment containing six substances specified in the directive. For manufacturers to successfully comply with RoHS, and similar legislation, they need the ability to exchange material content. This information would then propagate through the supply chain from the raw material suppliers to the final producer. At the time the RoHS directive was developed, there was no standard to support material data exchange through the supply chain. This necessitated the creation of a new data exchange standard. The design of this standard was complicated by the diverse nature of the electronics industry business processes and reporting practices. In fact, the complexity of the reporting requirements meant that traditional *ad hoc* standards development processes would likely fail to produce a viable standard. To overcome this, software development methodologies were chosen to be the basis for the standards development process. After reviewing several design methodologies, simple Uniform Modeling Language (UML) [2] modeling with class diagrams was chosen. The main benefit of using UML being, it offered a relatively high degree of improvement for the development process compared with a relatively low cost of implementation. The UML is one part of a structured design approach that starts with domain experts defining the scope and use requirements which are then developed into a data model.

NIST developed a data model (using UML class diagrams) that described the required underlying material content based on the requirements specified by the IPC 2-18 experts. This data model was used to generate an eXtensible Markup Language (XML) schema that defines the IPC 1752 Material Declaration standard [3]. An important result of this approach is that, while the IPC 1752 standard was developed to support EU RoHS, the data model was designed to be flexible enough that it could be modified to support additional material data from other content regulations (China RoHS, California RoHS, etc) with little effort. The salient point is that, even if different data exchange solutions were developed for every new piece of legislation, as long as they where based on the same data model, the solutions would be interoperable. This paper looks at the data model designed for the IPC1752 standard and how it can be revised for similar laws and directives.

2 Model of Present Material Declaration Exchange

The first step in developing a data exchange standard to support RoHS compliance was to examine the underlying issue of material declarations. In this case, a data model (an abstract representation of how data is represented and used) was developed. Specifically, a UML design model was created to show the different material composition data, associated business information, and the relationships between this information. (see Figure 1).

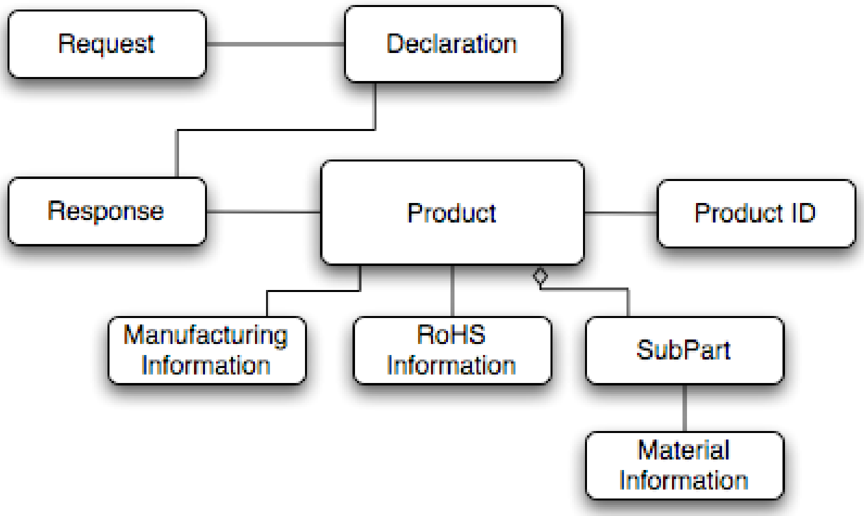

Figure 1. High level view of the original design model

The model contains a business information section including specific information about the requester and the responder needed for a material data exchange transaction. The model also captures material composition information. This is the heart of the declaration, covering regulatory information and the supporting material content data.

The data model captured the following information:

- Company information, contact information, and authorization information for the companies exchanging data. Additionally, business-to-business data needed for automating the data exchange is included here.
- Unique identification information for the part being declared. This information has been difficult to acquire, since non-RoHS and RoHS versions of the same part may have the same product identification. Therefore, manufacturing site, version, and effective date are captured along with the part number and name.
- Support for three basic levels of reporting; the yes/no declaration, substance category reporting (groups of substances), and substance level reporting (where every substance in the product can be reported).

- Information about substances and substance categories from both the request side and response side of the data exchange. This was needed to support specific companies' needs.

3 Limitations of the Present Model

Many of the problems with this current data model can be traced back to the fact that there was only a time window of six months to complete the data standard. This was driven by the small window of opportunity that industry had to understand the issues and implement solutions to meet the impending RoHS deadline of June 1, 2006. Because of the short development window, and the desire to be sensitive to the needs of small electronics suppliers, certain compromises were made.

- No support of multi-level sub-components: Parts can only be broken down one level into subparts. A subpart can not have another subpart. While this approach can work fine for simple declarations, it can not express complex multilevel declarations efficiently.
- Minimal support for multiple part IDs: A part family must be described using a single PartID attribute, and all the parts described must have the same weight. Although it is possible to associate multiple IDs with one product declaration, the IDs are presently squeezed into one attribute/field.
- No support for multiple legislation reporting: Because no other laws or declarations requiring material declaration for the electronics and electrical industry had reached a finished state when the first version of the model was designed, the regulatory information is specific to the EU RoHS and its exemptions.

While these issues could not be resolved for the first implementation of the design model, the IPC standards committee has begun developing version 2.0 of 1752. This presented the opportunity to revise the data model for the next version of the standard and using a software development methodology based around UML means that changes made to the data model can be propagated easily into the new standard.

4 Next Generation Model

This model and information presented here is only a prototype for discussion and is not meant to be final. As other countries around the globe begin to adopt environmental legislation similar to the EU RoHS, a more general container for regulatory information needs to replace the RoHS specific element in 1752 v1.0-1.1. Upcoming regulations, including China RoHS, EU Registration, Evaluation and Authorization of Chemicals Directive (REACH), and EU Energy Using Products (EuP), will require different product declarations. By creating a reusable class that can be used to represent many types of regulatory declarations for a product, multiple regulations may be associated with a single XML instance.

Besides the generalized declaration, there also need to be elements added to hold data specific to each new regulation. A survey of several of the upcoming legislations identified several unique data exchange requirements that are absent from the current model because they were beyond the scope of EU's RoHS. Listed below are several examples of data requirements that have emerged since the publication of the first model:

- China RoHS requires data on the safe use period, in which manufacturers identify the stable shelf life of the product before it leaks into the environment.
- China RoHS grants the producer the ability to report a substance as parts per million (ppm) at the part level instead of at the homogeneous material level for small objects under $4mm^3$.
- EuP requires the tracking of the total energy used in the manufacturing of a product.

One of the easiest requirements to address in the new data model will be the safe use period information requirement in China RoHS. Because of the methodology used to design version 1.0, the structure and attributes already present within the v1.0 design model and schema will require very little modification to support this information, since it can fit within the new generalized declaration.

Another issue that needs to be addressed is the ability to report concentration in ppm of homogeneous materials (as for EU RoHS) or mass (if the mass is under the China RoHS weight limit for small parts). Since the inception of EU RoHS there has been concern about how to report the quantity of a substance. RoHS requires that companies report the mass of substance relative to a homogeneous material, while other legislation and the Joint Industry Guide (JIG) require that a company report mass relative to the entire part (unless specified by a specific regulation), not just the material. Adding an attribute to qualify the reported mass as being reported at the part level or the homogeneous material level resolves this discrepancy.

The EU EuP Directive does not cover materials, but instead covers the energy used during the production and use of a product. Since the directive has not been finalized, it is not clear what information will be required, but it is likely the electronics supply chain will want to track this information in a similar manner to material data. Using a modular design, this additional energy related information may be added by creating a class associated with the product which holds the energy information for the product. Likewise, the manufacturing data will be modularized.

To provide declaration information for the new regulations, the RoHS declaration class will become more generic, which will allow declarations for other regulations. To support products that are shipped to multiple markets, it will support multiple declarations for a single part. Figure 2 shows a high level view of the prototype design model for version 2.0. It does not show the association multiplicity or sequence information. Additional information related to the XML schema has been removed to make the diagram easier to read. Interested parties may contact the authors for more detailed models.

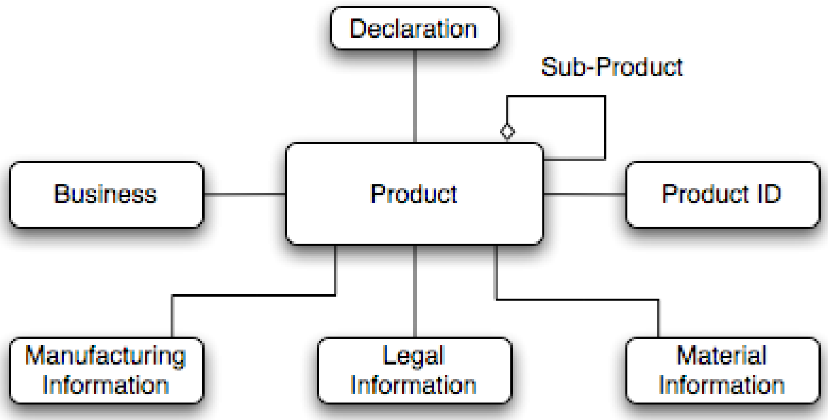

Figure 2. Prototype high level design model for next generation material composition data standard

The prototype proposed for the next generation model has several key classes, which include:

Declaration – defines the basic information for the data transfer, such as an identifier and version for the standard. This class represents the top-level element in the XML implementation.

Business Information – defines the two companies exchanging data, or a single company, to cover the case in which a supplier creates the declaration without a specific customer in mind. This class includes contact and authorization information and additional information needed to automate business-to-business transactions. This class changed little from v1.0, however, its association has been moved from the top-level class to the product class in order to support nesting of product information complete with all business information.

Product class – defines the product or group of products to which the declaration applies. This is the central class in the model. The other main classes are associated with the product class, and the product class is associated with itself as a subclass to allow nesting of product information. Structuring products this way means that an entire product declaration can be wrapped up and easily used as part of another product declaration.

ProductID information – Holds the identifying information for the product being declared. Version 2.0 will support multiple product IDs by allowing multiple ProductID objects to be included within a file. A part family ID may still be used as with v1.0.

Legal Information – includes the regulatory information and any legal language required for the data exchange to happen. This class is flexible so that it can handle legal information for specific regulations. Legal language about the file's data, along with regulation-specific language, is included here.

Material Information – holds the actual material content data. This data can be reported at the product level (e.g., is the product within the limits set by RoHS yes/no), the category level (e.g., JIG substance categories), or the substance level (e.g., JIG substances).

Manufacturing Information – contains manufacturing process information that is specific to the product being declared. This information is important since it is often different for alternate products that replace those with restricted substances.

5 Conclusions

The electronics industry is building advanced manufacturing facilities and supply networks to produce goods that have a complexity only imagined a few years ago. The data exchange standards to support this are equally complex. Creating and implementing these standards is a continuing task. By using simple tools such as those available with UML modeling in a structured development process, robust data exchange standards may be created that are easily modified to meet future requirements. These material declaration models and resultant XML implementations are a good example of how to apply software development methodologies to data exchange standards development.

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EXPRESS to OWL morphism: making possible to enrich ISO10303 Modules

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Abstract. ISO10303 STEP has been acknowledged by the world's largest industrial companies, as the most important family of standards for the integration and exchange of product data under manufacturing domains. With the advent of globalization, smaller enterprises (SMEs) looking to level up with world-class competitors and raise their effectiveness are also realizing the importance of the usage of this kind of standards. However, to enable a model-based interoperability, STEP industrial standards, the Application Protocols (APs) follow a modular approach, i.e. they are composed by a set of generic purpose modules sharable by a number of different APs. This way, the core STEP reference models contain vague definitions that sometimes raise ambiguous interpretations. A possible solution to overcome this barrier would be to add further semantics to the concepts defined and enable STEP modules as ontologies, thus providing an alternative to traditional implementations. SMEs can benefit even more from this alternative, since OWL is currently a widespread technology, with abundant low cost supporting tools comparing to the ones dealing directly with STEP.

Keywords. Interoperability, ontology, transformation, content-representation language.

Introduction

Interoperability and standardization have been playing important roles in lowering costs related to production, sales and delivery processes, which permits to reduce final prices, and increase competitiveness. Enterprise and systems interoperability is frequently associated with the usage of several dedicated reference models,

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covering many industrial areas and related application activities, from design phase to production and commercialization [1].

ISO10303, most commonly known as the Standard for the Exchange of Product Model Data (STEP), is one of the most important standards for representation of product information. However, despite the many success stories involving the large enterprises (i.e. from the aeronautics, ship building, automotive or aerospatiale sectors), where STEP enables estimated savings of $928 million per year, it still has some drawbacks [2]: STEP reference models are somewhat vague and contain definitions that can raise ambiguous interpretations among the industrial experts that have not been involved in the standardization process; and also, the use of languages that are unfamiliar to most application developers [1,4,5].

A solution to overcome the last problem would be to enable STEP industrial models, the Application Protocols (APs), in more user-friendly and supported technologies and standards, such as Extensible Markup Language (XML) [1,3-6]. Regarding the first drawback, an innovative approach would be to link STEP to the semantic web. It that were possible, it might be easier to reduce the misinterpretations, by associating sector specific semantics to each model.

In this paper we focus the harmonization of STEP with the Web Ontology Language, to cover both needs. OWL is an ontology language produced by the W3C Web Ontology Working Group. It is structured to be a major formalism for the design and dissemination of ontology information, particularly in the Semantic Web. OWL is intended to be used when the information contained in documents needs to be processed by applications, as opposed to situations where the content only needs to be presented to humans [7].

Because OWL is part of W3C's Semantic Web, the official exchange syntax for OWL is XML/RDF, a way of writing RDF in XML. However, since OWL has more facilities for expressing meaning and semantics than XML, RDF, and RDF-S (RDF Schema), it goes beyond these languages in its ability to represent machine interpretable content on the Web [7,8].

1 Model-based Interoperability: Building on Solid Knowledge

The increasing number of specialized and complementary software applications working for the industry, and specifically those covering inter-cross industrial areas, has driven industry in general, to look for standards for process and product data to support services, data exchange, and set up integration platforms to enable interoperability [9].

1.1 STEP Conceptual Models and the EXPRESS language

The standardization community is currently working hard to support the reuse, integration and extensions of already existent standards, stimulating recycling, and providing easier mechanisms to manage and understand the models. Modular approach is actually the newest activity related to the development of standards that responds to pointed needs [9,10].

STEP is nowadays one of the most important family of standards for the representation of product information. It contains more than forty APs that reflect the consolidated expertise of major industrial worldwide specialists working together for more than twenty years, covering the principal product data management areas for the main industries, e.g. oil and gas, automotive, aeronautics, aerospatiale. This kind of knowledge should not be wasted by the market, and gives STEP a distinct advantage over similar technologies and standards [1,3-6]. STEP is also one of the most innovative families of standards on the reusability sense. Application modules were recently introduced to the STEP architecture and are the key component to make its APs more interoperable, cheaper, easier to understand, manage, and quicker to develop [10].

However, the modular architecture in spite of promoting reusability raises the problem of abstracting too much the standards definitions because they stop being associated with any particular environment. Also, smaller industries like SMEs still don’t use STEP because of another problem: it is associated with technologies that lack tool support and require big initial investments [1,3-6]. The EXPRESS modelling language specified by STEP part 11 (ISO 10303-11) [11], is example of that. In spite of being a very powerful language, is not acquainted by most application developers and consequently is almost ignored by users outside the STEP community [1,3-6].

1.2 Model Morphisms (MoMo)

Another commom problem that is striking the communities working on interoperability, is the proliferation of terminology. This is a typical phenomenon that occurs when there are many different communities active on similar problems, but addressing them from different angles, with different backgrounds [12].

The InterOp network (www.interop-noe.org) intends to solve that issue, by introducing the MoMo concept, which is a terminology for model operations (i.e. mapping, merging, transformation, composition, or abstraction) independent from specific proposals. It uses the terms from consolidated mathematical areas, such as set theory, theory of functions and relations, and adapts them to the modelling context. This way, when applied to ICT purposes, a morphism details the relationship between two or more model specifications that may be described in different languages. A morphism can be classified as non-altering, if given two models (source and target), a mapping is created relating each element of the source with a correspondent element in the target, and the two models are left intact. Otherwise, the morphism will be classified as model altering, i.e. the source model is transformed applying some kind of function and generating a different output [1,5,12].

To describe unambiguously any tool that implements model morphisms, a reference ontology designated by MoMo ontology, was designed [13]. Using it, becomes possible to describe interoperability solutions related to model processing operations. Therefore, when properly instantiated, the ontology will provide a valuable knowledge-based for the MRS (MoMo recommendation system) to reason and make decisions and suggestions. Indeed, the MRS is able to assists any user in the re solution of mapping/transformation problems, by analyzing the ontology instances and recommending the most appropriate computational method(s) or tool(s) suitable for specific model morphism tasks [14].

2 Motivations for OWL

The Web Ontology Language can be the means to put way the enumerated problems that are common to formal industrial standard specifications like STEP.

OWL is used to define classes and properties as in RDFS, but in addition, it provides a rich set of constructs to create new class descriptions as logical combinations (intersections, unions, or complements) of other classes, or define value and cardinality restrictions on properties (e.g., a restriction on a class to have only one value for a particular property) [7].

It is a unique language since it is the first whose design is based on the Web architecture, i.e. it is open (non-proprietary); it uses URIs to unambiguously identify resources on the Web; it supports the linking of terms across ontologies making it possible to cross-reference and reuse information; and it has an XML syntax (RDF/XML) for easy data exchange. Semantically speaking, OWL is placed right above RDFS web stack layer (Figure 1).

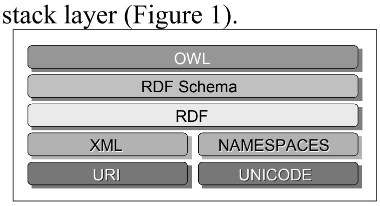


Figure 1 – Semantic Web Stack

One of the main benefits of OWL is the support for automated reasoning, and to this effect, it has a formal semantics based on Description Logics (DL). They are suitable for representing structured information about concepts, concept hierarchies and relationships between concepts. The decidability of the logic ensures that sound and complete DL reasoners can be built to check the consistency of an OWL ontology, i.e., verify whether there are any logical contradictions in the ontology axioms. Furthermore, reasoners can be used to derive inferences from the asserted information, e.g., infer whether a particular concept in an ontology is a subconcept of another, or whether a particular individual in an ontology belongs to a specific class [7,15].

3 A Proposal Mapping for EXPRESS and OWL

A first step to enable ISO 10303 industrial standards to a larger audience that can understand, reuse and implement them is to transform the EXPRESS models into OWL descriptions. The authors propose a mapping for the following EXPRESS statements (see Figure 2).

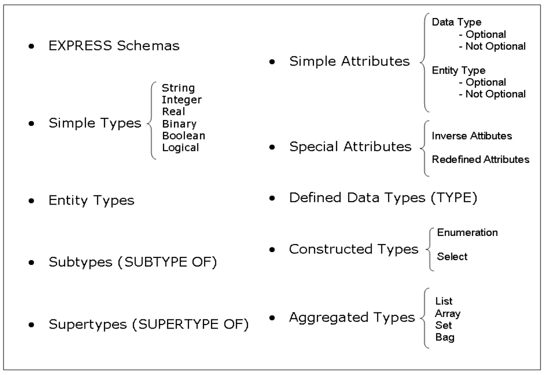


Figure 2 – EXPRESS statements mappeable to OWL

3.1 EXPRESS Schemas and Simple Types

Each OWL file represents an ontology. An OWL file header extends the RDF file header, by aggregating URIs to OWL vocabulary and to the ontology being described. In our approach, EXPRESS schemas were translated into OWL ontologies, by creating separated files to represent each one of them.

So, a typically OWL file representing an EXPRESS schema named *Fruit_schema* – which uses definitions from *Fruit_description* schema – should look like this:

```
<rdf:RDF
    xmlns="http://www.uninova.pt/ontology/Fruit_schema#"
    xmlns:owl="http://www.w3.org/2002/07/owl#"
    xmlns:rdfs="http://www.w3.org/2000/01/rdf-schema#"
    xmlns:rdf="http://www.w3.org/1999/02/22-rdf-syntax-ns#"
    xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
    xml:base="http://www.uninova.pt/ontology/Fruit_schema">
   <owl:Ontology rdf:about="">
     <owl:versionInfo>1.0</owl:versionInfo>
     <rdfs:comment>Fruit_schema</rdfs:comment>
     <owl:imports rdf:resource="Fruit_description.owl"/>
   </owl:Ontology>
</rdf:RDF>
```

The conversion of EXPRESS simple types (*String, Integer, Real, Binary, Boolean, Logical*) was direct, as they have equivalents in OWL (in fact XSD types). For example, *String* type was mapped into *xsd:string* type.

3.2 Entity Types, Attributes, and Inheritance Relationships

EXPRESS entities are used to define concepts from the real world which have properties that characterize them. In the entity-relationship, they would be tables, but in OWL they are classes. By using this principle, we can map directly any entity as well as their subtypes and supertypes (profiting from OWL classes inheritance). The OWL data property is used to represent EXPRESS simple attributes, as well as the OWL object property represents named attributes. OWL cardinality is used according to the EXPRESS attribute's optional flag.

Some EXPRESS inherited attributes from a supertype entity, can be renamed or retyped according to the user's needs. These redefined attributes are mapped using OWL classes' specialization. Regarding EXPRESS inverse attributes, which are pointers to the relating entity, the OWL inverse property is available for the same purpose. Table 1 shows an example of EXPRESS entities mapped into OWL.

Table 1. Entities

EXPRESS	
ENTITY Fruit; description : OPTIONAL STRING; END_ENTITY;	ENTITY Tree SUBTYPE OF (Thing); root : Root; END_ENTITY;

OWL

```
<owl:Class rdf:about="#Fruit">
 <rdfs:subClassOf>
  <owl:Restriction>
   <owl:minCardinality
 rdf:datatype=http://www.w3.org/2001/XMLSchema#int"> 0
   </owl:minCardinality>
    <owl:onProperty>
     <owl:DatatypeProperty rdf:ID="Fruit_description">
      <rdfs:domain rdf:resource="#Fruit"/>
 <rdfs:range rdf:resource="http://www.w3.org/2001/XMLSchema#string"/>
     </owl:DatatypeProperty>
    </owl:onProperty>
   </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>

<owl:Class rdf:about="#Tree">
 <rdfs:subClassOf rdf:resource="#Thing"/>
 <rdfs:subClassOf>
  <owl:Restriction>
    <owl:cardinality
 rdf:datatype="http://www.w3.org/2001/XMLSchema#int"> 1
    </owl:cardinality>
     <owl:onProperty>
       <owl:ObjectProperty rdf:ID="Tree_root">
        <rdfs:range rdf:resource="#Root"/>
       </owl:ObjectProperty>
     </owl:onProperty>
  </owl:Restriction>
 </rdfs:subClassOf>
</owl:Class>
```

3.3 Constructed Types

There are two kinds of constructed data types in EXPRESS: enumeration data types and select data types. The enumeration is a concept common to many other languages, and defines a set of names to be used in a domain. Regarding the select, it is a concept very characteristic of EXPRESS to define a data type that enables a choice among several named data types [11].

Enumeration and Select types were mapped through the use of OWL clauses *owl:oneOf* and *owl:unionOf*, respectively. In the Select case, it was also necessary to stand the oddity of each resulting class (see Table 2).

Table 2. Select type

EXPRESS

```
TYPE Citric_Fruit = SELECT (Orange, Lemon, Grapefruit);
END_TYPE;
```

OWL

```
<owl:Class rdf:about="#Orange">
  <owl:disjointWith rdf:resource="#Lemon"/>
  <owl:disjointWith rdf:resource="#Grapefruit"/>
</owl:Class>

<owl:Class rdf:about="#Lemon">
  <owl:disjointWith df:resource="#Orange"/>
  <owl:disjointWith df:resource="#Grapefruit"/>
</owl:Class>

<owl:Class rdf:about="#Grapefruit">
  <owl:disjointWith rdf:resource="#Orange"/>
  <owl:disjointWith rdf:resource="#Lemon"/>
</owl:Class>

<owl:Class rdf:ID="Citric_Fruit">
 <owl:equivalentClass>
  <owl:Class>
   <owl:unionOf rdf:parseType="Collection">
      <owl:Class rdf:about="#Orange"/>
      <owl:Class rdf:about="#Lemon"/>
      <owl:Class rdf:about="#Grapefruit"/>
   </owl:unionOf>
  </owl:Class>
 </owl:equivalentClass>
</owl:Class>
```

3.4 Aggregated Types

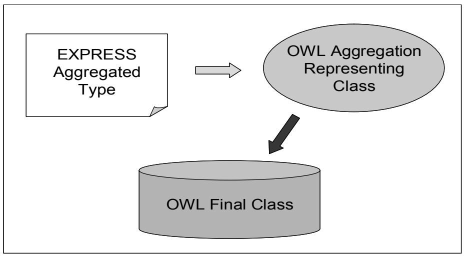
To map EXPRESS aggregated types was necessary to define an intermediate class, as there was no equivalent OWL structure to represent such types. Thus, EXPRESS *List*, *Array*, *Set* and *Bag* were first represented in an OWL metaclass, and the final class was set as subclass of this metaclass. With a new class we could easily manage properties and restrictions of each type, without changing its initial definition (see Table 3 and Figure 3).

3.5 EXPRESS Rules

The EXPRESS language contains a high level of expressiveness and uses constructs that are hard to map to other modeling languages. Among some of these constructs are rules, queries functions, and constraints to attribute values.

It was not possible to translate EXPRESS rules into OWL. Concerning the EXPRESS uniqueness rule, both languages have different ways to interpret this principle. While in EXPRESS a unique value is defined to an object and understood by all involved actors, there is no such possibility in OWL, where infinite URIs may be set to represent the same object. Moreover, as OWL is a declarative language, it is not possible to use it to represent functions statements. As well, the mapping of EXPRESS domain rules (WHERE clause) was also not possible.

Table 3. Aggregated types

EXPRESS	
TYPE Orchard = SET [1:?] OF Tree; END_TYPE;	 **Figure 3 – Aggregated types approach**

OWL

```
<owl:Class rdf:ID="OWL_Set_Tree">
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty>
        <owl:ObjectProperty rdf:ID="OWL_Set_belongTo_Tree"/>
      </owl:onProperty>
      <owl:allValuesFrom rdf:resource="#Tree"/>
    </owl:Restriction>
  </rdfs:subClassOf>
  <rdfs:subClassOf>
    <owl:Restriction>
      <owl:onProperty rdf:resource="#OWL_Set_belongTo_Tree"/>
      <owl:minCardinality rdf:datatype=
        "http://www.w3.org/2001/XMLSchema#int"> 1
      </owl:minCardinality>
    </owl:Restriction>
  </rdfs:subClassOf>
</owl:Class>

<owl:Class rdf:ID="Orchard">
  <owl:sameAs rdf:resource="#OWL_Set_Tree"/>
</owl:Class>
```

4 UniSTEP-toolbox: EXP2OWL Morphism

To accomplish EXPRESS based model morphisms, a research prototype, i.e. the UniSTEP-toolbox, is being developed applying the principles of the OMG

MDA methodology [16]. UniSTEP relies on a framework for the interpretation of STEP models and their transformation into complementary technologies. This toolbox already includes standardized transformations to XML Schemas (XSD) and UML using its interchange format (XMI), but also relational databases, and JAVA [1,5]. The EXPRESS to OWL is the most recent morphism being implemented in the toolbox, to integrate STEP with the semantic web world.

In some cases, industry is already taking advantage of this approach of abstracting STEP to more common technologies. One example is the case of the furniture sector, mainly composed by SME's, which through the efforts of the funStep group (www.funstep.org/) and the usage of UniSTEP-toolbox, is now becoming aware, motivated and in some cases implementing the standard AP236 for the representation and exchange of furniture catalog and interior design data, using XML Schemas [17].

4.1 Formal Tool Specification

The EXP2OWL morphism of the UniSTEP-toolbox, is currently using a static mapping described on section 3 of this paper. However it is predicted that the user (i.e. the company implementing the STEP AP, or consultants for the STEP AP) can configure the tool to choose among certain mapping parameters and obtain outputs with different semantic granularity capability. This way, the tool output could be just the plain data model, or could be added with properties prepared to contain further semantics on the defined concepts. Of course, in the last case, those semantics would have to be added using a post-processor (not part of the morphism).

Adopting the mathematical notation the morphism implemented could be formally defined on the following way. Let:

a) *MOD* be the set of all models described by the EXPRESS language;
b) *MXSD* be the set of all XML models described using XSD;
c) *CONF* be the set of all possible configurations for the transformation morphism, and $CONF \subseteq MXSD$;
d) *MOWL* be the set of all OWL models described using OWL light;
e) *MOWLMap* be the set of all OWL models obtained from an EXPRESS model following the section 3 mapping, and $MOWLMap \subseteq MOWL$

This being, EXP2OWL is a function $\tau\colon MOD \times CONF \rightarrow MOWLMap$ where $\tau(A,C) = B$, where $A \in MOD$, $C \in CONF$, and $B \in MOWLMap$.

4.2 Using MoMo Ontology

To improve the efficiency of MRS, the more morphisms are classified, the better. Indeed, all the morphisms that are part of the UniSTEP-toolbox are classified under MoMo's reference ontology so that any user looking to work with STEP models but desires to use different technologies, could be advised to use the morphisms implemented in this toolbox.

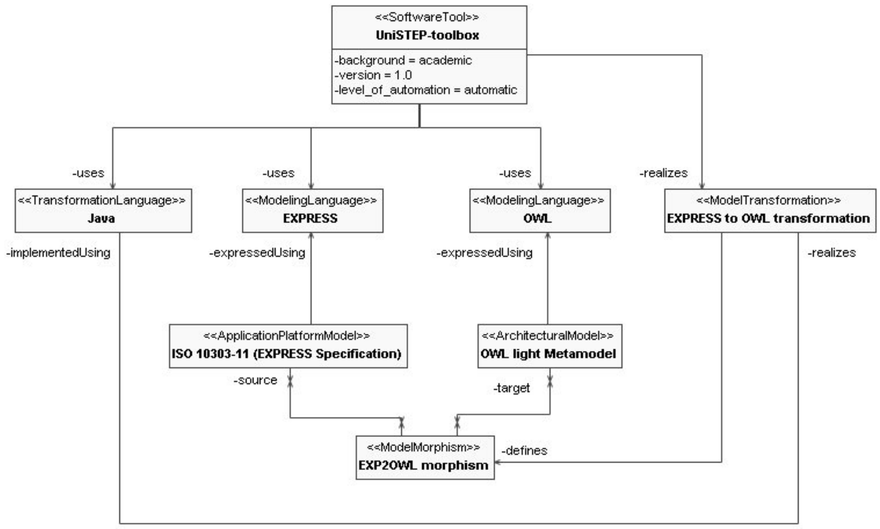


Figure 4 - Snapshot of the Instance of the MoMo Ontology for the EXP2OWL Morphism

The diagram from Figure 4 uses an UML notation to illustrate how the EXP2OWL is classified using the reference ontology for model morphisms. For the sake of simplicity, this figure does not reflect the entire set of elements of the ontology, especially some class properties. Having this classification performed, anyone (human or machine) should have only one interpretation of what the morphism is about, i.e. “UniSTEP is an automatic *SoftwareTool* with academic background that realizes an EXPRESS to OWL *ModelTransformation* implemented in the JAVA *TransformationLanguage* (is a restrictive classification for JAVA but expresses its role in this scenario). This transformation defines the *ModelMorphism* EXP2OWL which takes as input the source *ApplicationPlatformModel* represented using the EXPRESS *ModelingLanguage*, processes the *Architectural* part and generates a target model represented using the OWL *ModelingLanguage*”.

5 Closing Remarks

With so many different modelling and implementation standards being used nowadays, STEP is one of the most distinguished regarding product data. To promote the reusability of its industrial standards, ISO adopted the modular approach for STEP to enable more efficient development, standardization, implementation and deployment. Compared with the classic STEP architecture, this emerging approach promises to bring major advantages for users and developers [9].

However, the modular standards may raise the problem of becoming quite hard to understand due to vague definitions not associated with any particular environment. Yet, another problems arises when the chosen product model is described using one particular technology (e.g. EXPRESS) and is required to be integrated with end-user systems that use totally different technologies with different degrees of expressiveness like XML or OWL.

The integration of the EXPRESS language with the Web Ontology Language can be the means to put way the enumerated STEP problems, since OWL provides a valuable link with the emerging field of Semantic Web which is gaining high relevance in the global market, and has XML syntax for easy data exchange using web-based systems. The Semantic Web has the aim of extending the current Web infrastructure in a way that the information is given a well defined meaning, enabling software agents and people to work in cooperation by sharing knowledge [18]. This way, if STEP standards are transformed to OWL, they could in the future, be easily complemented with links to semantic information contextualizing the scope of the defined concepts regarding the environment were they are applied.

Moreover, representing EXPRESS modules as ontologies enables the use of OWL reasoning, a very powerful way to check inconsistence and incoherence of information. This can lead us to a scenario where human users can, in an easier way, exchange and verify EXPRESS represented data. Such scenario can enhance the use of EXPRESS language, promoting its adoption by a large number of platform-independent and language-independent users. The morphism developed is also part of a collaborative design project, described in [19].

The different degrees of expressiveness of the referred languages impede a full binding (e.g. EXPRESS rules), thus originating a partial morphism. In this case, the morphism results in the loss of some information. This way if a user needs to transform an EXPRESS model into XML based languages, namely OWL, without losing much information, it probably should combine more than one technique and tool. This combination could be suggested in an automatic way by the MRS that reasons on knowledge-base provided by the MoMo reference ontology.

6 Acknowledgments

The authors would like to thank all the organizations supporting the international projects that resulted in the development of the UniSTEP-Toolbox. Namely, the funStep community (www.funstep.org) and its members that somehow contributed for the presentation of this work; Also, CEN/ISSS and ISO TC184/SC4 for the effort in developing industrial standards and cooperating with the presented research.

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Complex Modelling Platform based on Digital Material Representation

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Abstract. Proposition of innovative software platform dedicated to modelling of metallurgical processes is presented in the paper. Developed approach is based on the idea of material representation in the form of digital data sets describing various material properties in different length scales. The platform is equipped with additional software modules dedicated to support data gathering, microstructure image analysis, mesh generation and performance of multiscale simulations. The latter module, based on Cellular Automata – Finite Element (CAFE) method, contains two algorithms related to modelling of microstructural phenomena occuring in material during deformation under varying conditions i.e. micro shear and shear bands analysis and recrystallization modelling. The complex approach described in this paper allows not only knowledge based prediction of detailed material properties after thermomechanical metallurgical processes but it also gives possibility to modell entire life cycle of considered material. Thus, it facilitates the investigation of properties of final products and their development by strong quality improvement. Moreover, the platform allows to limit costs of manufacturing by reduction of many expensive industrial trials and their replacement by pure virtual research. Some of the results obtained from application of selected software modules are presented in the paper.

Keywords. Digital material, multiscale modelling, microstructure image analysis.

1 Introduction

Numerical modelling is currently applied to predict material behaviour under manufacturing and exploitation conditions. The most commonly used method for this purposes is Finite Element Method (FEM), which can be applied to simulate a variety of problems, from simple experimental tests (e.g. tensile, torsion) to sophisticated processes consisted of complex structures and systems (e.g. cars, building, implants). FEM is able to simulate real processes occuring inside the material and its environment (tools), as well as interactions between them. Althought the method is becoming introduced in industrial aplications, it still

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requires development to improve the results of performed simulations. Thus, in recent years many modifications of FEM methods were develped e.g. *hp*-adaptation, non-continuous finite elements, etc. [1]. Nevertheless, there still exists a lot of constraints. Some of them are related to possibility of prediction the microstructural phenomena, which proceed simultanously in different length scales.

Another constraints are related to FEM high computational complexity, while the industrial companies expect short time of calculations. Therefore, alternative modelling methods are being developed [2]. The main objective of such techniques is focused on improvement of their efficiency and enhancement of the quality of obtained results, including material behaviour in all length scales. The models equipped with such methods facilitate designing of new materials and analysis of their behaviour during processes, which proceed on manufacturing and exploitation stages of materials' life-cycle. The papers published recently contain the propositions of innovative multiscale models, which take into consideration sophisticated material behaviour including microstructural phenomena. One of such approaches is Digital Material Representation (DMR), which offers the possibility of modelling in various length and time scales [3, 4]. The methodology can be used in models based on FEM as well as other alternative techniques like cellular automata (CA).

Contribution to development of the complex modelling platform based on DRM is the objective of this work. The review of the solutions available in the DMR field is presented in the subsequent section. Section 3 contains design and implementation details of proposed modelling platform, which is closely related to the idea of DMR but also equipped with additional simulation modules. The results generated by this platform are presented and discussed in section, 3 as well.

2 Idea of Digital Material Representation

The DMR offers possibility of material description in a complex form, which consists of various sets of metalurgical data. These components gather and analyse information that characterize material structure and properties in various scales. Thus, the input data for computer modelling methods, e.g. FEM or CA, can be easily prepared on the basis of such representation.

The more precise DMR is applied, the more realistic results of calclulations regarding material behaviour are obtained. Due to that solution, the detailed virtual analysis of simulation results can be performed, while errors of calculations are minimized. This allows the replacement of conventional methods, dedicated to determination of material properties, by the computer automatic analysis, which connects DMR with manufacturing processes modelling and with digital analysis of results (Figure 1).

The DMR concept was created quite recently, therefore, there are only few scientific publications, which consider this methodology. Interested approaches based on the idea of DMR are presented in [3, 4]. The basic assumptions of the proposed system in [3] joins the material structure with its basic properties, including grains morphology and texture. Such synthesized material is deformed and then investigated to obtain the properties of product after processing. The required additional data, like material phases, grains rheological models or their chemical composition, are stored in the external database. Since in this approach the phenomena occurring in other scales are not taken into consideration, the final results are reliable mainly in the macro scale analysis.

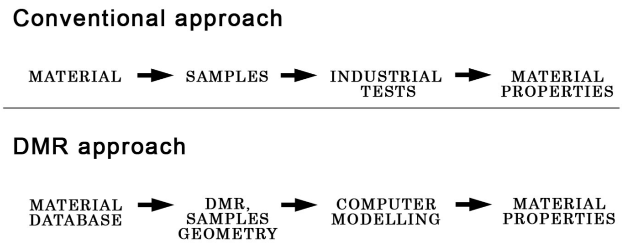


Figure 1. DMR basic concept in comparison to conventional approach [3].

The proposition presented in [4] is DIGIMICRO software, which supports 3D calculations based on DMR concept. The spatial microstructure is prepared by the Voronoi tessellation combined with additional optimization algorithms. The prepared material described by selected properties is used in simulations of compression tests. Simulations are performed using FE method, which is preceded by the process of microstructure anisotropic meshing. Final interpretation of results is facilitated by visualization module, which allows presentation of microsections sliced through the sample. Thus, the properties of digital material can be determined almost automatically and that reduces costs of real industrial trials. Works [3,4] became an inspiration for the Authors of this project to develop multiscale DMR engine, which is described below.

3 Multiscale DMR engine

The idea of computer system based on DMR methodology, which would be able to cope with problems of microstructural phenomena modelling in various scales and with analysis of real microstructures photographs, is presented in this work. The modelling platform equipped with such algorithms and external interfaces that are opened for new additional modules can be treated as a complex modular approach to modelling material behavior.

The main idea of the proposed modelling platform is presented on the first level deployment diagram in Figure 2. The basic DMR engine placed in the center of this scheme is responsible for interactions with users as well as for dynamic analysis and exchange of data between proposed modules. The subsequent steps of DMR engine algorithm can be enumerated as follows:

- Input data– it contains required initial conditions of the experiment gathered from users e.g. type of material, photograph of its microstructure, geometry of samples, type of experiment, range of temperatures, forces, etc.

- Reasoning – accordingly to the values of input parameters, the proper modules are selected e.g. dynamic recrystallization can be applied dependently on the range of temperatures and type of material
- Modelling – this stage consists of material structure preparation and its proper description, which is sent as DMR data. Afterwards the selected modelling algorithm is applied
- Visualization and interpretation – the last step is responsible for presentation of obtained results in the form of various 2D plots.

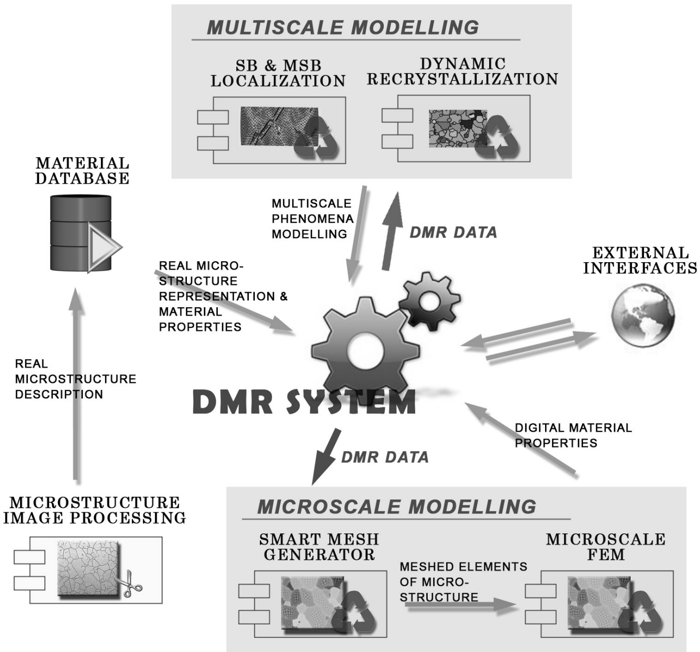


Figure 2. Main idea of developed complex modelling platform.

Each module presented in Figure 2 was designed and implemented (most of them in C++ and C#) by the Authors. Detailed specifications of particular modules functionality are presented in the following subsections.

3.1 Database Engine and Image Processing Support

The proposed database is implemented in relational database management engine MySQL and consists of five groups of tables. The first is dedicated to gathering of material properties, which describe specific material parameters in terms of environment termperatures and related metallurgical processes. Another tables store chemical composition of material and its rheological features. The next group is dedicated to general information, e.g. names or categories of materials. The last one gathers information about users, their passwords and contact data. The material database was implemented and is still developed as an internal project of MiTI

Department at the AGH – University of Science and Technology in Krakow, Poland.

Additionally, the module supporting data acquisition is attached to the system. The main objective of proposed module is processing of real microstructure photographs, gathered from optical microscope, and their automatic analysis to obtained digital representation of material microstructure [5]. The module's functionality is based on the usage of two internal algorithms i.e. modified Canny Detector [6] and Dynamic Particles filtering method [7]. The final result is presented in form of coloured image of microstructure, where each grain is marked with different colour. Moreover two text files containing grain borders description for meshing purposes and statistical characteristics of material are generated.

Presented above idea of the digital material representation directly fulfil the increasing need for accurate input data for advanced numerical analysis of material behaviour under loading conditions. Macroscopic material response is a result of complex interactions of various phenomena taking place in material at the same time but in different scales. Commonly used numerical approaches describe material behaviour mainly in macro scale. However, works related to nano or micro scale simulations using FE are becoming more and more popular [8].

3.2 Microscale Modelling

The meshing process consists of two tasks: (a) preparation of a special *control space* structure to provide the required sizing of elements throughout the domain and (b) discretization of the domain following the control space as closely as possible. The sizing information in the control space is stored in the form of an anisotropic metric and it can be automatically gathered from two geometrical sources, either from the user input or from the numerical adaptation process. All available sources are processed and stored in a single adapted control space (either quadtree or background mesh) structure using an adaptive procedure [9]. In the presented approach the control space is initialized with a uniform coarse sizing, which can be then further refined in a convenient way, by introducing a number of discrete metric sources at the areas of interests. After all discrete sources are inserted, the metric field is adjusted according to the prescribed element size gradation and it is then used for guiding the generation of a triangular mesh.

The meshing procedure starts with the discretization of domain contours. The created boundary points are triangulated using a modification of the Delaunay incremental insertion algorithm working in Riemannian space. The constrained triangulation is obtained by recovering all missing edges and removing obsolete elements. A number of additional points are inserted within the domain in order to achieve a *unit mesh* (i.e. mesh, where all edges have unitary metric length) property according to the control space. If the quadrilateral mesh is requested, a conversion procedure can be used. Finally, several methods of mesh post-processing are applied in order to improve the quality of elements (Figure 3).

Prepared mesh on the basis of the DMR can be used during investigation of behaviour of particular grains with different properties i.e. different crystallographic orientation.

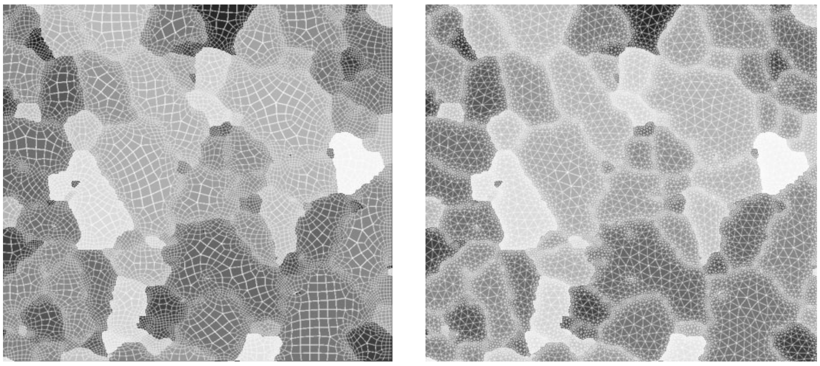


Figure 3. Digital microstructure obtained from the optical microscope image with applied mesh on the grains area.

Analysis of phenomena, which occur in the scale of single grains and their interactions, is a key to solve various problems that modelling of deformation processes has to face, i.e. the change in the deformation path, strain localization. Since such an analysis is crucial to support experimental observations, scientists are trying to capture these microscale processes [10].

3.3 Multiscale Phenomena Simulation

Disadvantage of conventional modelling techniques is lack of possibility to include discontinuous nature of material behaviour. A hybrid method based on the combination of Cellular Automata and Finite Element technique [11] overcomes that limitation and is one of the alternative numerical solutions. CA method is usually used to described material behaviour in micro and mezo scale. This method found wide range of application in simulation of microstructural changes i.e. modelling of static and dynamic recrystalization [12, 13]. The initial microstructure, with its geometry explicitly represented in the cellular automata space, is one of the key parameters that influence accuracy of the final results in these applications. DMR method provides a complex tool for such input data preparation (grain size, shape or grain orientation, material properties, etc.) used during further CA or CAFE calculation of micorstructure changes e.g. dynamic recrystalization [12].

A multiscale CAFE modelling of strain localization phenomena is another field of DMR application. Authors of this work have developed a model capable of simulation the development of micro shear and shear bands in micro and mezo scale, respectively, eventually leading to strain localization in macro scale. Detailed description of the CAFE model is described elsewhere [14], and schematic illustration of the algorithm is presented in Figure 4.

In each time step, information about the stress tensor is sent from the FE solver to the MSB space, where the development of microshear bands is calculated according to the transition rules [14]. After exchange of information between CA spaces, transition rules for the SB space are introduced, propagation of the shear bands is modeled and modified stress value is than sent back to the FE code.

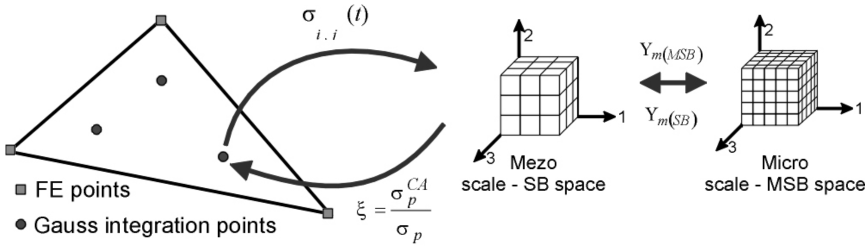


Figure 4. Information flow between scales in the CAFE model [14].

Comparison between results obtained from conventional FE approach and developed CAFE model is presented in Figure 5. It is seen in this figure that the CAFE model is capable to describe material behaviour more realisticly than the FE approach. However to obtain even more accurate results by the CAFE model the geometrical features such as grains have to be included in an explicit way in the model.

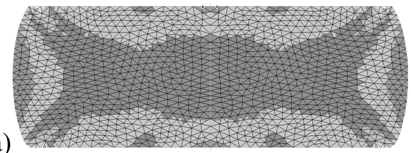
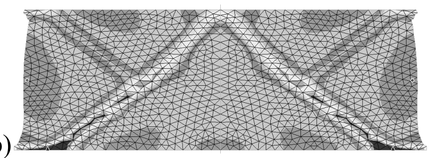
a)  b) 

Figure 5. Strain distribution obtained from the a) FE and b) CAFE simulation.

At this stage of the CAFE model development the microstructure is considered in an implicit way. However, it is known from literature [10] that influence of grain shape, size or orientation on micro shear and shear band development is crucial. That is why during further work, presented idea of DMR will be added to the developed CAFE model and complex analysis tool will be established.

4 Conclusions

Following the concept of Digital Material Representation presented in [3, 4] the complex solution dedicated to investigation of material behaviour under loading condition in micro, mezo and macro scale was developed. Presented model is an example of multi disciplinary approach to material science. From one side image processing techniques and MySQL database system, from the other side mesh generation algorithms and multi scale computational methods. Such an approach gives opportunity to overcome difficulties in precise modelling of material behaviour in various scales, what is of importance from the industrial application point of view. Future work will focus on further development of the system to extend its capabilities and to cerate a user friendly environment.

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Interoperability For Collaboration

Collaborative Implementation of Inter-organizational Interoperability in a Complex Setting

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Abstract. This paper explores the challenges in the collaborative implementation of inter-organizational interoperability through observations of social dynamics. We focus on an inter-organizational information system that has interfaces with several information systems managed by different organizations. This complexity increases degrees of difficulty of the implementation projects. Our main finding is that as the inter-organizational nature of the problem increases considerably the technical complexity of the implementation, it also significantly increases difficulties in the social dynamics. We argue that a careful analysis of these social issues can reveal some interesting viewpoints that otherwise may stay hidden. We limit this paper to consider only the implementation of an inter-organizational information system that is implemented to support pre-defined joint functionalities.

Keywords. Interoperability, implementation, inter-organizational information system, collaboration, social dynamics

1 Introduction

Inter-organizational information systems are implemented because they inevitably increase the possibilities of organizations to collaborate with each other [7, 15, 26]. Inter-organizational information systems allow, for example, enterprises to participate in the e-economy by enabling cross-organizational connections in a network or supply chain. Information system implementations are described challenging efforts that require expertise, insights and skills of several individuals [23]. Information technology has enabled ever quicker information sharing and transfer across organizational borders and this has come true because modern technology enables interaction without physical attendance. By saying this, we want to emphasize the increased interaction among people in organizations but also between organizations. However, implementing collaboration technology in inter-

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organizational settings may cause additional complexity compared to intra-organizational implementations [18].

Enterprises and other organizations have acknowledged the benefits gained from collaboration and joint ventures. The increasing attention of interoperability issues in information systems was noted in 1995 when Manola introduced his study on interoperability in large-scale distributed object systems [16]. His focus is on enterprise-wide client-server systems that are developed to support operational computing. Furthermore, Southon *et al*. [22] note that especially participating organizations with a degree of autonomy have much to gain from cooperation.

In this paper, we explore, from the social dynamics point of view, the issues that are to be faced as organizations build a joint information system. Especially, we try to give some in-depth insights to the challenges of that task. Our research methods were case study and participatory observation. The study material was gathered from a single case where several organizations from academia implemented an information system to support their mutual collaboration. Despite academic background of the research material we believe that our results are fairly well applicable to situations where enterprises are implementing inter-organizational information systems to support concurrent engineering methods.

One of the researchers participated in the case while collecting the material. She was acting as a project manager and thus she was also able to influence the goings in the implementation project. The research approach was very subjective and the interpretations based mainly on subjective experiences. However, there were several sources used when performing the study and the principles expressed by Klein and Myers acted as a backbone in the research [13].

2 Information System Implementation and Interoperability

Modern technology enables organizations to interact with each other without physical contact or attendance [17]. Close interaction is necessary when enterprises and other organizations collaborate with their partners or with their surrounding society. Inter-organizational information systems are planned to transfer information across organizational borderlines [10]. In recent years inter-organizational information systems have increasingly tended to support partnering among organizations [8] and organizations should link with each other to perform effectively in present-day environments [3].

In this paper, we consider implementation as an entire process from needs analysis and choice of technological solution, to the realization of the full benefits from the technology [18]. Information system implementations are also instances of organizational change ([4, 20]. Organizations and information systems are closely related because there is ever growing interdependence between business strategy and information systems and telecommunications [15]. Any change in this relationship requires changes in other components of the relationship.

In many organizations, information is distributed over several information systems and an exchange of information is often very difficult [6]. This distribution can be described with three layers: 1) business architecture that defines the organizational structure and the workflows for business rules and processes; 2) application architecture that defines the actual implementation of the business concepts coded in the application; and 3) technology architecture that defines the information and communication infrastructure where information technology tries to meet the business requirements.

The chosen architecture sets requirements also to interoperability. 'Interoperability' is a general concept that has different contents depending on the context it is used. NATO, the US and Australia define: "The ability of systems, units and forces to provide the services to and accept services from other systems, units or forces and to use the services so exchanged to enable them to operate effectively together." [1]. A more common definition states: "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" [9].

Manola notes the importance of interoperability at many different levels *e.g.*, physical level (data presentation) and object-model level (agreements on object interface characteristics) [16]. He extends the need of interoperability to semantic interoperability with agreements on meaning. He concludes that providing interoperability in large-scale business systems can be a long process.

Interoperability is recognized as the most critical issue facing businesses that need to access information from multiple information systems [19]. In their study on facilitating semantic interoperability among distributed and heterogeneous information systems Park and Ram highlight multiple interpretations of data by different users and systems in different contexts.

Klischewski describes how both interoperability and cooperation are needed to enable cross-organizational integration [14]. He argues that there are two prominent concepts pointing to different directions:

1) Information integration that aims at facilitating information flow across technical and organizational borders and

2) Process integration that focuses on interrelating steps and stages of process performance across technical and organizational borders. Klischewski concludes that it is important to understand three issues:

1) Interoperability requires a guiding vision of integration,

2) Each type of integration points to a different set of ideas, assumptions and technical means, and

3) Integration implies a strategic commitment to explicit forms of cross-organizational cooperation and their implementation before it can be modified into digitized mode.

3 Research Approach

This research was qualitative. Therefore it enables and requires the researchers to explain the research setting in detail enough to help the reader to understand the research approach. When explaining the case the role of interpretation is recognized, paying attention also to the experience that inevitably influences our actions [25]. The means of case study and participatory observation have been chosen due to their convenience in our research.

The use of participatory observation was realized especially when the researcher who acted as a project manager, was not active in the actual development work but observed and made notes while the experts in that area were working [5, 12]. However, the research approach was not emphasized in the project meetings because the utmost goal from the organizational view was to get the information system implemented.

The research material was collected as memorandums from project meetings and emails from the files of the project manager. Some of the memorandums were written by the project manager, the others by other people who were present in the meetings. The memorandums were accepted according to the protocol in the consequent project meetings and thus they give objective description about the situation. In addition to the official memorandums, the researcher wrote notes from discussions and encounters. There were no tape-recordings because some attendees denied their use in the meetings. This research aims to present the case realistic, pointing critically out some issues that appear problematic [24]. However, the confessional style is present due to the personal research material of the researcher.

Furthermore, the researcher was keeping a personal diary while managing the project and saved her observations there [2, 11, 21]. Interviews were not conducted, because the researcher was acting as a project manager and thus she might have influenced the opinions of the interviewees.

Totally independent source of research material came from the feedback that was voluntarily given by the end-users. At the end of the project altogether 580 feedback notes were sent to the project management.

4 The Case and Findings

The case in our research consists of an information system project where an inter-organizational information system (called I-System in this paper) was designed and implemented to be piloted before taking into nation-wide use.

In the project there were several organizations involved and they had chosen their representatives to participate in the project group. A commercial vendor was hired to implement the system. Due to the inter-organizational nature, the information system was to be implemented among several other information systems. In addition, due to the inter-organizational nature, also the interfaces between the necessary information systems had to be implemented.

The project started its actions in the summer 2003 when the first sketches about the future I-System were drawn on a blackboard. I-System was aimed to support the collaboration between the participating organizations and the information systems owned and managed by the organizations were considered in the very beginning. I-System was to be built on specifications that were made in another project by other stakeholders. Already then there were ideas about having several information systems to be connected with each other. Information would be transferred via utility files. An important risk was recognized: if the necessary connections were implemented one at a time, the interaction between the parties could become problematic. (Memorandum June 16, 2003).

The importance of the new information system was realized by one participant: *"If the information system will not be implemented, the actions will be declined in our organization. The stipulation for the nation-wide actions will be an information system!"* (Memorandum September 12, 2003). The chairman stated in the same meeting: *"Our motive is to get this information system as soon as possible because it's impossible to act in the current way."*

I-System was to have both intra-organizational and inter-organizational interfaces. The intra-organizational interfaces are described in Figure 1.

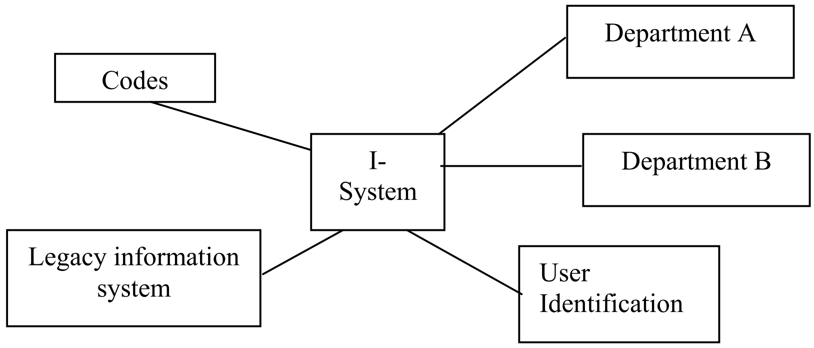

Figure 1. Intra-organizational interfaces

Figure 1 presents I-System connected with several other information systems in the organization. The users must be identified before letting them log into the system. Furthermore, there were several departments in the organizations and they had their own procedures how to act and manage their functionalities. The organizations had their own codes and abbreviations that were found in their database. And further, I-System was connected with the legacy system used in the organization.

Even if the need of several interfaces between information systems was realized in the first meetings, the building of the interfaces was not self-evident. The need to transfer information between information systems was discussed every now and then in the project meetings when the users wanted to have information to be transferred to their main systems. The users got positive response: *"They are planning to make changes that enable external information to be received."* (Memorandum May 4, 2005). However, the plans were not made concrete in the legacy systems.

On the other hand, it appeared that the legacy systems were not open to let other systems to access them. *"No files may be directly transferred to their servers."* (Memorandum August 24, 2005). This issue was discussed every now and then in the project. This discussion evolved especially when there were changes in the project personnel. *"We will probably build an interface in the legacy information system to enable automatic data input. In the future the data could be transferred automatically from I-System."* (Memorandum October 4, 2006). The answer remained the same: *"So far no automatic writing to the receiving systems may be done."* (Memorandum November 2, 2006).

I-System was planned to support collaboration between the participating organizations and this character necessitated interfaces to be build according to the organizations. Because the organizations were interdependent and they had their own information systems, the interfaces differed from each other. In the beginning there were only three user organizations participating but the number of them increased smoothly. In addition, in the development work there were other organizations needed that were responsible *e.g.*, some of the legacy systems and data administration. We perceived problems with commitment by some of the organizations, though. The project manager got email (September 16, 2004): *"It really seems that all tasks that were assigned to Acro [pseudonym] are left half-way."* There were problems with the user organizations, too. The project manager got email May 12, 2005: *"The situation is as before. We'll start the technical implementation at the end of the summer*." This email discussion continued on February 10, 2006: "*The progress has been slow. The specifications are almost ready. We'll try to get this fixed in the second quarter*." However, the assignment was not completed until the project was ended.

We also perceived reluctance in delivering information in organizations when there was need to get changes made in other information systems. On several occasions it was found that knowledge was not available there where it was needed. *"I'm sorry about this outburst but we don't really know anything about this task and this 'cgi' is everything we have been told even if we wanted to know something else about it, too!"* (Email August 8, 2005). This problem in interaction was evident *e.g.*, when the interfaces to offer data from a legacy information system were needed. We also noticed that the need was not informed to the actors that were responsible for the new functionality. *"We [project managers] cannot push them to transfer information in their organization. They have been present when we have discussed about transferring data between I-System and their information system."* (A phone call to the project manager from the vendor).

This reluctance also influenced interoperability between organizations because the information needed was not available in I-System that was to use it and to deliver it forward.

5 Conclusions

When analyzing research material we must be conscious of the interpretative nature of the task. In this sense, our personal experience influences also this, however, how objective we try to be in our approach.

We witnessed that high felt motivation from the very beginning was driving the project forward. All the same, motivation perceived by some people is not enough if pertinent people are not motivated. Due to the diversified setting with several actors interoperability was difficult to carry out. In our case, all desirable information was not available when users needed it in the new information system.

Further, we also noticed that not all needed information was forwarded in the organizations especially in case of distributed departments and units. This lack of information sharing inhibited future development and influenced also plans to develop I-System.

On the other hand, a higher level of interoperability was expected from the legacy system's point of view as new people asked for "automatic information transfer" from I-System. Again, this proposition was an evidence of new needs for close collaboration and interoperability between the information systems. So far no automatic transfer was allowable here but we believe that changes will be made in the near future. Because this specific need was expressed by the master information system, the feature is expected to be implemented before long.

In summary, the main results were: 1) despite the high motivation towards the joint information system there can be a considerable lack of information sharing; 2) during the implementation new expectations of higher interoperability may appear that hinder the progress of the project; 3) difficulties in the social dynamics are increased considerably due to the inter-organizational nature of the setting.

We believe that the issues found in the present study are quite common to all projects that try to implement inter-organizational interoperability. Our findings came from a single case and thus it is quite natural to expect that future work is needed to confirm these results.

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FICUS - A Federated Service-Oriented File Transfer Framework

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Abstract. The engineering data of a large enterprise is typically distributed over a wide area and archived in a variety of file systems and databases. Access to such information is crucial to team members and relevant processing services (applications, tools and utilities) in a concurrent engineering setting. However, this is not easy because there is no simple way to efficiently access the information without being knowledgeable about various file systems, file servers, and networks, especially when complex domain related data files get bigger. In a concurrent engineering environment, there is every need to be aware of the transparent and dynamic data perspectives of the other members of the team.

We have developed a Federated Service-Oriented File Transfer Framework called FICUS (Files In Chunks Utilizing Storage) with the objective to form dynamic federations of network services that provide engineering data, applications and tools on a grid. This framework fits the SORCER philosophy of grid interactive service-oriented programming, where users create distributed metaprograms using federated providers along with FICUS repository providers.

Our paper describes the methodology of how FICUS works along with the details of the implementation and extensions planned for the future. We believe the performance and reliability offered by FICUS will make it a very useful distributed file transfer protocol for a large design team and will make it very convenient to integrate heterogeneous legacy file systems.

Keywords. Data sharing, distributed file systems, federated systems, collaborative work.

1 Introduction

Managing engineering data is becoming an increasingly complex task. Heterogeneity of hardware and software platforms is one of the barriers to be overcome in achieving this end. With increasing use of computers, we have islands of automation that have resulted in information archival in legacy file systems.

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This makes the access to information easy for someone who uses a single repository as their primary or native environment. However, the information access problem increases manyfold when one wishes to access enterprise-wide information. Access to enterprise-wide information is very important in a collaborative setting when a number of people access a corpus of information, albeit with different perspectives. Major problems to be addressed include how to integrate all the information, how to deal with legacy systems and how to provide a wide view to the user abstracting all the hardware and software specifics of the individual systems. The federated service-oriented file transfer framework (FICUS) we describe in this paper enables access to distributed and replicated information over a wide area with special emphasis on efficient access to data repositories. This includes CAD drawings and other kinds of raster and vector data, in addition to voice and video clips that will be archived in the future. The need for accessing distributed information by people viewing from different perspectives arises in a concurrent engineering setting. Also, the efficient file download by many services sharing the same data becomes essential when requestors share the same copy of a master file at the same time.

Building on the OO paradigm is the service-object-oriented (SOO) paradigm, in which the objects are distributed, or more precisely they are remote (network) objects that play some predefined roles. A service provider is an object that accepts remote messages, called service exertions, from service requestors to execute an item of work. A task exertion is an elementary service request – a kind of elementary remote instruction (statement) executed by a service provider. A composite exertion, called a job exertion, is defined in terms of tasks and other jobs - a kind of procedure executed by a service provider. The executing exertion is a SOO program that is dynamically bound to all relevant and currently available service providers on the network. This collection of providers identified in runtime is called an exertion federation, or an exertion space. While this sounds similar to the OO paradigm, it really isn't. In the OO paradigm, the object space is a program itself; here the exertion space is the execution environment for the exertion, which is a network OO program. This changes the game completely. In the former case, the object space is hosted by a single computer, but in the latter case the service providers are hosted by the network of computers. The overlay network of service providers is called the service provider grid [5-7, 9] and an exertion federation is called a virtual metacomputer. The metainstruction set of the metacomputer consists of the method set defined by all service providers in the grid. Do you remember the eight fallacies of network computing? Creating and executing a SO program in terms of metainstructions requires a completely different approach than creating a regular OO program. In other words, we apply in FICUS the OO concepts directly to the service provider grid.

The SORCER environment [1, 10, 14-16, 20, 22-28] provides the means to create interactive SOO programs and execute them without writing a line of source code via zero-install, interactive service interfaces. Exertions can be created using interactive user interfaces downloaded directly from service providers, allowing the user to execute and monitor the execution of exertions in the SOO metacomputer. The exertions can also be persisted for later reuse. This feature allows the user to quickly create new applications or programs on the fly in terms of existing tasks and jobs. SORCER introduces federated method invocation based on peer-to-peer (P2P) [17, 18] and dynamic service-oriented Jini technology [4, 8, 12, 13, 18, 19, 21].

To integrate applications and tools on a B2B grid with shared engineering data, the File Store Service (FSS) [5] was developed as a core service in FIPER/SORCER. The value of FSS is enhanced when both web-based user agents and service providers can readily share the content in a seamless fashion. The FSS framework fits the SORCER philosophy of grid interactive SOO programming, where users create distributed programs using exclusively interactive user agents. However FFS does not provide the S2S flexibility with separate specialized and collaborating service providers for file storage, replication, and meta information that have been added in the SILENUS federated file system [1].

In this paper, the FICUS federated service-oriented file transfer framework is described that allows an exertion federation for collaborative, efficient data sharing across federating service providers in terms of files split into smaller chunks that are replicated and stored at multiple locations.

2 FICUS Architecture

FICUS has been designed to explore the file sharing concepts used in modern peer-to-peer technologies such as BitTorrent [2, 3], and investigates how they can be applied to a file system. FICUS is an extension to SILENUS, a federated file system developed at Texas Tech University [1]. The SILENUS file system is comprised of several network services that run within the SORCER environment, each of which provides a functional aspect of the file system. These services include a byte store service for holding file data, a metadata service for holding metadata information about the files (such as file names), several optional optimizer services, and façade services to assist in using these services. SILENUS is designed so that many instances of these services can run on a network, and the required services will federate together to perform the necessary functions of a file system. FICUS adds support for storing very large files within the SILENUS file system by providing two more services: a splitter service and a tracker service. When a file is uploaded to the file system, the splitter service determines how that file should be stored. If a file size is above a predetermined threshold, the file will be split into multiple parts, or chunks, and stored across many byte store services. Once the upload is complete, a tracker service keeps a record of where each chunk was stored. When a user requests to download the full file later on, the tracker service can be queried to determine the location of each chunk and the file can be reassembled.

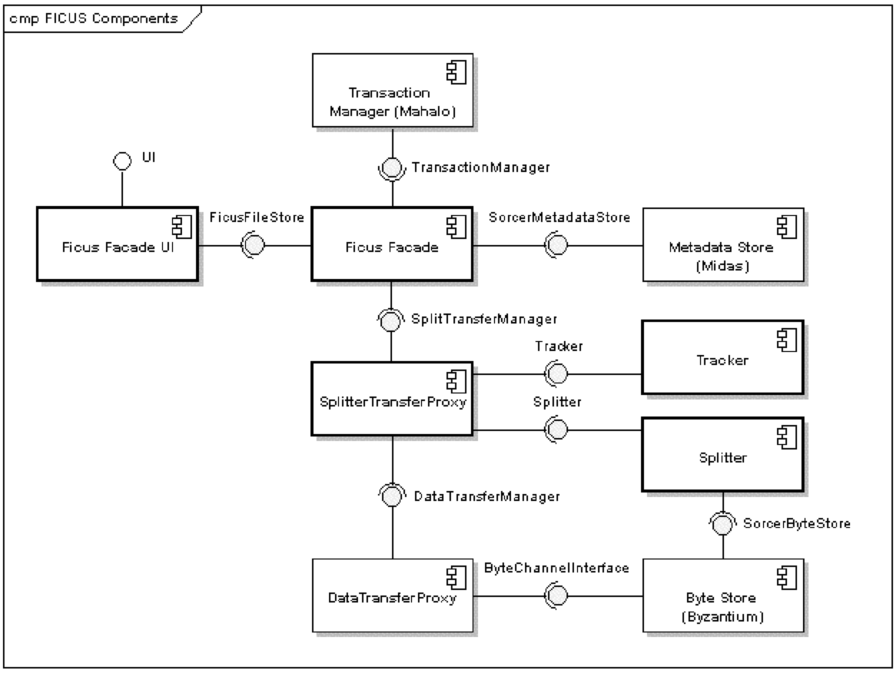

Figure 1. FICUS component diagram

2.1 Splitter Service

BitTorrent [2, 3] doesn't really have any set rules for determining file splitting parameters other than that all pieces must be of the same size (except for possibly the last piece) and the piece size in bytes must be a power of 2. It is normally left up to the hosting user to determine what the piece size should be used. In a file system, this decision should be handled automatically and transparently and should not bother end users with the specifics. Thus, a splitter service is responsible for determining whether or not a file should be split, and if so, what parameters should be used for splitting. Administrators can affect many of the parameters used in making this decision in order to optimize network, storage, and file usage. For example, an administrator can specify the minimum file size required for a file to be considered for splitting. A minimum and maximum chunk size can be specified along with a minimum and maximum number of file splits to use for any file. The splitter can use this information to calculate the optimum chunk size to use for a file based on the file's size and possibly other parameters as well, such as available storage space on each of the byte store services.

The splitter also provides services for splitting and reassembling large files on the requestor side through the use of proxies. A splitter proxy object can concurrently manage multiple byte store proxy objects for communicating directly with various byte store services. When a user or other agent uploads a large file, the splitter proxy can send parts of the file simultaneously to individual byte store services to store as chunk files. A splitter proxy could then download these chunk files from the multiple byte stores simultaneously and save them as file segments to recreate a copy of the original file.

2.2 Tracker Service

BitTorrent uses a tracker to help peers discover each other and to help peers determine the location of desired file pieces. A tracker service for FICUS provides similar functionality. When a large file is uploaded in chunks to the file system, the location of each chunk is recorded and this information is given to the tracker for storage in a database. During replication, a replicator service can also notify the tracker of any new chunk files that have been made. In addition to chunk locations, the tracker also records the size of the original file, the chunk size used, how many chunks a file has been split into, and an optional checksum for each chunk to see if the chunk file has been corrupted. When a split file needs to be retrieved, the tracker can be queried to find the locations of each chunk needed to completely reassemble the file.

Since a tracker service handles location information for files, it acts as a logical extension to a metadata store service. When a file is stored on a byte store service, the byte store names the file with a UUID to provide unique and persistent identification for the file content. The metadata store normally keeps track of where a file is located using the service ID of the byte store upon which a file is stored along with the file's UUID. In the case of split files, a tracker service records this information for each chunk file while the metadata store records the service ID of any tracker services that are tracking the file along with a similar UUID with a numeric extension to refer to the record number of the file within the tracker.

2.3 Façade Service

With the inclusion of these new services, an updated façade service is needed to assist with the coordination of the various file system services. Specifically, the façade service is responsible for discovering the metadata store services needed for browsing through the file system, and splitter services to initiate file storage and retrieval. When uploading files or performing other operations that require data alterations on more than one file system service, the façade is also responsible for keeping these actions under transactional semantics to verify that all required operations either complete successfully or abort. Due to the nature of the façade service, it can act as an entry point for other services into the file system. Through the use of a service browser such as Inca X [11], a user could obtain a GUI (ServiceUI [21]) for a façade service and interact with the file system directly without the need to install any additional software. The façade could also be used to manage and distribute remote event notifications. For example, once an upload has completed, a façade service could notify a replication service with the appropriate information to begin replicating the new file to additional storage services.

3 Uploading and Downloading

Many of the concepts found within FICUS can be compared to those found in other Internet based peer-to-peer programs such as BitTorrent. For example, in the case of BitTorrent, users can typically use their favorite web browser to find and download relevant torrent files located on public web servers. Similarly, a FICUS façade service can help users locate files they want from the file system using file records found on metadata store services. BitTorrent uses torrent files that contain meta-information about a file or set of files along with a URL for an Internet based tracker service used for connecting to peers. In FICUS, the metadata entry for a requested file contains a reference to a FICUS tracker service to use, which holds additional metadata information about the file along with file chunk locations. A BitTorrent client application can be used to acquire and share pieces of a file with peers. Similar functionality is handled by a proxy object provided by a FICUS splitter service. The following sections provide more information about how files are uploaded and downloaded using BitTorrent and FICUS to provide a better understanding of how the two compare.

3.1 BitTorrent

BitTorrent is a peer-to-peer technology that has become quite popular over the past few years. It allows a person to share a large file (or set of files) with many users while transferring relatively little data. It accomplishes this task by breaking the file into smaller pieces that can be quickly shared between other users. Once a user has downloaded a file piece, it can send the completed piece to other users who still require it. In essence, the upload bandwidth required to share the file is now distributed amongst the peers rather than making a single server solely responsible for doing all the uploading. User systems within the peer "swarm" are able to find each other and figure out which systems have desired pieces through the use of a tracker service running on the Internet.

In order to begin serving a file, a user would go through the following steps.

1. Find a tracker to manage the peers involved in transferring file pieces.
2. Generate a metainfo (torrent) file using the complete file to be served and the URL of the tracker.
3. Upload the torrent file to a website.
4. Start a BitTorrent client using the torrent file to begin seeding the full file.

Downloading the full file involves the following steps.

1. The user finds and downloads the torrent file from the web server.
2. The user loads the torrent file into their BitTorrent client.
3. The BitTorrent client connects to the tracker to find other peers.
4. The BitTorrent client downloads pieces of the file from others and shares the pieces it has with others.

Once all pieces are distributed into the peer swarm, clients can share with each other until they all have the full file.

3.2 FICUS

FICUS uses a methodology similar to BitTorrent for uploading and downloading files. However, since FICUS is a file system rather than simply an Internet file sharing service, there are some differences between these methods.

In order to upload a file to a FICUS file system, the following occurs.

1. A user requests to upload a file.
2. A façade service forwards file parameters to a splitter service to determine how to handle the file.
3. If the file is large, the splitter will get a reference to a tracker service and send back a splitter transfer proxy.
4. This proxy is sent back to the user end and is given a reference to the file.
5. The proxy sends pieces of the file to byte store services to store as chunks.
6. The location of each uploaded chunk is recorded by the tracker.
7. The tracker's service ID along with the file's record number are given to a metadata store service to indicate where the file locations can be found for future retrieval.

In order to download a file from a FICUS file system, the following occurs.

1. A user requests to download a file.
2. A façade service queries the location of the file from a metadata store.
3. If the file is split, it is forwarded to a tracker.
4. The tracker provides the locations of each chunk.
5. The chunks are downloaded from various byte store services and assembled into the full file.

4 Conclusions

FICUS is able to provide several benefits over traditional client-server file system in which file's are stored in their entirety. Many of these benefits stem from the service-to-service oriented nature of SORCER along with the file splitting capabilities of FICUS. In a traditional client-server based network file system, a large amount of storage space must either be found or created in order to store large amounts of data, especially if the data is contained in only a single file. The speed at which this data can be provided to others is usually limited by the maximum bandwidth available to the server, which can cause severe bottlenecks if many clients request the same data at once. If an error occurs during a file transfer, the client often has to restart the transfer from the beginning, which wastes time and magnifies the bottleneck issue. If the file server goes down, then these files are typically unavailable until the server can be restored. Basically, the major disadvantage of storing whole files within a client-server type file systems is that the server can easily become a single point of failure. To help alleviate this problem, many file servers run on expensive, high end, redundant server equipment. High speed RAID arrays are often employed to not only help recover from a hard drive failure, but also to provide increased throughput for client requests. Additionally, servers are often placed on high speed network segments to handle the necessary bandwidth requirements.

Many of these problems can be avoided by splitting large files into chunks and by using a service-to-service type architecture as provided by SORCER. By storing files in chunks across multiple storage locations, storage and network requirements become much more distributed. For example, when storing a large file, it is usually much easier to find several storage locations with lesser amounts of free space than it is to find a single location with a massive amount of free space. When downloading files, there may be several different storage locations that have the requested data rather than just a single server, thus it is far less likely for any single storage location to become a bottleneck due to a high number of file requests. If files are spread across multiple locations in chunks, a client could download multiple chunks simultaneously, thereby using the aggregate bandwidth of all storage nodes rather than the available bandwidth of just a single server. If an error occurs during a file transfer, then only the erroneous chunk would have to be transferred again rather than the full file, which can save a lot of time and waste less bandwidth.

The concepts and methodologies proposed by FICUS provide other opportunities for enhancing a file system as well. For example, after making a modification to a large file, it may be possible to save only the relevant chunk files that have changed rather than the entire file. This technique has the potential to save drastic amounts of bandwidth and storage space, especially when storing multiple versions of the same file. Special optimizer services could be designed for replicating chunk files that are used most often to more stable and higher powered machines, thus providing greater availability for frequently accessed data. Overall, the concepts proposed by FICUS provide many different avenues for exploration to enhance the scalability, reliability, and performance of distributed network file systems.

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Lessons Learned from the SILENUS Federated File System

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Abstract: The major objective of the Service Oriented Computing Environment (SORCER) is to form dynamic federations of network services that provide engineering data, applications and tools on an engineering grid with exertion-oriented programming. To meet the requirements of these services in terms of data shar-ing and managing in the form of data files, a corresponding federated file system, SILENUS, was developed. This system fits the SORCER philosophy of interactive exertion-oriented programming, where users create service-oriented programs and can access data files in the same way they use their local file system. This paper gives a brief overview of SORCER and then the SILENUS methodology is described.
Next, we discuss SILENUS gateway, management, and data services with related disconnected and data synchronization mechanisms. We also discuss experimental results of the implemented system.

1 Introdution

In an integrated environment, all entities must first be connected, and they then must work cooperatively. Services that support concurrency through communication, team coordination, information sharing, and integration in an interactive and formerly serial product development process provide the foundation for any CE environment. Product developers need a CE programming and execution environment in which they can build programs from other developed programs, built-in tools, and persisted data describing how to per-form complex design processes. Like any other services in the environment, a CE distributed file system can be structured as a collection of collaborating distributed services enabling for robust, secure, and shared vast repository of

engineering enterprise data.
Several systems exist to access data that is spread across multiple hosts.
However, except for a few exceptions, all of them require manual management and knowledge of the exact data location. Very few offer features like local caching or data replication.
Under the sponsorship of the National Institute for Standards and Technology (NIST) the Federated Intelligent Product Environment (FIPER) [12][13][11] was developed (1999-2003) as one of the first service-to-service (S2S) CE com-putting environments. The Service-Oriented Computing Environment (SOR-CER) ([15], [14], [16]) builds on the top of FIPER to drastically reduce design cycle time, and time-to-market by intelligently integrating elements of the de-sign process by providing true concurrency between design and manufacturing.
The systematic and agile integration of humans with the tools, resources, and information assets of an organization is fundamental to concurrent engineering (CE).
Two years ago we introduced a novel approach to share data across multiple service providers using dedicated storage, meta information, replication, and optimization services in the SORCER/SILENUS environment [1], a ser-vice oriented approach to distributed file systems. The access via WebDAV adds to the idea of heterogeneous interactive programming, where the user through its diverse operating system interfaces can manage shared data files and folders. The same data can be accessed and updated by different ser-vice providers and authorized users can monitor data processing activities executed by the service providers involved with co-operating WebDAV user agents. Like any other services in the P2P environment, the SILENUS services are also peers in the SORCER environment.
The paper is organized as follows. Section 2 provides a brief description of the dynamic service object oriented computing; section 3 describes the SILENUS methodology; section 4 presents disconnected operation and data synchronization; section 5 describes experimental results using the NFS adapter; section 6 provides concluding remarks.

2 Service Oriented Computing

Instead of thinking of a service offered by a particular host, the current paradigm shift is towards services in the network – the metacomputer is the grid of service providers . In classical distributed applications, it is necessary to know exactly on which host a particular service is exposed. In most dis-tributed file systems, for example, it is necessary to know the name of a host that a particular file is stored on. In a service-oriented (SO) environment a service provider registers itself with a service registry. The service registry facilitates lookup of services. Once a service is found a service requester binds to the service provider and then can invoke its services. Service requesters discover a registry and then lookup a needed service. On the other hand, a provider can discover the registry and publish its own service, as depicted in Figure 1.

In the service protocol-oriented architecture (SPOA), a communication protocol is fixed beforehand and can not be changed. Based on that protocol and a service description obtained from the service registry, the requester can bind to the service provider – create a proxy used for remote communication over the fixed protocol. In SPOA a service is usually identified by a name and/or some attributes. If a service provider registers by name, the requesters have to know the name of the service beforehand.

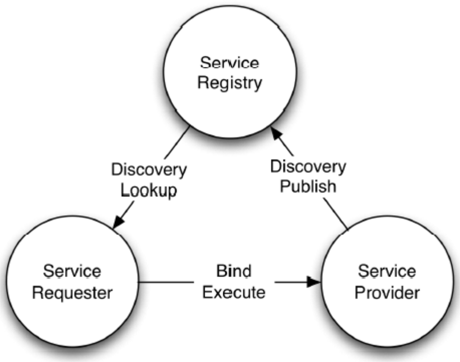

Fig 1. Service-Oriented Architecture

In the service object-oriented architecture (SOOA), a service is identified by a service type (interface) rather than its implementation, protocol. Registering services by interface has the advantage that the actual implementation can be replaced and upgraded independently from the requesters to which only interfaces have to be known. Different implementations may offer different features internally, but externally have the same behavior. This independent type-based identification allows for exible execution of service-oriented programs in an environment with replicated services. In SOOA, a proxy – an object implementing the same service interfaces as its service provider – is registered with the registries and it is always ready for use by the requester.

In a federated service environment not a single service makes up the system, but the cooperation of services. Services can be broken down into small component service instead of providing one huge all-in-one service. These smaller component services then can be distributed among different hosts to allow for reusability, scalability, reliability, and load balancing. Instead of applying these metacomputing concepts to compute services only, they can, and should, also be applied to data services as well. Once a file is submitted to the network it should stay there. It should never disappear just because a few nodes or the network segment goes down. Also, it should not matter what client node the file is requested from. With the SILENUS distributed file system in place, SORCER also provides transparent, reliable, and scalable file-based data services complementing the existing compute services.

SORCER is a federated service-to-service (S2S) metacomputing environment that treats service providers as network objects with a well defined semantics of dynamic service object oriented architecture (DSOOA) based on the FIPER methodology [12][13][11]).

2 SILENUS Methodology

SILENUS is based on a dynamic service object oriented architecture. As such, it consists of individual service objects, which, when combined, provide the SILENUS functionality. These components can broadly be categorized into gateway components, data services, and management services. Figure 2 gives an overview of the SILENUS architectural components.

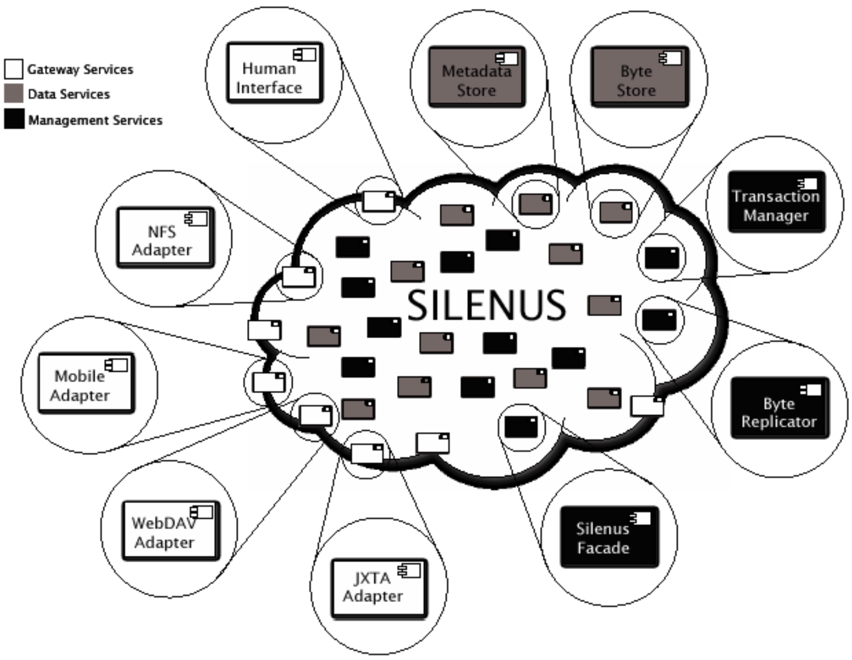

Fig. 2. Component services of the SILENUS architecture

To store data in the SILENUS file system, the following assumptions about the data are made:

• File metadata is relatively small. Therefore there is no a problem to replicate the file metadata.
• File content is relatively large. Therefore files should be replicated for reliability, but not onto every system.

• Management data, e.g., proxies to needed services and transactions, can be handled autonomically. That type of data does not have to be known to requesters explicitly, but it can be dynamically discovered in runtime in the SILENUS environment.

3.1 Gateway Services

The Service Interface, NFS Adapter, Mobile Adapter, WebDAV Adapter, and JXTA [6] Adapter are client modules. Each one of them serves a particular type of client. The ones given here are just examples, adapters could be written for any other existing file storage solution. The service interface (ServiceUI) [10] provides support for file storage and management through a proprietary user interface attached to a service provider. It provides access to the extra fea-tures, which are not available through the other interfaces: advanced features such as manual migration, number of replicas, log-file viewing, and others. The service interface should only be needed for these extra features and can be ignored by most users. The WebDAV Adapter provides support for oper-ating systems that have support for WebDAV, such as Windows, Mac OS X, and newer UNIX systems. It provides support for existing applications. This gives current operating systems the possibility to use the SILENUS file storage directly with no need to install any additional support. The NFS adapter provides support for older UNIX systems that do not have WebDAV prein-stalled. These adapters are just examples of various mappings from SILENUS to existing systems, other adapters can be developed as well.

3.2 Management Services

The SILENUS Facade and Transaction Manager provide coordination ser-vices. To make the client modules even smaller, the coordination between the client modules and the providing services is sourced out to the SILENUS Facade. Facades are gateways to the SILENUS file storage for both user agents and service providers. Each Facade provides a dynamic entry point to the underlying SILENUS file metadata and content storage services. It takes care of transactional semantics between file content and meta information storage. The facade provides support for discovering the relevant services that participate in a requester’s file upload/download federations. A Transaction Manager is used for ensuring two-phase commit transactional semantics for file uploads that involves at least metadata store and byte store services. The Transaction Manager used in SILENUS is a Jini [3] standard service for handling transactions in a distributed environment. The Byte Replicator and other optimizer services provide support for autonomic computing. In a classical data storage solution, an administrator has to manually move and distribute files among different servers. In SILENUS, this is done by optimizer services. These services will analyze the current network conditions and make decisions on where to store files, where to keep replicas, and even when to startup and shutdown services needed and underutilized ser-vices.

Each optimizer service is a separate component, allowing the SILENUS administrator to chose exactly which kinds and how many optimizer services to run on the network.

3.3 Data Services

The Byte Store provides functionality for creating and retrieving file content. The Byte Store does not provide file attribute storage. It does, however, provide support for retrieving attributes that are derived from the file data. Such attributes include file size and checksums. These can be used to verify the integrity of file contents. The Byte Store provides fast access to the files stored on the provider's host. Stored files are usually encrypted, but can be stored unencrypted for performance reasons.
The Metadata Store provides functionality to create, list, and traverse directories. It also provides functionality to retrieve the file data location. File metadata is all the information that is either included in the actual file data or that can be derived from the file data, such as file name, creation date, file type, type of encryption, and others. As a matter of fact, the file storage location, the file name, and even the directory a file is in are nothing different than just three file attributes. This allows all these attributes to be handled in a standard way persisted in the Byte Store's embedded relational database. Multiple versions of one file may exist in the database for recovery purpose.

4 Experimental Results

The SILENUS system was designed and implemented as part of a dissertation research at Texas Tech University [2]. Over the course of three years, the system has been designed, refined, and implemented. The core services, some management services, and some gateway services have been implemented and deployed in the SORCER Lab environment. The NFS adapter was used to test the SILENUS framework performance.

What	0 KB	10 KB	1MB	100MB
Disk to disk (local)	0.0 sec	0.0 sec	0.0 sec	0.7 sec
Disk to SILENUS	0.2 sec	1.6 sec	1.7 sec	22.8 sec
SILENUS to disk	0.0 sec	0.1 sec	0.2 sec	16.6 sec

Fig. 3. Data collected for SILENUS performance using the NFS adapter in a 100 MBit network. The NFS adapter was run locally (1.8 GHz Core-Duo); the byte store on a remote machine (1 Ghz AMD Duron)

Figure 3 shows that the performance of the SILENUS system is not so much dependent on the actual file size but rather on the number of requests.

Creating an empty file is almost instant, but it still requires a file metadata creation. Retrieving an empty file is instant, as there is no file content to retrieve. For small files, the time for creating the file is about 2 seconds, not really dependent on the file size. Retrieving a file is much faster: no transaction is needed and no modifications are done. For a large file, the actual network performance shows up as indicated in Figure 3 . Without any overhead, a 100 MB file could be transferred in about 9.3 seconds. For file upload, the SILENUS system reaches 40% of the maximum network performance. For file download this increases to 56% of the maximal network performance.

Given the overhead of locating the file, transferring it from a byte store to the NFS adapter, and through the NFS protocol to the local host these values are very satisfying. For concurrent engineering environments these values are good enough to share large data files, such as CAD designs. As reading files is more efficient, this system could be used with large files that must quickly be distributed to multiple engineers.

5 Conclusions

This paper highlights the issues involved in designing and implementing federated file systems and demonstrates the feasibility of such deployment in CE federated environments. The presented SILENUS architecture shares the attributes of grid systems, P2P systems, dynamic service object oriented programming, and inheriting the security provided by Java/Jini security services.

It is modularized into a collection of core distributed providers with multiple remote Facades. Facades supply with a uniform access points via their smart proxies available dynamically to file requesters. A Facade smart proxy encapsulates inner proxies to federating providers accessed directly (P2P) by file requesters.

Core SILENUS services have been successfully deployed as SORCER services along with WebDAV and NFS adapters. The SILENUS file system scales very well with a virtual disk space adjusted as needed by the corresponding number of required byte store providers and the appropriate number of needed metadata stores to satisfy the needs of current users and service requesters.

Work is underway to improve upload- and download speed through a BitTorrent like system with the FICUS framework [17].

The system handles very well several types of network and computer outages by utilizing the presented disconnected operation and data synchronization mechanisms. It provides a number of user agents including a zero-install file browser (service UI) attached to the SILENUS Facade. This file browser with file upload and download functions is combined with an HTML editor and multiple viewers for documents in HTML, RTF, and PDF formats. Also a simpler version of SILENUS file browser is available for smart MIDP phones.

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A P2P Application Signatures Discovery Algorithm

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Abstract. In this paper, we introduce a P2P application signatures discovery algorithm based on the combination of sequence mining with digital search tree. At the same time, we develop an application which contains two functions. One is the pre-treatment of packages, and the other is the discovery of application signatures. Finally, we use the real packages, which are snatched from the network, to gain effective application signatures.

Keywords. P2P application signatures discovery, sequence mining, digital search tree

1 Introduction

P2P is a kind of distributed network, where the participants share resources. P2P applications are now extending rapidly in the Internet. The current P2P traffic capacity is even more than traditional web applications, occupying above the half of the total network capacity. Various security problems will soon face with the huge developing range of P2P traffic capacities. We need to identify P2P system for real-time, in order to discovery and monitor P2P networks and block malicious information. There are two ways that commonly used to identify P2P system. One method recognizes P2P application according to P2P network transmission behavior characteristic, which does not analyze the payloads [1]. The other method detects the payloads and finds signatures that match with known P2P application signatures. In order to hide its flow and avoid being detected based on ports, some P2P applications often transform the ports. As more and more P2P applications can operate on any port, the method based on the port number identification is no longer valid in the identification of P2P traffic [2]. Therefore, all data packet must be carried on the depth identification. It is said that the payloads of transport protocol TCP should be detected. So it can be judged whether the packets contain

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the sample signatures. That is the main idea of Deep Package Identification (DPI) based on application signatures.

2 Application Signatures Discovery Algorithm

The characteristic of P2P application signatures is high frequent and fixed position. Key Tree data structure is used to calculate the frequency and location of application signatures. Meanwhile, the sequence mining algorithm which can discovery high frequent sequence is adopted in order to get application signatures.
In this section, first we give a brief view of digital search tree and sequence mining, and then we introduce the combination algorithm.

2.1 Digital Search Tree

Key Tree is also called Digital Search Tree. It is a tree with more than 2 degrees. Each node in the tree contains an element that is a character of string. The characters in each path from the root to the leaf node represent a string. The special symbol '$' in leaf node indicates the end of the string. There is variable in the leaf node for counting the frequency.
Key Tree has characters as following.
(1) Each character of the string is distributed in the path from the root node to the leaf node. Therefore, the size of keyword sets is irrelevant to depth of the tree.
(2) Key Tree is an ordered tree. Each internal node x stores an element such that the elements stored in the left brother node of x are less than elements stored in the right brother node of x. It is assumed that symbol '$' is less than any other symbol.
There are two storage structures to represent Key Tree. The first one is child-brother list (double list). The second one is multilinked list (Trie tree). This paper selects the first one to implement Key Tree.

2.2 Sequence Mining

Sequence mining is concerned with finding statistically relevant patterns between data examples where the values are delivered in a sequence. A sequence is an order list of itemset. It is denoted as $\alpha = \alpha_1 \to \alpha_2 \cdots \to \alpha_n$ where α_i is a item. The length of α is n. A sequence with k items is called k-sequence. A sequence $\alpha = \alpha_1 \to \alpha_2 \cdots \to \alpha_n$ is contained in another sequence $\beta = \beta_1 \to \beta_2 \cdots \to \beta_m$, if there exist integers $i_1 \le i_2 \cdots \le i_n$ such that $\alpha_1 \subseteq \beta_{i_1}$, $\alpha_2 \subseteq \beta_{i_2}$, ..., $\alpha_n \subseteq \beta_{i_n}$ [3]. For example the sequence ($B \to AC$) is a subsequence of ($AB \to F \to ACE$), since $B \subseteq AB$ and $AC \subseteq ACE$. A frequent sequence is maximal if it is not a subsequence of any other frequent sequence. The problem of mining sequential patterns is to find the high frequent sequences among all sequences that have a certain user-specified minimum support. Agrawal [3] presents AprioriAll to mining sequence pattern. It is a three-phase algorithm: first finds all itemsets with minimum support, transforms the database, and then finds sequential pattern. But this algorithm does not handle time constraints. GSP [4] explores a candidate generation and test approach to reduce the number of candidates to be examined. The previously developed sequential pattern mining methods are used in customer database, DNA database and etc.

2.3 Combination of Sequence Mining with Digital Search Tree

For P2P application, we wish to find the sequence pattern in payloads. The difference with traditional sequence mining application is that the location information must be considered. Some characteristics which appears in specific positions are application signatures, while appears in other positions are general data. Based on the peculiar circumstance, this paper designs a new algorithm, which uses the idea of sequence mining and the statistical function of Key Tree to discovery application signatures of network packets. Since the algorithm is very similar to Apriori algorithm, it will face the same problem as Apriori algorithm. It needs a scan of the original database for each pass, so there is a lot of I/O operation. The efficiency of the algorithm will be affected. Key Tree will exactly solve the problem of massive I/O operates. It only needs one time I/O operation to read payload, and the subsequence selection can obtain data from Key Tree.
As a result of using Key Tree's structure, data is compressed. When large amounts of data stored in external storage is added to the tree, the memory space occupied is smaller than external storage. Meanwhile, we can also recover the original data without information lost. The statistical function of Key Tree can be used directly, so we need not to design an additional statistic program. The implementation process will discover frequent itemsets, which similar to steps of traditional sequence mining. First it finds the frequent 1-sequences L_1, which are in the same position within different payloads. Then it joins L_1 into C_2, the set of candidate 2-sequences. It deletes the all sequences $c \in C_2$ such that some 1-subsequences of c are not in L_1, and gets L_2. Using the same method, it tries until generate C_k, which turns out to be empty. Then it outputs all k-sequences.

2.3.1 Data preparation

Ethereal is used to capture packet from network and filter some unrelated packet, so that some packets generated by some kinds of P2P software are obtained. Ethereal prints the data using text file format for analysis. After simple processing, the most useful information is obtained, such as the protocol type, the source IP address, the source port, the destination IP address, the destination port number, and DATA segment. DATA segment is the key object that we analyze; other parts of packets are only used for the later output and artificial analysis.
The following is a TXT format data packet outputted by Ethereal.

```
No.     Time        Source              Destination          Protocol Info
 16 0.657392     219.133.248.3   128.59.19.185       TCP       38771 > 45234 [PSH, ACK]
Seq=0 Ack=0 Win=65493 Len=111
Frame 16 (165 bytes on wire, 165 bytes captured)
Ethernet II, Src: 128.59.16.1 (00:d0:06:26:9c:00), Dst: IntelCor_59:7e:f8
(00:13:20:59:7e:f8)
Internet Protocol, Src: 219.133.248.3 (219.133.248.3), Dst: 128.59.19.185
(128.59.19.185)
Transmission Control Protocol, Src Port: 38771 (38771), Dst Port: 45234 (45234), Seq: 0,
Ack: 0, Len: 111
Data (111 bytes)
0000  42 d8 8c d4 aa 94 cc 82 69 9a f7 e8 88 6e 99 f0   B.......i....n..
0010  c9 cd e1 12 a8 ac e3 1b dc 24 3f af 4f e0 b0 26   .........$?.O..&
0020  7b 0a a0 50 7d 7b c8 53 d2 b2 d6 09 9f c8 f9 dd   {..P}{.S........
0030  b5 fa 4a 19 0f 7d e1 1b 2d fc b5 42 de c8 97 c2   ..J..}..-..B....
0040  10 35 41 0e a5 72 f2 2e be 66 03 49 1e 49 0b 22   .5A..r...f.I.I."
0050  e4 9d e8 db cf d0 1a fe a4 91 94 1c ff ee bd d6   ................
0060  6e 1f 40 c2 42 63 94 5c e9 5f 90 99 f7 50 33      n.@.Bc.\._...P3
```

Figure 1. TXT format data packet outputted by Ethereal

After simple processing, the protocol type, the source IP address, the source port, the destination IP address, the destination port number and DATA segment are obtained as following.

```
TCP 219.133.248.3 128.59.19.185 38771 45234 > 42 d8 8c d4 aa 94 cc 82 69 9a f7 e8 88
6e 99 f0 c9 cd e1 12 a8 ac e3 1b dc 24 3f af 4f e0 b0 26 7b 0a a0 50 7d 7b c8 53 d2 b2 d6
09 9f c8 f9 dd b5 fa 4a 19 0f 7d e1 1b 2d fc b5 42 de c8 97 c2 10 35 41 0e a5 72 f2 2e be
66 03 49 1e 49 0b 22 e4 9d e8 db cf d0 1a fe a4 91 94 1c ff ee bd d6 6e 1f 40 c2 42 63 94
5c e9 5f 90 99 f7 50 33
```

Figure 2. Data packet after simple processing

TCP in figure2 represents the transport layer protocol is TCP. '219.133.248.3' is the source IP address. '128.59.19.185' is the destination IP address. '38771' and '45234' are source port and destination port respectively. '>' is the start symbol of data segment, and subsequence characters are content of data segment.

2.3.2 Data storage using Key Tree structure

The payload of each data packets is inserted into data structure, so that Key Tree is constructed step by step. Here, each element of the Key Tree is one byte of the payload. Therefore the highest frequency bytes can be identified, and the position of it can also be located. The main steps are as following.

(1) Reading the data payload of data packets.

(2) Partitioning the data payload into elements. (Each element of Key Tree is one byte.)

(3) Inserting every element into Key Tree.

(4) Using method provided by Key Tree to obtain the frequency table in descending order.

(5) Getting the high frequency application signatures.
It is very simple and easy to implementation using Key Tree. There is some sample data that is chosen from real-data in table 1. 'No.1, No.2… No.8' represents identifier of each data packet. '0, 1…13' in first row represents the index of bytes in each packet. Because different packets have different length, the short packet will be filled with '*' to up to enough length.

Table 1. Sample data which is chosen from real data

	0	1	2	3	4	5	6	7	8	9	10	11	12	13
No.1	03	3f	02	3b	8a	55	97	05	12	1a	6c	7d	46	97
No.2	69	36	02	97	c9	35	9c	75	9c	58	ea	4c	42	68
No.3	57	8d	02	7f	a4	0c	ee	cb	fa	a4	ac	19	a1	8b
No.4	69	38	02	d1	95	b1	ea	24	38	cf	92	8f	67	18
No.5	57	93	02	b5	24	1a	0d	18	9f	e9	fd	54	67	7b
No.6	5e	64	A6	c8	ce	75	1b	b1	63	de	a5	fb	*	*
No.7	69	3a	02	97	71	8e	68	d7	95	8f	2a	24	0c	7d
No.8	97	ad	1f	7f	26	ca	eb	3e	a0	75	25	96	87	6b

In fact, the count of corresponding bytes in the same location can be operated in column direction. So, we establish a Key Tree for each column, and store each Key Tree into a link list (each node of the list is a Key Tree). The values in the column and the identifiers of each value are stored in the nodes of Key Tree. In order to examine the packet identifier of each value, the identifier is also stored in a link list. After all Key Trees are created, the frequent 1-sequences can be found by using the statistical function in Key Tree. But it can only find the application signatures whose size is only one byte. It could not organize effective memory structure to discovery long frequent sequence.

2.3.3 Frequent 2-Sequence mining

The next step is the focus of frequent 2-itemsets generation. It is the union process for frequent 1-itemset produced in last step. It should be noticed whether the two items are in same position. If they are in same position, they will not be united. The union is not only for bytes, but also for location and identifier of packets. In last step, the frequent and the identifier of values are recorded, while the locations are not recorded. The location can be obtained according to the index of the list. So it is not convenient for farther using. We should design a simple storage structure for recording the useful information outputted by Key Trees and the location information in the list. The key problem is the synchronization for the value and the location. If there are any mistakes, the subsequence process can't continue. It is not only a process for union and filter, but also a process for storage structure reorganization. It will provide a storage structure for long sequence mining. We design a class called longSignal to store frequent 2-sequences. There are three lists to store variables. Information list is used to store the 2 bytes value of 2-sequence (the application signature). Position list is used to store the identifier number of data packets. Situation list is used to store the location of the application signature of data packets. The elements in situation list must be corresponding with the elements in information list.

2.3.4 Frequent n- Sequence mining

The mining process will become easy as a result of the forming of fixed format after frequent 2-sequence. As long as we pay attention to the synchronization of the location and the byte value, we can use the union and selection functions in new storage format to implement maximum sequence mining.

In the frequent n-sequence creating process, union is different from traditional sequence mining algorithm. This algorithm only connects data in the same data packet. If the location of data has overlap, the value of data in the same numerical position must be same. So there are three limitation factor which we must consider, the identify number of data packets for L_{n-1}, the position of L_{n-1} and the value of L_{n-1}. This makes the algorithm is complicated than the traditional sequence mining method. The synchronization between the byte value and location transform to the synchronization information list and situation list. If there is an operation in either information list or situation list, the other will also do the operation meanwhile.

The main methods are as following.

- void inOrder() // Sorting the information list and situation list according to the situation value.
- boolean isSameSituation()// Judging whether they are appearing in the same packet. If the byte value in the same situation is different, they are impossible to be found in the same data packet.
- boolean isValueable(int total, float level)// Judging whether it is worthy of reserving according to the min-support. Here, total is the overall number of data packets, and level is the minimum support threshold.
- void union()//Determining whether two sets can be merged by using isSameSituation (), then union two longSignal, so that the item with same situation will be merged.
- boolean equals()//If the three lists of two longSignal are same, then they are equal.

The completeness of the algorithm is tested on virtual data. The role of the algorithm in the practical applications is also tested based on real data test.

3 Experiments

3.1 Testing on simulate data

In order to get results on different conditions, we test the algorithm using simulate data. The input simulate data is as following.

> 01 23 03 23 44
> 23 23 03 33
> 01 23 93 84 77
> 01 23 03 43 44
> 66 32 03 45 67
> 55 44 93 57 83

> 44 02 03 04 42
It contains the DATA segments of 7 data packets. We can find that the ‘01 23 03 44’ occurs in 0^{th}, 1^{st}, 2^{nd}, 4^{th} bytes of 1^{st} and 4^{th} packets. ‘01 23’ and ‘23 03’ appears three times separately. The highest frequent character is ‘03’ which occurs five times.
If the min-support is 25%, the output is ‘[01, 23, 03, 44] [0, 1, 2, 4] [1, 4]’. Here, [01, 23, 03, 44] represents the application signature□[0, 1, 2, 4] represents the location of the application signature□[1, 4] represents 1^{st} and 4^{th} packets.

If the min-support is up to 40%, the output has two sequences.
[01, 23] [0, 1] [1, 3, 4];
[23, 03] [1, 2] [1, 2, 4].
First sequence represents that ‘01’ and ‘23’ occur in 0^{th} and 1^{st} byte of 1^{st}, 3^{rd} and 4^{th} packets. Second sequence represents that ‘23’ and ‘03’ occur in 1^{st} and 2^{nd} byte of 1^{st}, 2^{nd} and 4^{th} packets.

If the min-support is up to 50%, the output has two 1-sequences.
[23] [1] [1, 2, 3, 4]
[03] [2] [1, 2, 4, 5, 7]
First sequence represents that ‘23’ occurs in 1^{st} byte of 1^{st}, 2^{nd}, 3^{rd} and 4^{th} packets. Second sequence represents that ‘03’ occurs in 2^{nd} byte of 1^{st}, 2^{nd}, 4^{th}, 5^{th} and 7^{th} packets.

3.2 Testing on real data

We also test the algorithm on real data which is scratched from network as skype application is login. It is known that the 3^{rd} byte in DATA segments of lot of packets is ‘02’. The algorithm finds the sequence. [02] [2] [7, 8, 55, 56, 59, 60, 65, 66, 140, 142, 143, 144, 145, 146, 148, 149, 150, 152, 153, 156, 158, 159, 176, 177, 178, 179, 180, 181, 298, 299, 300, 301]. ‘[02]’ represents that ‘02’ is the application signature. ‘[2]’ represents that the location of application is 2^{nd}. In factually, it is the 3^{rd} byte of the DATA segment, but the index of line is from 0. ‘[7, 8, 55, 56, 59, 60, 65, 66, 140, 142, 143, 144, 145, 146, 148, 149, 150, 152, 153, 156, 158, 159, 176, 177, 178, 179, 180, 181, 298, 299, 300, 301]’ represents the identifier of packets which value 3^{rd} byte is 02. Compared with real data, we can find that the result is correct. For example, the DATA segment of 7^{th} packet is ‘03 3f 02 3b 8a 55 97 05 12 1a 6c 7d 46 97 51 5c 24 91 6f b3 eb 9e a3’.

4 Conclusions

This paper presents an application signature discovery algorithm. It can be said to be a variant of Apriori algorithm. The design of the new algorithm is not completely in accordance with the mode of Apriori algorithm, because it must focus on the location information. The kernel idea of this algorithm is from the Apriori algorithm, but the coding process is completely independent. We determine the completeness of the algorithm through test on virtual data. Based on real data test, we can see the role of the algorithm in practical applications. Although the algorithm does not yet have a good ability to discover low frequent signatures, it provides a high frequent signature discovery method. The other hand, since the algorithm adopts idea of Apriori, therefore it is still unable to avoid some of the drawback of Apriori algorithm. The efficiency of discovery exceed long sequence is low. Since P2P application signatures are not too long, the low efficiency of such extreme circumstances can be tolerated. Meanwhile, we can also set up a limitation of the length of signatures. So that, we could get segments of exceed long sequences quickly, without a long time waiting.

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Knowledge Management

Knowledge Oriented Process Portal for Continually Improving NPD

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Abstract. Business process management integrated with new product development (NPD) provides practices to help companies to improve their competitiveness. However, few companies know the benefits of these practices and few have the culture of systematically sharing knowledge about these practices to continually improve their NPD. In order to encourage companies to use process management with systematic sharing of knowledge, this paper proposes the development of a knowledge oriented process portal. This portal comprises information related to generic NPD reference models and its continual renewal by using the body of knowledge (BOK), made available by a community of practice (CoP).

Keywords. business process management, new product development, web-based systems, knowledge sharing, community of practice.

1. Introduction

New product development (NPD) is a business process aimed at converting needs into technical and commercial solutions. To accomplish an efficient NPD it is important to define and to manage it in agreement with business process management (BPM). BPM along with strategic planning provide inputs to monitor business process performance indicators. This combination may indicate the way to perform necessary changes to continually improve NPD. The definition of a NPD reference model promotes a single vision of product development to all actors in the process. This vision has the purpose of leveling important knowledge between the stakeholders.

Existing elements of the reference model, i.e. tools, methods, templates, can be adapted to the company's NPD maturity level. This knowledge associated to these elements should be dynamic, that is, it should be updated in agreement with the creation of new solutions and corresponding information. Thus, it is possible to

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have a continuous improvement from simple piece of information to complex information structures. A way to make this knowledge dynamic is by participating in a community of practice because it enables production and sharing of knowledge related to reference models.

In reality, few companies know the advantages of these practices and few are used to systematically share knowledge on these practices to continually improve their NPD processes. To obtain these advantages companies have to incorporate these concepts into their strategies.

Therefore, it would be very useful for these companies to have a Web environment that helps them to know how to integrate BPM to systematical knowledge production and sharing. The use of information and communication technology (ICT) combined with the Internet increases the access to knowledge and specialists, wherever users interested in BOK are.

This environment could enable people to access reference models and all the information pertaining to them; to insert learned lessons and best practice related to the model activities to be shared with all stakeholders in the company; to access a community of practice, which allows contact with specialists and knowledge sharing.

The objective of this paper is to develop proposal of a knowledge oriented process portal, which offers an environment that enables organizations to define their own NPD reference models (standard process) — or even to use existing reference models—and to continuously update the BOK associated with their reference models.

It is important to emphasize that the use of this technology should be combined with other necessary aspects to create such an environment. Some of these aspects are: business strategies; knowledge management strategies and process; organizational culture; human resources management and so on. All these aspects contribute to continuous improvement of the process. This paper will deal with the development of a tool to manage NPD business process knowledge.

The following sections briefly summarize research on BPM, NPD, knowledge sharing, and web portals. Section 2 outlines BPM because of advantages of these management principles. Section 3 presents some NPD concepts and features. Since knowledge sharing and IT are powerful aspects of BPM, Section 4 describes knowledge sharing and web portals. Section 5 presents the goal of this project: to create a portal to assist companies in using NPD.

2. Business Process Management (BPM)

Business Process Management (BPM) is about both business and technology [15]. BPM is regarded as a best practice management principle to help companies sustain a competitive edge. Based on a holistic perspective, BPM combines Total Quality Management (TQM) that is incremental, evolutionary and continuous in nature and Process Re-engineering that is radical, revolutionary and a one-time undertaking, and is regarded as suitable for performance improvement in most circumstances [7]. In the so called third wave the goal is to apply BPM toward innovation [15]. On the other hand there are author that emphasizes BPM as a technological tool, seen as an evolution of workflow management systems [1].

In this case BPM life-cycle has four phases: process design, system configuration, process enactment and diagnosis. The focus of traditional workflow management (systems) is on the process design and process enactment phases of the BPM lifecycle. This definition of BPM extends the traditional workflow management (WFM) approach by supporting the diagnosis phase and allowing for new ways to support operational process [1, 2].

Since in this paper the scope is to integrate NPD process improvement in a broader BPM framework, the focus is on the business vision of BPM. However the implementation of BPM technology is a very important issue, though it is considered in the Product Lifecycle Management (PLM) systems.

Hung [7] defines BPM as an integrated management philosophy and set of practices that incorporates both incremental and radical changes in business processes, and emphasizes continuous improvement, customer satisfaction and employees' involvement.

BPM is a structured and systematic approach to analyze, improve, control and manage processes to increase the quality of products and services. This approach depends on the alignment of business operations with strategic priorities, operational elements, use of modern tools and techniques, people involvement and, most importantly, on a horizontal focus that can best suit and deliver customer requirements in an optimum and satisfactory way [10, 17].

New product development (NPD) is often recognized as the key process to enhance competitiveness [4]. To this end, NPD improvement should be in harmony with BPM practices to ensure the commitment with the company's strategic goals.

3. New Product Development (NPD)

New product development is a business process carried out by a group of people to transform market opportunities and technical possibilities into information to assist the design of a commercial product [5]. NPD is considered to be a critical business process to increase a company' competitiveness, diversity and product mix—especially in the international market—and to reduce product lifecycle [4, 13].

Some characteristics of NPD are: high level of uncertainty and risk in activities and results; important decisions made in the beginning of the process when uncertainty is higher; manipulation and generation of great amount of information; activities and information deriving from many sources and, because of this, in need of integration; multiple requirements considering all phases of product lifecycle and customers' needs [13].

To obtain efficient management of product development it is necessary to make the process visible to all stakeholders. This may be achieved by business process modeling, which results in a map or representation that describes the company's business process. It is possible to create such a business process model to define other instances in accordance with each company's projects. Usually, a generic reference model is created for one industry sector, which may be used in other sectors. Thus, companies pertaining to the same sector can define their standard process models by adapting the generic reference model to their contexts. The instances may be created based upon standard processes for many types of projects. It is possible to obtain with a reference model a single vision of product development and, thus, to equalize the knowledge among all stakeholders participating in a specific development [13].

Some examples of NPD reference models with different levels of detail are: the PDPnet reference model [13], MIT Process Handbook [9] e Capability Maturity Model Integration (CMMI) [16]. The PDPnet model was adopted as a generic reference model to NPD in this work, which will be described in Section 5. This model synthesizes the best NPD practices [13]. This reference model contains following phases: product strategic planning; design planning; informational planning; conceptual design; detailed design; product production preparation; product launching; product and process follow-up; product discontinuation. The model highlights the integration of strategic planning and portfolio management; the incorporation of PMBOK concepts [12] into the planning phase; definition of integrated cycles for detailing, acquisition and optimization of products in the detailed design phase; insertion of optimization activities; validation of productive processes and techniques to meet ergonomic and environment requirements; and integration of product launching phase where other business processes such as technical assistance and sales processes are defined and implemented.

Existing elements in the reference model—i.e., tools, methods, templates, best practices—can be adapted to the company's NPD maturity level. This knowledge should be dynamic, that is, it should be updated to be consistent with new information. Some ways to share knowledge—knowledge sharing concepts (strategic resource to companies) and portals (one of the web-based tools)—are explained in the next section.

4. Knowledge Sharing and Web Portals

Since knowledge is considered to be the companies' primary strategic resource, researchers and managers have tried to determine new ways to efficiently gather these resources and manage them to produce new knowledge [6]. There is an increasing need for companies to be pro-active—i.e., to support knowledge creation and reutilization—and to have systems that assist them in making knowledge sources or information available to users, wherever they are. In this direction, new Internet-based technologies facilitate information exchanging among companies and enhance collaboration among people, in synchronous and asynchronous ways. Moreover, these technologies improve knowledge generation, storage and transference [3].

In this context, it is possible to use web portals—i.e., infra-structures that promote, through a single access point, the integration of people, applications and services. They allow the collection, management, sharing and utilization of information, structured (e.g., textual documents, web pages, etc.) or not structured (e.g., images, videos, sounds, etc.), available in many sources, such as application databases. Web portals provide these services in a secure, individualized and customized way, allowing the visualization of relevant information according to users' permission [3, 14].

5. Knowledge oriented Process Portal

Nowadays, markets are generally perceived as demanding higher quality and higher performance products, in shorter and more predictable development lifecycle and at lower costs. Companies are using Information and Communication Technologies in their NPD activities to accelerate it, to increase productivity, facilitate collaboration, communication and co-ordination of NPD teams, foster versatility, produce and share knowledge on new products, improve new product decisions, and develop superior products [11].

The development of the Knowledge oriented Process Portal in this project was based on the aforementioned concepts. This proposal is also part of a broader project, which aims at establishing a web environment to integrate many NPD tools.

5.1 Objectives

The purposes of this Knowledge oriented Process Portal are:

1. To offer an environment that enables organizations to define their own NPD reference models or to use existing reference models. This reference model comprises best practices and describes activities, information and resources utilized in these activities, including methods, techniques and tools, as well as roles played by the people in the organization in charge of them.

2. To manage the body of knowledge (BOK) associated with the NPD reference model. This BOK can be modified by a community of practice, producing and sharing knowledge about the model components.

5.2 Methodology

The research method adopted was of a hypothetical-deductive nature. A portal prototype was developed, which included a generic NPD reference model. The hypothesis was that a portal could facilitate the access to a reference model by companies, integrating systematic creation and sharing knowledge, to obtain the NPD continuous improvement. To this end, the PDPnet reference model [13] was made available to the community of practice (http://www.pdp.org.br).

The method employed in the development of the portal was the Rational Unified Process (RUP) [8]. It is based on the iterative and incremental development by means of the following phases: conception, elaboration, construction and transaction. This method was chosen because it has an evolutionary character, necessary to make the portal requirements clear in each development phase, which are described in the next section.

5.3 Requirements

The portal functional requirements can be classified into 5 categories:

- To allow the portal administrator to insert the reference model components: activities, activity inputs and outputs, activity-detailing tasks and description, methods, techniques, tools and templates of documents (resources) used to carry out activities; and roles played by people in charge of activities;
- To allow the portal administrator to import the graphic process model of process modeling tools and create a textual model accordingly and vice-versa;
- To allow portal users (companies) to use the available reference models in order to define their standard NPD processes. The users may adapt the reference model to their contexts excluding or inserting activities and other model components.
- To allow portal users to insert lessons learned about the NPD reference model to achieve the continuous improvement of the process. To this end, it is necessary to report lessons learned from using the model components (activities, information, tools and methods) and the knowledge about these components. The related knowledge may include any object of the BOK (described in following).
- To allow portal users to participate in a community of practice because it is a way of managing the body of knowledge (BOK) associated with the reference model. Users can access knowledge available in articles, presentations, books, magazines, research projects, academic work, sites, cases, news, events, dictionaries, e-learning courses, standards, guides, contact of specialists and formal courses. Any kind of information that carries tacit knowledge too. Furthermore, users can access the community's comments about the BOK of the reference model.

5.4 Functional Structure

Figure 1 shows the functional structure of the portal. The idea is that users/companies could refer to a model—initially the PDP reference model [13]—existing in the portal. The model contains information about tools, methods, procedures or routines, and document templates to assist in the accomplishment of the activities.

The portal may also be used by users/companies as an instance to create their knowledge bases using the structure developed in the portal. Once users create their standard process models, the information in them could be modified or criticized when allowed by the companies/users.

The support to users to improve the knowledge related to standard process models will be provided by the community of practice (CoP), which will allow users to contact NPD specialists, access links to interesting websites, papers, books and other important research material. Thus, the portal will have a dynamic nature, promoting knowledge sharing among users, who in turn can improve their BOK's on their standard process models. At the moment CoP support is being provided by means of PDPNet.

The integration with modeling tools allows the conversion of textual models in graphic models and vice-versa.

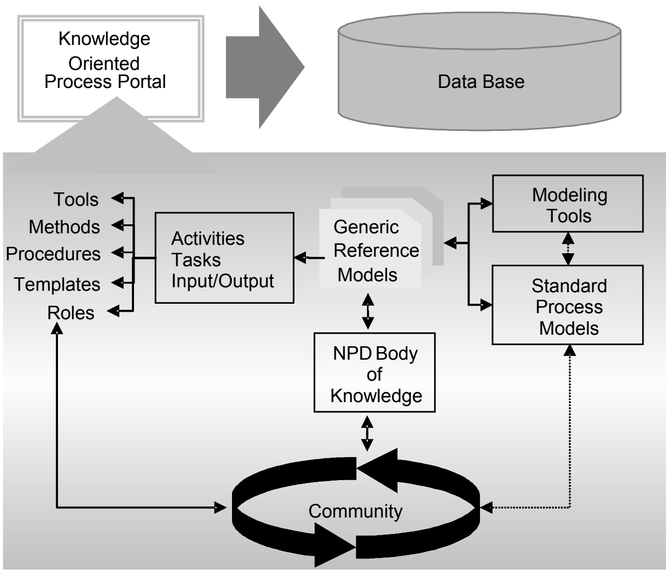

Figure 1 – Functional Structure of the Knowledge oriented Process Portal

6. Conclusion

In the context of NPD management with BPM principles, portals could be used to integrate people and provide access to information/knowledge collaboratively and with a cycle of knowledge retention, use and sharing. This cycle generates new knowledge, which is incorporated into NPD reference model activities, continually increasing companies' capability in product development.

It is hoped that the knowledge about NPD reference models will be used by a larger number of companies, since the content of the portal is open and free.

The integration between the NPD reference model and the dynamic BOK allow users to select the knowledge more appropriated to their needs and even to define their own standard NPD process. Moreover a company can include in its standard NPD process part of the BOK available, so it can leverage the competency of its NPD team members. The participation in the available community of practice is important to keep the company updated. Being free and open make it possible to be used by small and medium enterprises (SME), which cannot sometimes afford to hire consultants to improve their NPD processes.

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Knowledge Sharing and Reuse in Potential Failure Mode and Effects Analysis in the Manufacturing and Assembly Processes (PFMEA) Domain

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Abstract. The Potential Failure Modes and Effects Analysis in Manufacturing and Assembly Processes (PFMEA) represents an important preventive method for quality assurance, in which several specialists are involved in the investigation of all the causes and effects related to all possible failure mode of a manufacturing process, still in the initial phases of its development. Thus, the decisions based on the severity levels of effects and on the probabilities of occurrence and detection of the failure modes can be planned and prioritized. The result of this activity consists of a valuable source of knowledge about the manufacturing processes. However, this knowledge is hardly reusable in intelligent retrieval systems, because in general all related information is acquired in the form of natural language and it is not semantically organized, and therefore its meaning depends on the understanding of the specialists involved in the production chain. In this context, this paper describes the development and implementation of a formal ontology based on description logic (DL) for the knowledge representation in the domain of PFMEA, which fundamentally intends to allow the computational inference and ontology-based knowledge retrieval as support to the activities of organizational knowledge in manufacturing environments with distributed resources.

Keywords. PFMEA, Knowledge Representation, Ontology, Description Logic

1 Introduction

The Potential Failure Mode and Effects Analysis in Manufacturing and Assembly Processes (PFMEA) is an analytical method of quality engineering for the analysis of a manufacturing process, still in the initial phases of its development, in order to identify all of the potential failure modes, their causes and effects on process

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performance. And, consequently, starting with the results of this systematic analysis, the engineers can review their processes in order to propose actions that aim at eliminating or reducing significantly the probability of occurrence of these failure modes, or to increase the detection probability of the failure mode associated with a certain cause [16].

Due to its relevance, the theme of PFMEA has been discussed significantly in the literature and, especially, a common characteristic stands out, which is: when the PFMEA method is carried out in an appropriate way, it results in a significant amount of pieces of information and knowledge about the processes of an organization, and therefore it is a valuable source that can provide technical support to the anticipated detection of weak points in a process design, cost reduction along the product life cycle, and lower levels of modifications during the production phase [17, 5].

However, this valuable knowledge obtained at a high cost is hardly shareable and reusable in the context of intelligent knowledge retrieval systems, since the functions and failure modes concepts, among others, are not semantically organized. So, its meaning will depend on the human interpretation. Also, due to the great amount of information and current knowledge resulting from the FMEA analyses already accomplished as well as the fragmentation and distribution that usually happens along the production chain, the reutilization task becomes imprecise and unproductive [17, 5].

On the basis of these issues, this paper describes the development and implementation of a formal ontology for knowledge representation in the PFMEA domain, with an alternative to the problem of semantic barrier. The proposed ontology was coded through the OWL DL (Web Ontology Language - Description Logic) language pattern [20], as a means to enable the knowledge sharing and reuse in an agent-based mediated knowledge management context.

2 Ontology as a Knowledge Representation

In the last few years, researches on the use of ontology as a way to represent knowledge has been essential in many applications, which include multi-agent systems, knowledge management systems, intelligent integration of information, and semantic-based access to the Internet [1]. In particular, Dittmann *et al.* [5] and Lee [10] suggest that the use of ontologies can be an innovative alternative to represent the knowledge resulting from the application of the Failure Modes and Effects Analysis method.

However, in the literature there is no universally agreed formal definition of ontology. Thus, in this paper, the adopted definition is the one proposed by Zúñiga [21]: “an ontology is an axiomatic theory made explicit by means of a specific formal language” and “is designed for at least one specific and practical application” and “consequently, it depicts the structure of a specific domain of objects, and it accounts for the intended meaning of a formal vocabulary or protocols that are employed by the agents of the domain under investigation.”

2.1 Description Logic as a Formal Ontology Language

Description Logic (DL) is the most recent family of formal languages of knowledge representation based on first-order logic, and consists of basic descriptions of the application domain, *i.e.*: atomic concepts for the classes or group of individuals with similar characteristics; atomic roles for properties of these concepts or binary relations between individuals, and from them, other complex descriptions that can be constructed as axioms using a set of logical operators called concepts constructors [3].

A knowledge base that refers to an application domain, formalized through description logic, comprises two fundamental components [3, 8, 18]: (a) TBox, a terminological component, which represents the intentional knowledge or the knowledge about the characteristics of the concepts, comprising a group of terminological axioms that define these concepts from other primitive concepts and roles; (b) ABox, an assertional component, which represents the extensional knowledge or the specific knowledge about the individuals (instances) and their relationships within the same abstraction level, represented by an additional group of assertional axioms, which reflect the instantiation of the terminological component.

In spite of the potential of the formal languages based on description logic in the realm of knowledge representation, their real applicability takes place through the computer systems that implement them, as well as the capacity of those systems to process the represented knowledge in an explicit way with the objective to infer implicit knowledge through a specific inference service [13].

Many different computer systems with inference services are presented in the literature, among which is the RacerPro Server System [13], which is used in this work, and it provides reasoning service based on tableaux algorithms [4] for the language of descriptions logic $ALCQHI_{R+}$ [8], as well as making available a semantically well-defined ontology-based query language (nRQL, new RacerPro Query Language) and the nRQL query processing engine that can be accessed by the default TCP communication port [13].

3 Development of the PFMEA-DL Ontology

The development of ontology consists of a group of activities of conceptual modeling and, therefore, it should be based on consistent methods and methodologies on a scientific point of view.

Thus, in the context of this work it was adopted the so-called Methontology methodology proposed by Fernándes-Lopés *et al*. [6], based on the IEEE standard for software development. In this paper, the activities of the development process will be highlighted: conceptualization and implementation.

3.1 Conceptualization of the PFMEA DL Ontology

The PFMEA-DL Ontology proposed in this work was developed in its conceptual phase in consonance with the concepts and terms established in the SAE J1739 standard [15] and in the AIAG reference [2], thoroughly used in the area of quality engineering. Thus, the knowledge domain was modeled considering the description of concepts and their relationships starting with seven main concepts elements: Product, Process, Function, Failure, Actions, FMEA Description and Images.

In this scenario, the Product Concepts represent the domain of the product model, particularly its logical structure, and it corresponds to the classes and subclasses of products. The Process Concepts represents the logical and temporal structure of the processes, their respective operations and pieces of equipment, for a given industrial plant. The Function Concepts comprises a model of functions associated with each process or operation.

In the Failure Concepts the fundamental concepts and relationships of the PFMEA method are represented, which include: potential failure mode, effect of failure, causes of failure. In an innovative way it links the concept of potential failure mode with the concepts of primary and secondary identifiers, as well as the allocation of the failure with regard to a model of features as proposed by Shah and Mäntilä [14]. This is done in order to reduce the possible ambiguity between the instances of the concept Potential Failure Mode and to increase the expressiveness of the semantic representation of the knowledge and the capacity of the inference service and knowledge retrieval tasks. Figure 1 illustrates the model of concepts and roles (binary relationships) among instances for the Failure Concepts.

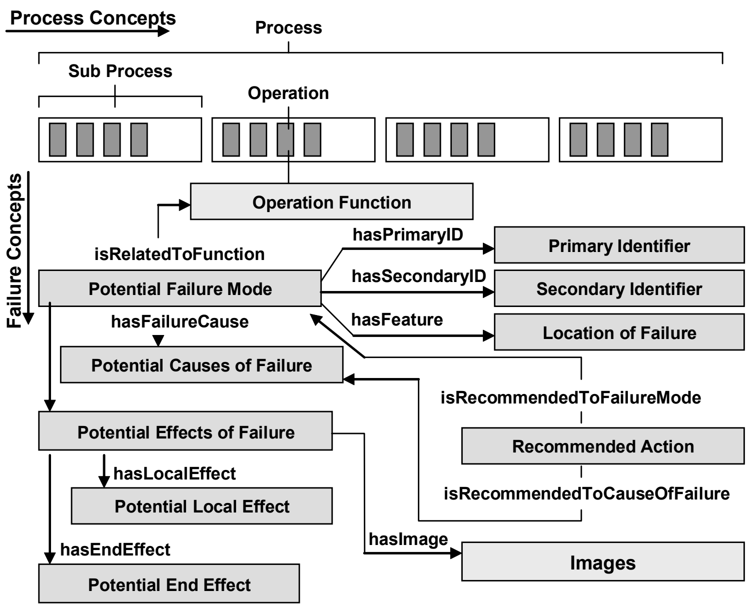

Figure 1. Model of concepts and roles of the Failure Concepts element

The concept of "primary identifier" represents the generic aspects related to the failure manifestation and failure inducing agent, involving: the main characteristic of the failure mode, or still the characteristic of the environment under which the failure mode occurred, or the kind of solicitation. The "secondary identifier" represents the aspects related to: types of involved materials, characteristics of failure or presence of other factors or specific means. For example: Failure Mode: Direct chemical attack; Primary Identifier: Corrosion; Secondary Identifier: surface exposed to corrosive media [19].

In the Action Concepts, the concepts and current relationships resulting from the risk analysis of the PFMEA method are represented, such as: current process control for prevention and detection, a rating criteria (severity scale, occurrence scale and detection scale), risk priority number, recommended actions, actions taken and responsibilities. The FMEA Description represents the other concepts regarding the core teams and responsibilities.

Finally, the ontology includes the Image Concepts, whose objective is to represent the concepts and relationships, such as: material description, metallographic preparation, and material processing history, besides the concepts related to the image type and image source, allowing the semantic-based image indexing related to a failure effect.

3.2 Implementation of the PFMEA DL Ontology

The PFMEA-DL ontology was implemented through the standard language for ontologies OWL DL (Web Ontology Language - Description Logic), developed by W3 Consortium [20], which combines a great power of expressiveness with the possibility of the inference service common to the description logic [9], using the Protégé-OWL Ontology Editor [12].

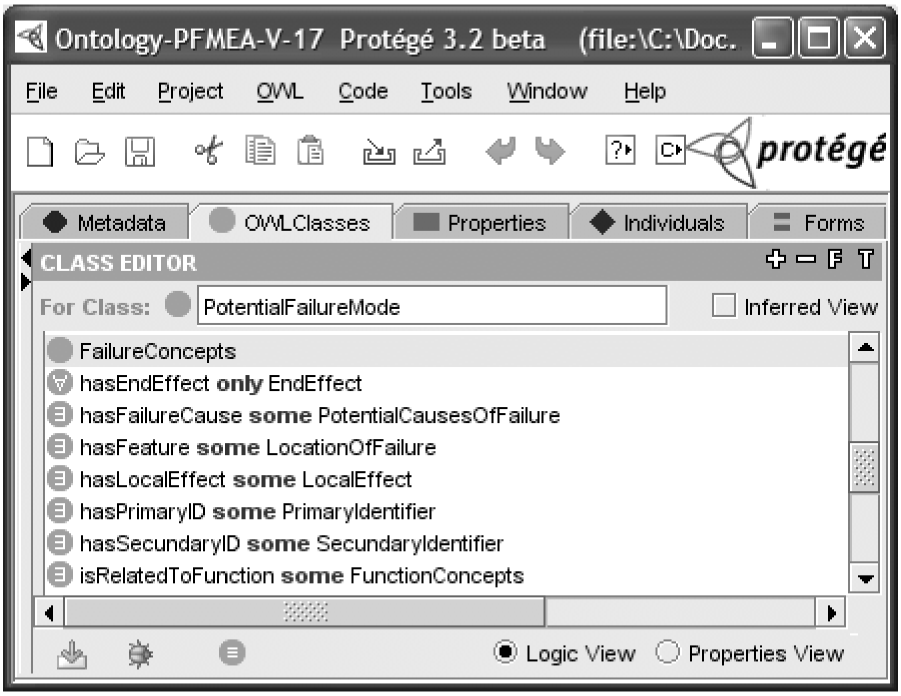

Figure 2. Protégé OWL Classes Tab snapshot

In this context, figure 2 presents the logical structure of classes and subclasses modeled in the Protégé OWL Editor, demonstrating the application of the property restriction to the OWL Subclass PotentialFailureMode.

It is important to observe that the application of the existential quantifier restrictions ∃ in Equation 1, is analogous to the existential quantifier of Predicate Logic and consist of describing an anonymous “unnamed” class that restricts a group of individuals (instances) of the subclass “PotentialFailureMode” connected to individuals of the “PotentialCausesOfFailure” subclass, through the “hasFailureCause” object property, which will be determined automatically by the inference service of the reasoning engine.

$$\exists\ \text{hasFailureCause some PotentialCausesOfFailure} \tag{1}$$

Along the process of development of the ontology, with the purpose of maintaining the methodological coherence, an ontology evaluation approach was adopted starting with the dimensions proposed by Gangemi *et al*. [7], which are as follows: structural, functional, and usability-profiling. In this work the functional dimension stands out.

The functional evaluation involved, initially, instancing the proposed ontology starting with a knowledge body of reference already validated, which resulted from the application of the PFMEA method by manufacturing processes specialists of a company producing roller bearings in the realm of a SixSigma project [11]. By applying this example, it was possible to evaluate the accuracy of the PFMEA-DL Ontology, confronting the answers from the inference service and the knowledge retrieval tasks accomplished with the concepts, relationships and instances represented in the ontology with the cognitive model presented in the literature.

Figure 3 shows an example of a complex query from the ABox perspective.

```
RacerPro Log
? (RETRIEVE
    (?POTENTIAL_CAUSES_OF_FAILURE ?POTENTIAL_END_EFFECT_OF_FAILURE)
    (AND (?POTENTIAL_CAUSES_OF_FAILURE
          |http://www.owl-ontologies.com/Ontology1144700912.owl#PotentialCausesOfFailure|)
         (?POTENTIAL_END_EFFECT_OF_FAILURE
          |http://www.owl-ontologies.com/Ontology1144700912.owl#EndEffect|)
         (?POTENTIAL_CAUSES_OF_FAILURE
          ?POTENTIAL_END_EFFECT_OF_FAILURE
          |http://www.owl-ontologies.com/Ontology1144700912.owl#isRelatedToEndEffect|)
         (?POTENTIAL_CAUSES_OF_FAILURE
          |http://www.owl-ontologies.com/Ontology1144700912.owl#Oil_remainder_on_cage|
          |http://www.owl-ontologies.com/Ontology1144700912.owl#isACauseOfFailureMode|)
         (?POTENTIAL_END_EFFECT_OF_FAILURE
          |http://www.owl-ontologies.com/Ontology1144700912.owl#Oil_remainder_on_cage|
          |http://www.owl-ontologies.com/Ontology1144700912.owl#isAEndEffectOfFailureMode|)))

> (((?POTENTIAL_CAUSES_OF_FAILURE
     |http://www.owl-ontologies.com/Ontology1144700912.owl#Temperature_to_low_in_washing_bath|)
    (?POTENTIAL_END_EFFECT_OF_FAILURE
     |http://www.owl-ontologies.com/Ontology1144700912.owl#Stained_phosphating|))
   ((?POTENTIAL_CAUSES_OF_FAILURE
     |http://www.owl-ontologies.com/Ontology1144700912.owl#Spooling_mouthpiece|)
    (?POTENTIAL_END_EFFECT_OF_FAILURE
     |http://www.owl-ontologies.com/Ontology1144700912.owl#Stained_phosphating|))
```

Figure 3. Complex ABox query and their results - RacerPro Log snapshot

The objective of this complex query (figure 3) is to recover all the Potential End Effects and the Potential Causes of Failure for a given Potential Failure Mode, which is an instance of the concept Potential Failure Mode, in this case “Oil remainder on cage”. It is important to observe that the query combines concepts atoms (#PotentialCausesOfFailure) and role atoms (#isRelatedToEndEffect) through the query constructor “and”.

The end effects is the impact of a possible failure mode on the highest process level and is evaluated by the analysis of all the intermediate levels, and it may result from multiple failure modes. Thus, in figure 3, the instance “Temperature too low in washing bath” is a potential cause of the failure mode “Oil remainder on cage” and its respective end effect is the instance “Stained phosphating”.

However, nRQL also provides complex TBox queries to search for certain patterns of sub/superclass relationships in taxonomy (OWL Document) [8].

4 Summary

This paper presented the development of a formal ontology based on description logic (DL) for the knowledge representation in the PFMEA domain. The proposed ontology was developed from the conceptual point of view, in consonance with the concepts and terms widely recognized in the quality context.

The proposed ontology was implemented through the OWL DL (Web Ontology Language - Description Logic) and the RacerPro Server was used as core engine for reasoning services and nRQL query processing.

The functional evaluation showed the semantic consistency and the applicability of the proposed ontology to support knowledge sharing and reuse in the PFMEA domain, as well as being promising as support to the activities of organizational knowledge in manufacturing environments with distributed resources.

Finally, the proposed ontology was developed as a means to work as a terminological component TBox for other specific knowledge base for applications toward complex manufacturing processes, *e.g*. in thermoplastic injection moulding, in future ontology-based knowledge retrieval systems applications, and for agent-based mediated knowledge management.

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Collaboration Engineering

Collaborative Product Pre-development: an Architecture Proposal

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Abstract. Nowadays, designers usually interact with teams of distributed stakeholders using information and communication technology, aiming time/cost reductions and quality improvement. However, a lack in collaboration and knowledge management support mechanisms persists, especially in the product pre-development. Best practices for product pre-development are still ill-defined because information available for designers in this phase are still instable and too abstract. Portfolio management highlights reasons, restrictions, tendencies and impacts, using competitive intelligence concepts insights on a knowledge management perspective, in order to classify project proposals in accordance with the organizational strategy. An agreement about what is really important to organizational strategy, along with a right team appointment, can contribute to empower portfolio management decisions. To achieve such an agreement, it is necessary to understand the different viewpoints in the negotiation process, to reduce impositions and the dependency from senior professionals with consecrated skills. The proposed architecture can contribute to portfolio management commitment, increasing the rate of right decisions and the support for these decisions, enabling coherence on similar situations. A collaborative product pre-development can extend the organizational capacity to obtain competitive advantages, because a consistent pre-development results in minor deviation on subsequent phases of the new product development.

Keywords. Product pre-development, collaborative portfolio management, collaborative knowledge management.

1 Introduction

Globalization and the technology evolution urge for adaptive organizations. Product lifecycles are increasingly reduced, requiring more agility and flexibility from project teams in new product development (NPD). The great challenge is how to make feasible the collaboration in early NPD phases, when vague and incomplete information make collaboration hard [1].

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First stages in the product definition are insufficient supported by computer tools [2] because they are nonfigurative processes, and it is difficult to model the concept generation. Great impact decisions are taken without the right comprehension of the context, by experience absence or even by ideas imposition.

It is in the pre-development that the relationship between ideas is established. Engineering, sales, directors, distributors, as well as call centers are involved. Ideas are evaluated in terms of money, technologies and competences, and also risk management; considering financial, production, human and market capacity; is performed. Usually it's difficult to evaluate and quantify some parameters in portfolio management, such as the project links with organizational strategy, to define how many information is necessary to decision making, to suppose how will be the marketplace, and to understand the customer tendencies.

Empowered decisions with effective involvement are linked to the different viewpoints comprehension. To minimize impositions and dependences, it is required a full understanding about how people collaborate and also by discovering performance measurements that transform intangible in tangible.

This article presents a preliminary architecture proposal intended to improve collaboration conditions in the product pre-development, by using Fuzzy Logic, Intelligent Agents and Web Services on product innovation management and collaborative knowledge management processes.

2 Collaboration, CSCW and Groupware

The idea behind the collaboration concept is to add efforts, competences and abilities, aiming a determined goal; for example, to obtain a product innovation. Some projects could be only feasible with an effective collaboration between interested people, inside or outside the organization.

Computer Supported Cooperative Work in Design (CSCW-D) involves studies about the use of computer technology to support collaboration between project teams, distributed or not, in order to create a favorable environment to quality improvement, conflicts resolution, and to reduce time and money spent on NPD.

Environments that enable all people to fully express their creative potential, making them feel part of a shared intention (social dimension), will increase the knowledge creation (collaborative knowledge) and will obtain the economic benefits from the achievement of the goals (business dimension) [4]. Many efforts have been conducted to develop computer mechanisms in order to support teamwork. Important initiatives in collaborative product development adopt Web technology as Collaborative Engineering infrastructure, because it provides favorable conditions for information sharing between distributed project teams [2].

CSCW systems can improve the efficacy on collective decision-making, offering facilities to information retrieve, share and use, which stimulate interactions, reducing problems as disorganized activities, member's domination, social pressure, and inhibition [5]. The term groupware is used to describe the technology resulting of CSCW researches. These resources make ideas sharing more efficient and accurate, simplifying processes and supporting parallel tasks execution, increasing knowledge and expertise sharing on teamwork [6].

2.1 HCC Consideration in CSCW Systems

Human-centered Computing (HCC) approach is an interdisciplinary knowledge field that tries to adequate computer technology insertion in human context. HCC is going to improve personnel capacities regarding perception and cognition during interaction between computer systems and people, in a way that technology development focus human needs, and do not try to adapted people to technology.

Groupware tools were presented like adequate mechanisms for overcoming obstacles that exists in work environments. However, many of those obstacles are due to human characteristics, and justify more attention in their management, for example: low performance in group activities; work processes ill-documented; nonexistence of data from everyday definitions; rejection of new truth; difficulties in the communication and the expression of ideas; concerns about function loss (strategic competence preservation); concerns about opportunities loss (facts suppression); absence of a vision about the benefits in sharing.

Frequently the user doesn't think something is quick to learn, easy, efficient, or even helpful regarding his objectives [7]. In any system, clear metaphors should be prominent used to permit that users quickly learn and do your own deductions using a pre-existing knowledge. Some systems are designed with all possible and imaginable functions, remaining to the user the responsibility to adapt the application context to achieve his objectives and satisfy his needs and expectations.

Functional characteristics in CSCW applications that can be easily perceived by users are determinant success factors: important functions that are forgetful, are incomplete, or inaccessible, increase the chances of system failure [5]. As user requirements are not properly considered in the conception of computer systems, continuous changes in the system are required by the users [8]. Even though the system conception is linked to user needs, the lack of knowledge by the designer about implemented requirements can cause problems [5]. These aspects show the importance to consider HCC in the CSCW environments implementation.

3 Collaborative Product Development

Collaborative product development has been considered by researchers and professionals on industry as the key for cycle time reduction and improvement related to product quality and reliability [5]. It's a systematic approach that associates the collaboration in new product development context and a consensus making strategy to satisfy more fully user needs. Some success factors in this area involve teamwork, communication improvements, project management, information sharing and consistency [2].

Analyzing some kinds of advanced manufacture systems, as product data management, supply chain management, enterprise resource management, manufacturing execution system, customer relationship management, demand chain management, among others, it's possible to perceive that such systems do not consider adequately the collaboration support needs during product lifecycle, because they aren't designed according to the current business requirements, and they focus specific activities in the companies [9].

Several models have been proposed to identify those requirements in business environment, but just for certain collaborative functions, including product portfolio management, collaborative product customization, collaborative product development, collaborative product manufacturing, collaborative component supply, and also extended product service. Although each one of those models involves a certain collaboration function, they don't act in an integrated way on product lifecycle context [10]. Beyond the difficulty to model, project, integrate, automate, monitor and optimize processes in product lifecycle management, the ability to support collaboration in different levels is a challenge to be pursued [9].

There is a perception that a large amount of collaborative effort is required from project teams during product lifecycle, but these efforts should start before the beginning of the development phase, already in pre-development. And the intangible nature of the pre-development requires from CSCW-D researchers an even more attentive regard.

4 Product Pre-development

The product pre-development is characterized basically by the definition of the projects that will be developed in the organization. The pre-development mission is [3] to guarantee that strategy direction, stakeholder's ideas, opportunities and restraints, can be systematically mapped and transformed in a project portfolio.

In the product innovation management, portfolio management represents [11] the business strategy expression, defining where and how resources will be put in the future. Project selection can involve value measurement approaches as well as other decision criteria – for example, a competence creation in a strategic area that can be important for the organization to survive [12]. The complexity involved in the product pre-development requires know-how and wisdom accumulation, and making tools that can adequately support designers in the initial phases of new product development is highly desirable [2]. The portfolio management efficacy can be improved using collaborative systems in product innovation, by overall visibility offered in decision-making, or by the stimulus to share ideas, increasing commitment and minimizing domination.

5 Architecture Overview

A system for collaboration support in product innovation management should have its focus on portfolio, and be able to prepare a dynamic structure to incentive the generation and capture of abstract ideas, whose expression can be concrete functional specifications [6]. It should have a universal workspace, accessed via Web, with integrated resources to project management, document management, project agenda and calendar [5], among others. The problems solution should not occur only in a reactive mode, but also in an active one. Beyond to support portfolio management, the architecture should incorporate techniques and best practices aiming to stimulate the project goals alignment, the effective knowledge and information use, and the increase on decision-making ability [6]. Figure 1 illustrates a general view of the proposed architecture.

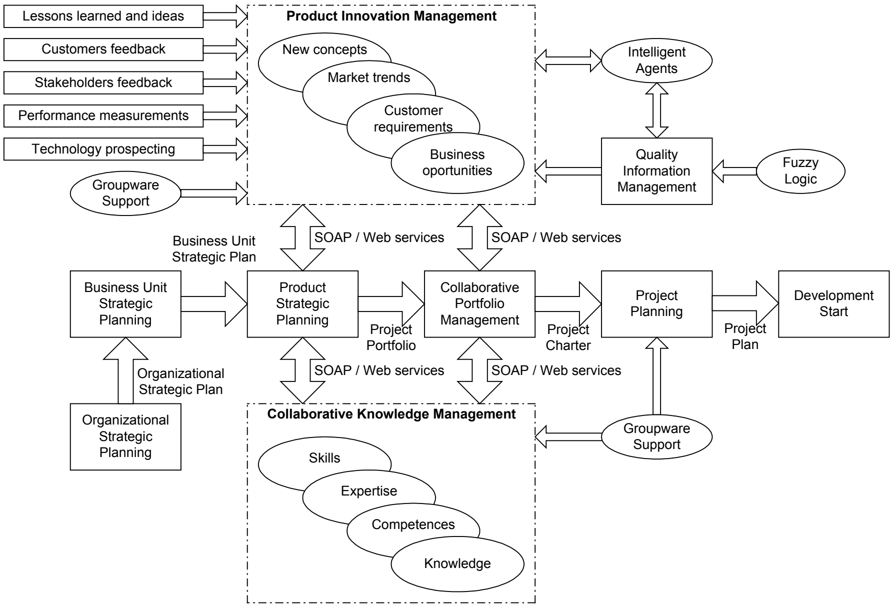

Figure 1. Architecture for collaborative product pre-development

The proposed architecture is based in Web technology, it is modular and service orientated, incorporating best practices in groupware systems. It was considered that SOA (Service Oriented Architecture) approach is indicated to Web resource sharing in collaborative product development [1]. An SOA application has several small modules of specialized software, which can be implemented in any programmation language; it is distributed, remotely accessible, interoperable, and reusable, by adopting standardizations [13]. SOAP, or Simple Object Access Protocol, is a standard protocol to exchange messages between computer programs, used in Web Services creation. Messages SOAP are XML documents based on W3C specifications.

The merge between Internet and Web technology, known as Web services, has great potential to collaboration support [10,14,15]. It's a new paradigm in distributed systems, where tasks are performed through networked computers, each one dedicated to attend an objective, involving accessible remote programs using Internet protocols, encoded in XML, and platform independent [16].

In order to analyze the complexity involved in portfolio management, methodologies to evaluate inexact information related to product characteristics are needed. For example, Fuzzy Logic, that employs approaching and interpretation instead accuracy, permitting to incorporate subjective and linguistic values in decision-making criteria [17]. The Fuzzy Logic is based in the principle that human thinking is structured in object classes, and not in numbers. It permits to capture intangible or inexact information, generally described in natural language, and convert them in a numerical format, that can be processed by computers. Therefore, its application in computer systems to collaboration support in product pre-development is promising, taking into account that in this context it is necessary to work with hardly quantifiable parameters, as the "information quality" available to decision-making, the project adherence into competitive strategy, the ratio in which the users are attended in their needs, the product market placement in relation to competitors, the market trends, among others.

Autonomy is the main characteristic of the intelligent agents. They possess an explicit representation, a model, in that decisions are taken by means of symbolic reasoning [18]. However, that kind of system is capable to perceive and do modifications in an environment. The advantage of using agents is the possibility to structure intelligent environments using abilities collection, and also the fact that their autonomy can make them work in independent way in any task, in a proactive posture, that differentiates them from systems based on client-server architecture [18]. Among several applications involving intelligent agents are finding, filtering and retrieving information, which can be presented in a format that facilitates the users' comprehension. This can be the case, for example, of the information manipulated in product strategic planning, or in the use of lessons learned in previous projects. Therefore, it's promising to apply intelligent agents in computer systems used to support innovation management.

Product strategic planning should be aligned with business unit strategy, which is backed by organization strategy. Product innovation management, collaborative knowledge management and project planning have groupware support, to improve collaboration and communication, which can be integrated using Web Services.

6 Related Works

[19] presents POPIM (Pragmatic Online Project Information Management), a collaborative management system to extended environment product development projects. Its structure offers a shared workspace to improve team communication, sharing, and collaboration on projects, accessing on-line information. The system supports collaboration and knowledge management during the project development phase, but does not contemplate the pre-development.

[17,20] involve computational systems based in Fuzzy Logic to establish criteria for project selection in portfolio management, but do not consider collaboration between the people on decision-making during the criteria ranking.

[21] adopts the collaborative knowledge approach on product innovation management to conceive the eProduct Manager, a Web system prototype for portfolio management. The authors claim that the final version will be built in a structure that integrates four modules: goals, actions, teams and results. Forms are used to store the organization goals, setting out knowledge that before was tacit, and also to record problems and ideas, in which the user does a strategic alignment ranking for each new product concept. In [6] is described its architecture main elements: controls (consumer requirements, strategic impulses and performance measurement); mechanisms (individuals, teams and revisers); entrances (ideas,

problems); and exits (project revisions, scorecards and exception reports). It seems that a new prototype would use intelligent agents and Web semantic.

[10] proposes a business model called "collaborative product services in virtual enterprise", based in Web Services, which is going to integrate the majority of the functions related to collaboration on product lifecycle. The authors defend the application of PLM systems to collaboration support during all product lifecycle, but don't clearly define the requirements of such a system (based itself in a classification of the nature of the collaboration process) and don't consider pre-development peculiarities.

[22] presents the WS-EPM (Web Services for Enterprise Project Management), a service oriented architecture to business projects management. In what it refers to the product pre-development, there is an operation to project prioritization named Prioritization Web Service (PWS), which considers, as criteria to conduct different projects coordination, the following factors: tangible value, intangible value, project scope, required time to market, convenience to develop the project inside or outside the company. The PWS appears graphically associated with all WS-EPM operations in product lifecycle, hinting that the system is used in the entire new product development process, and not only in pre-development.

7 Conclusion and Future Perspectives

This work highlights the importance of computer systems to support planning, accompaniment, control and decision-making processes that should be centered in the requirements of the collaboration among professionals involved in product pre-development, in order to facilitate the conversion of the experience acquired into structured knowledge for new challenges.

There is a lack of support mechanisms to stimulate collaboration in product pre-development and to improve the impartiality and the repeatability in the portfolio management. Efforts dedicated to solve this problem will result in effectiveness on competitive strategy.

A comprehension about how people can be able to collaborate, associated with investments on technology infrastructure, can help to transform intangible aspects in tangible. The proposed architecture should facilitate the understanding about different viewpoints, focusing in what is important on product innovation management: all the people involved on collaborative portfolio management, contributing to reach convergence on decision-making.

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Collaborative Augmented Reality for Better Standards

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Abstract. Concurrent engineering depends on clear communication between all members of the development process. As that communication becomes more and more complex, the quality of the standards used to move and understand that information likewise becomes more and more important. If the standard is incomplete, redundant, or ambiguous, most of the expected benefits are lost. In order to improve data exchange standards, explicit data models are required. However, creating those data models is a process that requires collaboration between domain experts. What is needed is a solution that encourages interaction without requiring a high level of data modeling expertise. Focus is a software tool designed to provide such an environment. It is a distributed design and conferencing application which uses augmented reality to allow domain experts to come together in real time for data modeling. By developing Focus, we hope to allow domain experts to create data models without first having to learn complex UML modeling programs. Because of the networked nature of Focus, it is easier to ensure the participation of the best domain experts regardless of location. This paper details the development, features, and expected benefits of Focus in a collaborative engineering environment.

Keywords. 3d, collaboration, data modeling, UML, standards development, Ruby.

1 Problem

Concurrent engineering depends on clear communication between all members of the development process. As that communication becomes increasingly complex (including CAD models, diagnostic data, process control data, etc.), the quality of the standards used to move and understand that information likewise becomes more and more important. Current information transfer standards tend to be designed by domain experts. Traditionally, a group of domain experts gather together and begin to develop the new standard in an *ad hoc* manner. Requirements and document structure are discussed, a written description is produced, and the standard itself is created in a way that agrees with the documentation.

Standards developed this way often suffer from ambiguity, redundancy, missing information, and/or excessive complexity. Terms used in the textual description may be ill-defined; the result is often that the standard contains a

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vaguely defined element, or that one developer expects an element to mean one thing, while another developer is equally sure that it means something else. Apart from the confusion caused, ambiguities mean that constraints upon the valid range of element data are often underused, which can impede automated processing of the standard. Furthermore, as the standard itself is created by hand, information found in the textual description may be missing from the standard altogether. If information is repeated, or referenced multiple times, in the textual description, it may also appear several times in the standard. Empty (and therefore unnecessary) "container" elements may become part of the standard because they were part of the implementing experts' mental framework during the conversion from textual description to formal standard.

All of the above problems stem from an attempt to combine two separate steps of the development process into one. The first step is to determine the standard's domain, which is generally the answer to the question "*what* information and/or interactions are we trying to capture?" The second step is to create a particular implementation, which can be characterized by the question "*how* will that information be stored and moved around?" When those two steps are performed simultaneously or in reverse order, the standard often suffers. What is needed is a tool that allows domain experts to work solely on the domain of a standard without falling into the trap of designing an implementation at the same time.

2 Solution: Focus, a distributed 3D modeling tool

The Focus 3D telemodeling tool attempts to improve the quality of information exchange standards by borrowing a proven technique from the software industry: data modeling. A formal data model captures only the domain information of a standard; implementation questions are entirely removed from the process. Domain experts are therefore able to describe the required data and interactions with the appropriate amount of complexity, without concern about the eventual language used to implement the standard and its particular idiosyncrasies. This approach not only provides a clear, unambiguous description of the scope of a standard, it also reduces the amount of time necessary to create the implementation, as much of that process can be automated using existing software tools. Moving the definition of a standard away from a textual description also makes for quicker consensus between experts, as language and style issues no longer factor into acceptance of the standard.

A proper collaborative data model, however, can be difficult to achieve. The cost of face-to-face meetings continues to rise, and existing solutions for remote collaboration fall short when considering the problem of data modeling. Audio conferences are insufficient, as data modeling is almost entirely a visual task. Existing visual tools, such as web and video conferencing, are limited in that only one person can actively work on a model at any given moment.

To address the aforementioned problems, we developed Focus. It allows domain experts to create data models without having Unified Modeling Language (UML) expertise, and without being in the same physical location. Focus uses augmented reality to create a shared, 3D environment. Abstract data modeling concepts like classes, associations, and generalizations are represented with concrete objects that can be directly manipulated by the users.

Augmented reality deals with “the overlay of virtual imagery on the real world.” [2] More technically, it is the process of using specified, predefined marker objects to position rendered, 3D objects within a real video stream. In Focus, that process is combined with a 3D display device like a head-mounted display, a head-mounted camera, and a hand tracking device. The result is that the user is presented with a 3D data model that appears to float, for example, atop the user’s desk. The user can reach into the model and make changes, and any other logged-in users, in remote locations, can see the same model. The model behaves like a real object -- the user can get up and walk around it to see it from different angles.

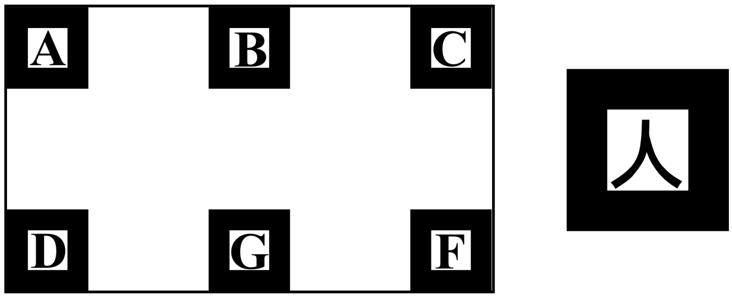

Figure 1. Example primary (left) and secondary (right) fiducials

Each user in the system is given a virtual representation (an *avatar*) that shows their position relative to the model.

3 Tracking the User

In order for a user to interact with the Focus environment, it is necessary to know three things: their position relative to the model, the position of their hand relative to the model, and any actions they are performing on the model. Position tracking relies on two visible markers, or *fiducials*, as seen in Figure 1. The primary fiducial represents the position of the model; it is free standing, and would typically rest on a desk or table in front of the user. The secondary fiducial is attached to the user’s hand, and tracks that hand’s position.

The user’s perspective on the scene is extrapolated from the apparent size and orientation of the primary fiducial in the user’s video camera feed. Each user’s camera provides a video feed that duplicates their real-world point of view. Whenever a new frame of video is available, Focus searches that frame for the two fiducials, and provides their position in 3D space. The data model is rendered at the position of the primary fiducial; a cursor and other indicators are rendered at the position of the secondary fiducial. Anyone else in the system also has a perspective on the model, so the user sees other avatars appear where they are “standing” relative to the model.

Actions performed by the user are captured in one of two ways. A data glove, capable of tracking finger positions, can be worn, in which case the user interacts with Focus using a simple gesture language. Alternatively, the user can simply hold any device that can provide the system with left- and right-click functionality; in this case, the system uses standard mouse events to trigger actions. Since Focus uses the secondary fiducial to track the hand's position, a small presentation remote works just as well as a mouse. Focus treats all actions as occurring at the hand's position. For example, if the user wants to create a new object, they would reach their tracked hand into the model at the position where the new object should be, and perform the "Create" gesture. The resulting configuration is flexible, in that only a camera and a pointing device need to be connected to the system, and scales well with increasing video (and therefore fiducial-tracking) quality, since no changes are required when an upgraded camera or display device is attached.

4 Modular and Distributed-Computing-friendly

Focus was designed from the beginning to be modular. Each piece of the system can be replaced with a minimum of fuss. Video input, fiducial tracking, user input, and 3D rendering are all designed to be swapped out with new modules as technology improves. Focus uses a NIST-developed dependency injection framework called Trimurti [12] to decouple these application modules. Each module in the system knows what services it provides, and what services it requires. Trimurti is responsible for connecting the requested modules together, taking into account each module's requirements.

One advantage to this approach is that it makes the addition of new functionality very easy; as an example, we have implemented two different modules for user input (gesture and mouse input), which can be interchanged with a single name change in the module assembly code for Focus. Another advantage is that modules can be provided remotely. Each module knows that its required services have been provided, but it speaks to those services through Trimurti, which can make use of a distributed computing framework. The clearest example of this process is that the main repository, in which all Focus projects are stored, will be kept on a separate server; all Focus clients will access the repository as if it were local, but it will be supplied remotely. Distributed computing also allows us to run a Focus client on a nominally underpowered machine. Fiducial tracking, a fairly computationally expensive process, can be offloaded to another machine, again requiring only a single-line code change.

5 Hardware and software

When creating Focus, we felt it was important to keep the cost to a minimum. The target was to keep total system cost below the price of a dedicated video conferencing system. Focus uses inexpensive, currently available hardware, and is built using only free software. It is designed to be cross-platform; initial development was done on Mac OS X, but all software components work on Linux and Windows as well. All Focus software will also be made freely available for further development.

For video capture, we are using a few different Firewire-based web cameras; all provide video frames in standard delivery formats, and are therefore supported on multiple platforms. Gesture input is handled with an inexpensive data glove which tracks finger positions, but the system can also be operated using a standard mouse. The most expensive component of the system is the head-mounted display (HMD). This is also the component likely to see the most improvement over the next few years. We are primarily using a display which makes use of relatively new organic light-emitting diode (OLED) displays to provide bright displays that are high-resolution when compared with other, similarly-priced HMDs. However, as the technology matures, further increases in both resolution and the user's perceived field of view will certainly improve the usability of the system. HMDs in this class can be found for less than $1000.

Focus utilizes the following software:

ARToolkit [2] for user position tracking and real video capture
Coin3D [5] for 3D scene management and rendering
Libp5glove [10] to interface with the data glove
DRb [6] for the underlying distribution of our modules
Trimurti [12] to decouple the application modules

Additionally, Focus is written in Ruby. As a number of the software components were not capable of communicating in Ruby, we created Ruby-language bindings for ARToolkit, Coin3D, and Libp5glove using SWIG [11]. Using Ruby, a higher-level, object-oriented language, shortened the overall development time; adapting these existing and relatively mature toolkits was considered a better solution than attempting to write our own tracking algorithms and glove interface driver.

6 Designed for simplicity

The primary purpose of Focus is to allow domain experts to create data models quickly, so simplicity of interaction is critical.

Whenever possible, the interface makes use of direct manipulation: 3D drag-and-drop is used for model arrangement, new vertices are added to association lines by grabbing and pulling on the line.

When direct manipulation is not feasible, Focus uses familiar interface metaphors, such as a tool palette like those found in graphics programs.

The gesture language has been designed to use simple gestures, like "Create" and "Select," which may be concatenated.

All actions are persistent, so the user does not need to "Save" progress.

Some actions (deletion of model elements, certain renaming actions, etc.) require acceptance by the user, but until that acceptance is received, the action is provisionally accepted and affected objects are clearly marked as needing attention.

All data models are also persistent. A user may create a new model, but may also resume work on an existing model, which may have other participants already at work. When the current session is complete, the model simply waits on the server for further modifications.

Part of designing for simplicity required providing users with instant, non-blocking feedback. When an action is invalid, the user is told during the action rather than after failure. If items cannot be dropped in a particular location, their appearance changes while the user is dragging them. If an action does fail (e.g. the user drops the items even though they are marked as un-droppable in that location), Focus informs the user via an information display along the edge of the screen, and does not request user intervention before continuing. The same information display is used to inform the user of other changes to the environment, such as new users joining a domain modeling session.

Searches follow the instant, non-blocking philosophy as well. As search terms are entered and modified, results are highlighted within the model, and the resulting selection can be used for any of the other available actions in Focus. One of the advantages of a 3D model layout is the ease of defining a spatial search. A user can query the model in a traditional way (looking for occurrences of a particular piece of text or range of numbers), but can also include spatial criteria results within a certain distance of the user's position, or of a selected element in the model).

7 How it works

Now that the underlying technology and design philosophy have been discussed, the next step is to explore what a Focus modeling session is like. In this example, a data modeling project has already been created on the repository server at some previous time. The user wishes to resume work on this project. She places the main fiducial, which is a rectangle roughly 5x7 inches in size, on the desk in front of her. She puts on the HMD and glove, and starts the Focus client program. At startup, it connects to the repository server; the user authenticates for a particular project, and is logged in. She is now participating in that project's modeling session. The data model appears atop the main fiducial on her desk, and other users' avatars appear around the desk at their respective relative locations.

Each object in the data model has a representation in 3D. Classes have a default representation (see Figure 2), but can also be assigned model fragments. For example, a circuit board class might have a 3D model of a board as its representation. Focus can read model fragments stored in SGI's OpenInventor format, which can be created from any number of free and for-pay 3D modeling tools. Associations, generalizations, and other connections between classes are drawn as lines.

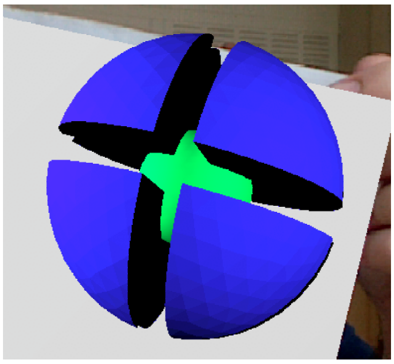

Figure 2. Default representation of a class

Each user working on the model has a 3D palette of tools available to them; one user's palette is active at any moment, and only that user may modify the model. (It should be noted that this was a design decision intended to enhance collaboration, and the single active palette may be abandoned in the future in favor of any user being able to modify the model at any time.) While inactive, the palette contains a representation of the active tool being used on the model, the name of the active user, and a button to request control of the model. Our user's palette is inactive to start. She presses the button to request control. When control is relinquished by the active user, her palette becomes active and populates with the available tools. These tools perform functions familiar to users of graphical editors -- tools for the different types of classes and associations that may be created, move, delete, and search. At this point, the user can make changes to the data model, rearranging, adding, modifying, and deleting model elements; all other users will see her changes reflected immediately in their own client applications.

8 Status

The design phase of Focus is complete, including the following steps:
Use case catalog
Publication on Focus architecture
Investigated component technologies
GUI design whitepaper published [1]
The implementation phase of Focus is ongoing.
The following components have been completed:
I/O hardware purchased
Software components developed and tested
Basic system functionality complete
Create, modify, rearrange and delete model elements
Simple associations between model elements

9 Future steps

Development on Focus continues, with several organizations planning to test it as the center of a model-driven process for standards development. Once the first iteration is complete, additional features such as more complete UML coverage and automated schema generation are planned. Additionally, as hardware prices continue to fall, it is possible that "see-through" HMDs (which display only the rendered 3D content on a transparent display) will be integrated into Focus, removing the display resolution issues inherent to small, inexpensive cameras.

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A Pedagogical Game based on Lego Bricks for Collaborative Design Practices Analysis

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Abstract. In this paper we present a pedagogical game intended to simulate the collaborative design activities of mechanical products as part of the formation programme for future engineers. This game is based on the adaptation of the Delta Design game developed at M.I.T. The principle of the game is to co-imagine a space shuttle built in Lego® blocks with functions and rules assigned for several students. The software used (MLCad) provides for a shared and distributed use of the game. The core objective is to create a situation that brings the students together in a way that encourages them to experiment with different designs by making compromises, overcoming conflicts, and working within the constraints of the game. The underlying theory of this model is that by encouraging collaboration among each other when addressing the different obstacles and variables encountered, the students will have a better understanding of their own behaviour and the behaviour of other members. Thus, the students will intuitively contemplate the diverse and beneficial methods of collaboration required for practices between trades.

Keywords. Pedagogic game, Lego bricks, collaborative design work.

1 Introduction

Throughout the competitive character of the market, product design is affected and driven by the constitution of multidisciplinary teams capable of efficient collaboration. The collaboration practices between trades become an essential catalyst for creative sharing of skills. By its socio-technical characteristic, the collaboration is a relatively complex phenomenon to study and to formalize in the organization [1]. The interaction between the individuals themselves, as well as the interaction with the surrounding systems (objects, context, etc.), creates major concern in the academic and industrial world. We must keep in mind that collaborative work starts at the moment the actors exchange opinions on the existing information, share their experiences, define common targets, and compile

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data and capabilities. All of these activities are carried out together with a common objective. However, this description hides both the difficulties and the obstacles. We share Reynaud's perspective on this affaire. He notes, "the individual competencies are as fought as they are added" [2]. In regards to the social aspect of the project, the multi-disciplines usually involves actors of various departments, possessing complementary skills and of different cultures (reference frame, vocabulary, formation, history, experience, etc.), yet with each participant envisioning the creation of a different end product. As a result, the participants independently develop their own strategies when forming personal objectives and criteria of evaluation. The study of collaboration is relatively complex in the industrial context. Likewise, the education of individuals is also a major concern for most academic institutions and particularly among engineering institutes. In the end, preparing future engineers with real technical knowledge while allowing them to acquire collaborative competencies remains a challenge for these institutions. The actors' technical and economical knowledge is constantly growing. Due to this issue, engineering institutes must teach an ever greater number of disciplines to their students. Therefore, this situation leads to difficulties in comprehending other areas of expertise and generates significant problems when exchanging and sharing among trade interfaces [3]. Nowadays, the training of individuals focussed on the development of know-how and aptitudes of collaboration remains a major problem. In fact, it is necessary to recognize the strong contextual character of the collaboration from its numerous "parameters" (personal development, individual and group psychology, enterprise culture, power game, general working habits, etc.). For this reason, the aptitude to collaborate is often perceived as a competence that is essentially learned by experiences and real situations. It is accordingly very difficult to reproduce such a training environment when striving for a pedagogical goal. However, the internships and student projects are the first answers delivered by the academic institutions to encourage their future engineers to act as actors of collaboration in real situations. In this paper we propose a design game with the intention that engineering institutes use it as a pedagogical tool for the teaching of collaboration. This game, essentially based on LEGO blocks, was developed to simulate the multi-disciplined design of a technical object. Also, the game aims to lead a group of students to experience a constrained situation where everybody's participation is needed. Even though the students attend the same class (or course), they all have different backgrounds (normal or technical high school, etc.) and engineering options (General Product design, industrial organization or Process Automation Master). These differences enable the groups to be heterogeneous, although not entirely representative of the diversity to be found in the industry and enterprise world.

More particularly, we adapted several concepts of the game "Delta Design" (which was developed at M.I.T by Bucciarelli) and these will be presented in part 2 of this article. Part 3 of this article will be comprised of our presentation of the game. In the final part, we will conclude by distinguishing the limits and perspectives of our work.

2 The Delta Design game

In the Delta Design Game [4] game, each of the four players receives two documents. The first part presents the team composition and target. This directive also specifies the global task to be undertaken by detailing the design requirements of the house. This first part is the same for all participants. The second part of the document, different for each trade, outlines the essential requirements for the correct execution of the role assigned to the player.

2.1 The design objectives of Delta Design

In the Delta Design context, life on DeltaP is presented as being far from what we actually have on earth. First of all, DeltaP is not a planet, but in a planned flat world. Next, the teams design in a 2-dimensional space; thus, not in 3-dimensional as most are accustomed to. In order to ensure that the designed product respects specifications (requirement sheet) and that it pleases the client in terms of aesthetics and function, a representation on a simple piece of paper is sufficient. The team must design the residence by assembling these equilateral triangles in either red (heating triangle) or blue (cooling triangle) formations. Due to the use of triangles as a residential building component, their aesthetic and thermal functions are much more complex than their form and dimension. Therefore, each team's task is to design a house that takes into account and integrates all of the constraints and tastes of the customer, as well as the characteristics and components of the triangles.

2.2 Delta Design Collaboration

The design team is composed of a project manager, a structural analysis specialist, a heat engineer, and an architect. One of the directives is to hide the specification document between the members of a same and opposing team. After this common game, each player receives a document that includes the objectives and constraints of its trade, but this is something we will not explain here.

It is important to note that these rules are sometimes vague and subjective and can be precise and formal. By analysing the various trade rules given to the players, we realise that they were defined in order to create alliances and oppositions between the players. Afterwards, this equation allows us to observe opportunities for collaboration and negotiation between players who address their respective constraints while building the house. The foremost interest of Delta Design game remains the analysis of the collaboration "highlights." An external viewer or a set of viewer-player can do this analysis by trade. While each Delta Design experience produces new results, we may still take notice of the numerous "highlights" that frequently punctuate the development of the experience. Frequently the conversations between the players are interesting: a balance of power is settled between the players, and sometimes, a social hierarchy appears. During the short presentation of each trade the final subject (i.e. designing a new house) is temporarily left aside to profit from another matter: the structure and the hierarchy of the group. At this moment, the personalities of the group appear: the stronger players try to impose and lobby or their preferences in a dominating way over the other trades. Subsequently, there is a variation to interpret the instruction of non presentation of the specification document. Indeed, because the specification document is not shown and thus the players cannot talk or exchange about it, some people see it as a form of concurrence within the same group. On the other hand, some people reinterpret their assigned constraints by organising them hierarchically in an opportunist way.

2.4 Delta Design : results and limits

Analysing the corpus, the pictures and videos of a session with Delta Design allow us several opportunities for insight and observation of individuals in a collaborative situation. In this paper, we will not develop the pedagogical interest of this approach as the reader may consult the paper [5]. Thereby, through reflective analysis [6], he can better understand and analyse his own behaviour during a collective action. However, we have identified some limits of the Delta Design game.

First of all, the future design product engineers occasionally have a lack of enthusiasm or concern for the experiment. This is related to the fact that the final objective of the experiment is the design of a house assimilated to the formation of architecture and with characteristics not focused on the mechanical product technology.

The representation of the object to be designed (under the triangle assembly) seems to be too abstract to solicit more interaction between the players. Moreover, the 2-D format differs from the 3-D formats (CAO) traditionally used in product design.

The game format imposes its utilization at the present moment and does not allow for a test in a distributed environment

Taking these limits into consideration, we designed a different game focused more upon mechanical product design. This aforementioned game is presented below.

3 The new design game based on Lego blocks

3.1 The design game's objectives

The objective of the proposed game is to design a space shuttle (cf. example figure 1) by assembling Lego® blocks while respecting various constraints. The choice of block is essentially based on upon its ease of use, its allowance for building, its resemblance with mechanical products (an airplane, a car), and its functional free software used (ex: MLCad) to remotely build and share virtual assembling models. It is important to note that numerous pedagogical games (engineering specific, marketing formation, and enterprise coaching) have been designed using these types of blocks (http://www.seriousplay.com/).

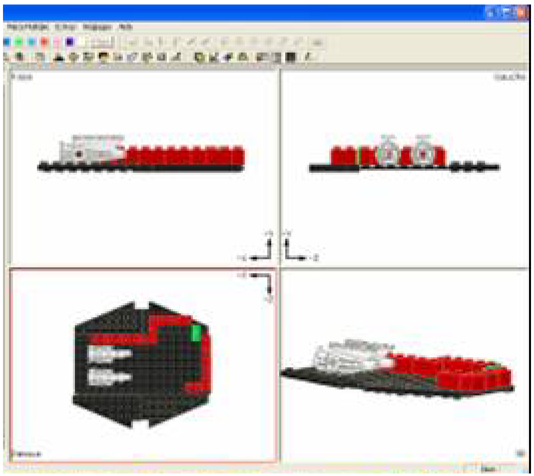

Figure 1. Examples of space shuttle built with the software MLCad

3.2 The multi-trades team's mission

This is an extract of the introduction that each player will receive once the team is composed.

Our galaxy is not only composed of these atoms, but also of a magnitude called the "slowness" that impregnates the matter and modifies its characteristics. You have to design the slowness as a homogenous field of anti-energy of variable potential. The slowness is included in a standard scale of +15 L° and -15 L°. However, this scale is not always adapted. The average slowness of a living organism is 0 L° and is endurable without corporal damages at around 5 L°. It is important to realise that it is impossible to partition slowness and use its potential and effects. The properties of certain blocks exist for that purpose.

In order to achieve the global objectives, we have created a random draft principle to draw the targeted values. We aim to use this to define the different targets for the different teams, for example: a team will be in charge of designing a space shuttle to transport x number of individuals to a speed y, for a given autonomy of t. Each different type of transport has different characteristics and obligations. All of the variables are taken into consideration in the common specification sheet. The elementary blocks to construct the final product are used by means of a reduced and specific database, obtained from the set of Lego® type blocks. This database can be used virtually with the free software MLCad (http://www.lm-software.com/mlcad/) or in a tangible way in the event in which the Lego® blocks have been actually purchased. The blocks are differentiated by their attributes (form, type, and color). These attributes also give the blocks special characteristics in terms of weight, cost, mechanics, or heat resistance. There are 5 types of blocks:

red represents heat resistance, pink represents energy reserves, blue represents mechanical resistance, yellow represents aerodynamics, and green represents ergonomics and aesthetics. Weight, heat, mechanical resistance, and cost characterize each block. There are three types of assemblies that can be made to fix the blocks: the high heat resistant assemblies, the structural assemblies, and the standard assemblies. Two motor families (big and small) with non-proportional power, weight, and heat diffusion parameters are proposed. Each model within each family has similarities (the "sport" model which is powerful, but not economic; the "big carrier" model which is cheaper; etc.). Different examples of forms are available as well: rectangular wings with yield a high carrying capacity, but are not well adapted to speed and offer high air resistance; "delta" wings which yield high performance, but need more power, and thus more fuel; etc. The dimensions solely characterize the frame plate (the number of "wedges"). They can be fixed amongst each other by means of mechanical resistance type blocks.

In this manner we restrain the students and force them to enter into an unknown world within which their calculations will be reassuring and manageable.

3.3 The rules from each discipline in the design game context

Within the game, we have a series of rules that belong to each of the implicated disciplines and assigned to each of the design game players. These different disciplines are: the assembly manager, the motor engineer, the ergonomist, the wings' responsible and the "slowness-man". We have expressed the rules in both a quantitative and subjective manner. This enables us to condition our work habits necessary for the project and avoid our tendency to only cooperate when required to satisfy the constraints. The rules are designed to encourage the actors to cooperate, negotiate, and to converge on an acceptable compromise for everyone.

The Assembly Manager must guarantee the budget is followed. He is also responsible for the surveillance of the project's energy consumption. "It is imperative that your point of view is taken in account in every design choice made by your team, all along the game. Only you are to keep the budget and the energy usage to an acceptable level ". He must calculate the material costs and the salaries given to the team members. The motor engineer has the following mission: to choose the dimension for the motor(s) to be used for the shuttle, to place it (them), and guarantee their proper operation under any and every circumstance. He is also responsible for the motor power supply. The "slowness-man" requirements begin as follows: "You must choose the shuttle internal slowness from the beginning, as it influences the shuttle speed. Once it has been chosen, you must disperse the slowness and keep it contained to the best of your ability". The ergonomist must define the internal organization of the space shuttle. "the distribution of rooms will have an impact on the design choices for which the rest of the team is responsible. Think about the consequences of your own choices. You are responsible for the comfort and practicality within the shuttle. It is your duty to make everybody follow the slowness imposed for the each room by the specification sheet."

Lastly, the wing's responsible must choose "the size of the wings, which responds approximately to the following law: Sails = 30 % number of frame

wedges* Km*Number of motors. It is also necessary for the wings to be three times bigger than the frame length.
Some disciplines have calculation rules that must be applied in order to calculate various parameters (speed, power, consumption, slowness) and also to calculate the dimension of various shuttle components (motors, batteries, wings, compartments).

4 New Lego® game tests: very encouraging results

We are implementing different tests with engineering and Ph.D. students. To this day, two groups have enabled us to experiment with new rules and a new functioning mode. Within its imaginary world, the game that has been proposed permits the users to be placed in an ambiguous environment: pleasant and unnerving at the same time. The appeal of the "CAD utility" of the Lego® game is undeniable compared to the triangle papers of the Delta Design Game. We assist to a true passion on the screens that present the CAO model of the space shuttle (see figure 2). However, we observed that the computer strongly restricts the number of manipulations and limits the sharing of the intermediate design object. Moreover, a future improvement could consist in adding physical Lego® blocks in order to construct the first physical prototype of the space shuttle before producing it using MLCad.

Figure 2. Photo taken during the first Lego® game tests

5 Conclusion and perspectives

After the tests and the finalization of our rules, we would like to propose an experience between several institutions (engineering schools, universities) in order to test this game in a distributed way (between several teams) and at distance (at different locations). The goal of our game is to approach socio-technical practices [7] of the engineers that use at the same time i) CAD models (in our case, the MLCad model), ii) proprietary utilities (in our game, the team could prototype the first versions of the space shuttle with real physical Lego® blocks). We place ourselves in the current movement that aims at the mobilisation and mutualisation of academic means, in particular in the case of the training of complex capacities such as the job collaboration. When fulfilling this condition, the young modern engineers [8] could be integrated more easily in the socio-professional networks. The game will be presented in the form of free tests to the participants of the CE 2007 conference.

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A Reasoning Approach for Conflict Dealing in Collaborative Design

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Abstract. In collaborative design process, multidisciplinary virtual teams' integration – involving exchange and sharing of knowledge and expertise – frequently generate a lot of conflicting situations. Different experts' point of views and perspectives, in addition to several ways of communicating and collaborating in knowledge level, make all this process very hard to tackle. Aiming to minimize the appearance of early design conflicts and to solve the rest of them, this paper presents an approach to represent knowledge in design process based on Web Ontology Language (OWL). OWL is structured to be a major formalism for the design and dissemination of ontology information. The use of OWL reasoning is intended to be a consistent way to verify the information given by several experts, trying to avoid redundancies, contradictions and misunderstoods. A prototype, based on the Function-Behavior-Structure design framework, that uses OWL to input data, was built up to validate this approach.

Keywords. Collaborative design, ontology integration, reasoning, conflict resolution.

1 Introduction

Current trends in collaborative design domain have focused on the increasing needing of teamwork. Complex industrial problems involving different knowledge areas require, even more, heterogeneous virtual teams to collaborate in order to solve them. These teams should exchange their knowledge and expertise, creating a collaborative network.

The enterprises' collaborative design process uses, even more, geographically distributed knowledge, resources and equipment [16]. Virtual team members work in parallel with different tools, languages and time zones. Collaborative engineering proposes to face these problems by reorganizing and integrating the set

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of development activities, starting from design early stages [6]. An important part of the collaborative work consists of communication and sharing of data, information and knowledge, among individuals with different points of view and specific objectives concerning their particular domains. Once these points of view and objectives are considered inside the same scope, divergences arisen from this process lead frequently to conflicts.

This paper proposes an approach to attenuate design conflicts. This approach is based on OWL reasoning, where all exchanged data and information will be represented as OWL classes, in order to use an OWL reasoner. To validate this proposal, a little prototype was implemented, taking as scneario a distributed architecure for collaborative design, previously described in [2] and [14].

2 Design conflicts and OWL reasoning

2.1 Conflicts in collaborative design

A conflict is an incompatibility between two design decisions or between two distinct design objectives [8]. It can be considered that there is a conflict when one or more propositions cannot coexist in the same time at the same design space [4].

Design space: is a multidimensional representation of the design process parameters' set – models, but also design goals, the socio-cultural references that define the designer's work method.

Publication: publishing a proposition means to put together proposed instances of product model and the subpart already instantiated of the design space. This union is only possible if there is no interference between these two sets that means, if all of their elements are coherent.

Attenuation: conflicts can be extremely consumers of resources (development time, budget, materials). That is why it is so important to prevent them, trying to detect them in early design stages. Identify them, categorize them, and notify the different involved parts, in order to put the situation under control as soon as possible. These tree steps are called strategies of conflict attenuation [10][4].

2.2 OWL reasoners

The Web Ontology Language (OWL) [12], released as a W3C recommendation in February 2004, is an expressive ontology language that is layered on top of RDF and RDFS. OWL can be used to define classes and properties as in RDFS, but in addition, it provides a rich set of constructs to create new class descriptions as logical combinations (intersections, unions, or complements) of other classes; define value and cardinality restrictions on properties (e.g., a restriction on a class to have only one value for a particular property) and so on.

OWL is unique in that it is the first ontology language whose design is based on the Web architecture, i.e., it is open (non-proprietary); it uses Universal Resource Identifiers (URIs) to unambiguously identify resources on the Web (similar to RDF and RDFS); it supports the linking of terms across ontologies making it possible to cross-reference and reuse information; and it has an XML syntax (RDF/XML) for easy data exchange.

One of the main benefits of OWL is the support for automated reasoning, and to this effect, it has a formal semantics based on Description Logics (DL). DLs are typically a decidable subset of First Order Logic. They are suitable for representing structured information about concepts, concept hierarchies and relationships between concepts. The decidability of the logic ensures that sound and complete DL reasoners can be built to check the consistency of an OWL ontology, i.e., verify whether there are any logical contradictions in the ontology axioms. Furthermore, reasoners can be used to derive inferences from the asserted information, e.g., infer whether a particular concept in an ontology is a subconcept of another, or whether a particular individual in an ontology belongs to a specific class.

Examples of OWL reasoners [11]:

- F-OWL [5]: an ontology inference engine for OWL based on Flora-2 (an Object-Oriented Knowledge Base Language).
  - Euler [3]: an inference engine supporting logic based proofs. It is a backward chaining reasoner and will tell you whether a given set of facts and rules supports a given conclusion.
  - Pellet [13] is an OWL DL reasoner based on the tableaux algorithms developed for expressive Description Logics. After parsing OWL documents into a triple stores, the OWL abstract syntax are separated into TBox(axioms about classes), ABox(assertions about individuals) and RBox(axioms about properties), which are passed to the tableaux based reasoner.
  - Hoolet [7] is an OWL DL reasoner that uses a First Order Prover to reason about OWL ontologies.
  - Cerebra [1] is a product of Network Inference, and its technology provides a commercial grade, robust, scalable implementation of the DL algorithms that use OWL documents in their native form. These algorithms are encapsulated into a run-time engine that is provided as a service to other applications or services and can respond to queries about ontologies from those applications.

The OWL Test Cases document [9] defines an OWL consistency checker as follows: an OWL consistency checker takes a document as input, and returns one word being consistent, inconsistent, or unknown.

But, while consistency checking is an important task, it does not, in itself, allow one to do anything interesting with an ontology. Traditionally, in the ontology and Description Logic community, there is a suite of inference services held to be key to most applications or knowledge engineering efforts. It is imperative that a practical OWL reasoner provide at least the standard set of Description Logic inference services, namely [13]:

- Consistency checking, which ensures that an ontology does not contain any contradictory facts. The OWL Abstract Syntax & Semantics document provides a formal definition of ontology consistency that Pellet uses. In DL terminology, this is the operation to check the consistency of an ABox with respect to a TBox (this corresponds to being an OWL consistency checker).

- Concept satisfiability, which checks if it is possible for a class to have any instances. If class is unsatisfiable, then defining an instance of the class will cause the whole ontology to be inconsistent.
- Classification, which computes the subclass relations between every named class to create the complete class hierarchy. The class hierarchy can be used to answer queries such as getting all or only the direct subclasses of a class.
- Realization, which finds the most specific classes that an individual belongs to; or in other words, computes the direct types for each of the individuals. Realization can only be performed after classification since direct types are defined with respect to a class hierarchy. Using the classification hierarchy, it is also possible to get all the types for that individual.

3 A reasoning approach

The architecture proposed in [2] is based on the Function-Behavior-Structure framework. This framework is built up to take users' requirements, to transform them into formal specifications and to use these specifications to describe product's functions, behaviours and structures (Figure 1). All this process is done by several geographically distributed designer groups, called agencies.

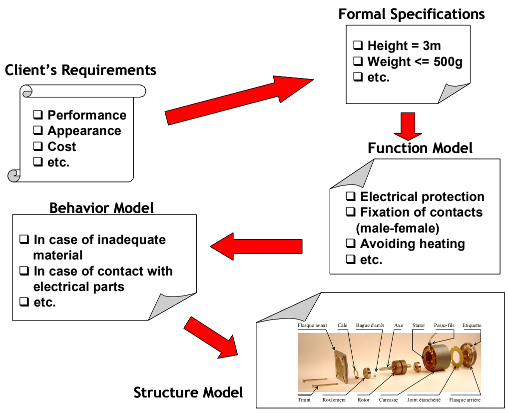

Figure 1. Function-Behavior-Structure

Each agency represents a specialty, a knowledge domain. An agency aggregate one or more designers (called agents). Each agent has a private workspace of data and information. In the private workspace, he prepares his propositions before submit them to other agents. The interaction with other agents is provided by an agency shared workspace (ASW). The ASW has the same structures present in agent private workspace, but in a higher level, because all data and information contained in there were previously agreed among all concerning agents. In the same way, communication inter-agency is provided by a project shared workspace [15], a global workspace to store the final design models (Figure 2).

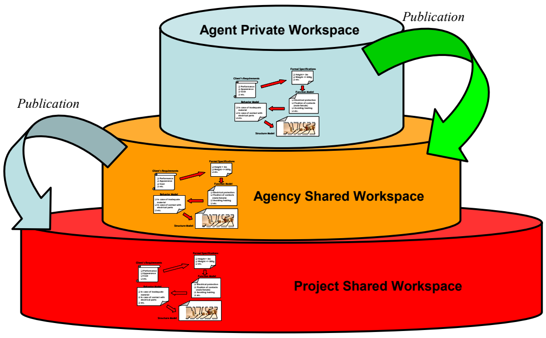

Figure 2. Shared Workspaces

Our proposal consists of creating an intermediate step when publishing to higher levels. The approach is to execute an OWL consistency checking in every proposition to be published. This intends to guarantee the coherence of the information being passed through. The goal is to take advantage of the OWL reasoning to prevent early conflicts. For example, it can be defined an OWL superclass to represent a metal alloy, named ClassA. ClassA represents structures constructed using aluminium-cooper alloy. ClassA may determine that its weight property cannot have value higher than 100g. So, for all subclasses representing structures of aluminium-cooper alloy, this stands as a rule to be followed from now on. If a ClassB intends to extend ClassA, its weight property must necessarily be set to less or equal 100g, otherwise, it will not be published.

4 Prototype

A prototype has been built up in order to validate the proposed approach. Providing a computational environment, it intends to be an infrastructure tool through which several experts can collaborate in order to achieve a product design. Collaboration in this context comprises interaction among different knowledge areas. In an effective and collaborative environment, experts came from different areas can integrate their knowledge in a simultaneous way, looking for an expressive gain of productivity.

Experts have their own way to see and to understand the subject, according to their duties. Therefore, providing mechanisms of data representation to create a "common language" understood by the experts was the way chosen to detect specification conflicts.

An electrical connector design, as depicted in [6], was chosen as scenario to this prototype. The work required to deploy this connector is decomposed in several subsystems, corresponding to different disciplines (mechanical, electrical, thermal, etc.). The goal is to simulate the design process of this trying to identify potential conflicts, by using OWL reasoning. Figure 3 shows the connector's overall structure and his components.

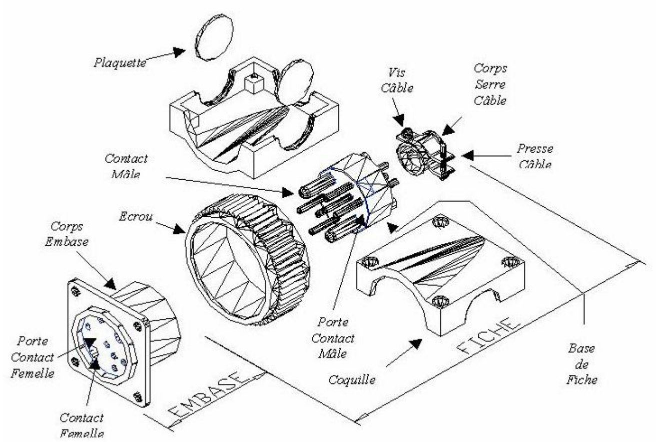

Figure 3. Electrical Connector Design

The prototype is based on John Gero's Function-Behavior-Structure design framework [14]. According to this framework, a product structure is obtained starting from function and behavior models related to the product. Every structure model is derived from one or more behavior models. Behaviors are derived from function models and every function will be defined from one or more formal product specifications. Hence, as these models are interrelated, the main goal here is to formalize product requirements, turning them into formal specifications (OWL classes).

The prototype's internal structure comprises three roles: system administrator; specialists, called agents; and specialist groups, called agencies. The system administrator is the project manager. He is in charge of project creation, definition of objectives, date delimitation, attribution and management of agents and agencies. Attributions given to agents and agencies include right access and system using access. Actors are agents (experts) and agencies (expert groups) which are involved in the product design.

Figure 4 shows a potential conflict situation. Inside the Design Agency can be seen two experts, a mechanical engineer and an electrical engineer. Both of them disagree about a specific piece height, what generates a conflict.

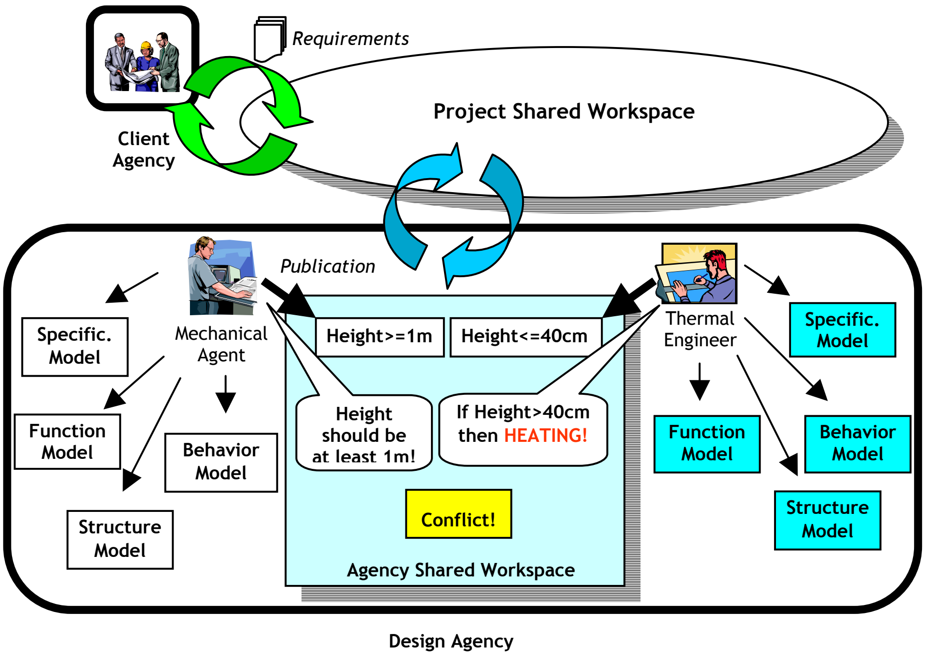

Figure 4. Potential Conflict Situation

In this case, the conflict was avoided because before the second agent publish his proposition, he was informed by the system that the content to be published was not consistent neither coherent. So, in this case he must necessarily to redo his work or try to negotiate with the other involved agent.

5 Conclusions and perspectives

Representing knowledge in OWL offers a reasonable trade-off between expressibility and decidability, witch when used to verify product specifications in collaborative design may fit as an efficient conflict attenuator. Nevertheless, two important limitations remain: efficient reasoning on real-world ontologies containing a large set of individuals is still a challenging task and OWL cannot be used efficiently to model certain application domains.

To attenuate these problems, we intend to model applications by using EXPRESS language (ISO 10303-11), an industry standard conceived to provide information and data exchange and system interoperability. This step intends to give robustness to the system. For such, to achieve such a scenario, a conversor "EXPRESS to OWL" is being built up, to keep the advantages of the OWL reasoning.

Moreover, next steps comprise implementing the agents' negotiation process and also to improve the OWL reasoning to work with the case-based approach, profiting from the entries previously put into the knowledge base.

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Interface design of a product as a potential agent for a concurrent engineering environment

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Abstract. Product design is currently a subject that involves various kinds of knowledge. In order to develop products that are successful in the market it is necessary to involve people from different areas of the production cycle, such as: marketing, assembly, processing, sales, among others, in addition to consideration of clients' wishes. To address these issues in the development of a product, a design method that uses tools based on the principles of simultaneous engineering needs to be used. Interface design of a product should consider information from the areas mentioned as well. In this way, development of a method for interface design in the initial phases of product design could be an element of effective use of Simultaneous Engineering in the design. The purpose of this paper is to describe how the development of a method for interface design can contribute to the establishment of a Simultaneous Engineering environment in the initial phases of product design. To accomplish this, it is necessary to use techniques such as DFA, DFM, and FMEA in those stages of the design.

Keywords. Interface design, Concurrent Engineering, Conceptual Design, DFA, DFM, FMEA

1 Introduction

The Concurrent Engineering (CE) is a work philosophy which objective is to enhance the product development process. This is searched by the information sharing between the different knowledge areas involved in this task.

The CE is defined like a philosophy and an environment too. How philosophy is based on the recognition of each one and your responsabilities to the product quality. Like an environment it is based on the simultaneous product development and on the processes which affect it in its lifecycle [1]. To Noble [2], CE is typically defined like the integration of the design processes: product and

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manufacture. The objective of this integration is to reduce the time and the cost of product development and to produce a product that attend to client expectations.

Kerzner [3] point that CE is an attempt to execute work in parallel. Better than those carried through sequentially - where the greater inconvenience is that the chosen conception will pass for all the stages of design without a detailed evaluation of the difficulties of manufacture (execution) of the product. This search to design 'on the right way in the first time' by means of the concurrence among the product design and its related processes.

So we can see that there are limitations on the sequential design process. Rozenfeld et al [4] point some of them:

- isolation between the product research and development and product design areas. This causes a lack of integration with the general strategy of the business. This is increased by the different languages and understands of the design problem used by those areas;
- existence of organizational and communication barriers between these areas and the remain of the company;
- little participation of the high administration in the main definitions of the goals of these areas;
- hierarquization and linearity of the information flow between the areas of the company
- little envolvement of the suppliers in the creation phases of the product;
- resistance to controls and to the accounting of costs in R&D and Product Design because these areas deal with activities of risk;
- extreme specialization of the professionals of the area;

This way the authors present a model of Design Process based on the CE principles which is formed by three phases: Informational Design, Conceptual Design and Detailed Design.

In this context, the interface design appears like a tool to effectivelly implement the CE environment. This is due to its characteristic of connect different components of product. Related to the interface design are the areas of manufacture, assembly and reliability [5]. So, the development of a methodology of interface design is a potential factor of implementation of a CE environment.

The objective of this paper is to develop a bibliographical research about the interface design to give the base to the development of a methodology of interface design in the conceptual design phase using like support tools the DFA, DFM and FMEA methods.

2 The interface design

The Conceptual Design phase (Figure 1) is considered one of the critical points in the design process [6] because it is at this point that structure and concept of the design are defined. It is estimated that up to this point about 20% of the work involved in the design is completed, and that this percentage is responsible for defining 80% of its cost [7]. This is due to the fact that the up to the Conceptual Design one is working with the abstract phase of the process, after that, one moves on to the concretization of the product. As a result of its importance, this phase has some points requiring a better definition.

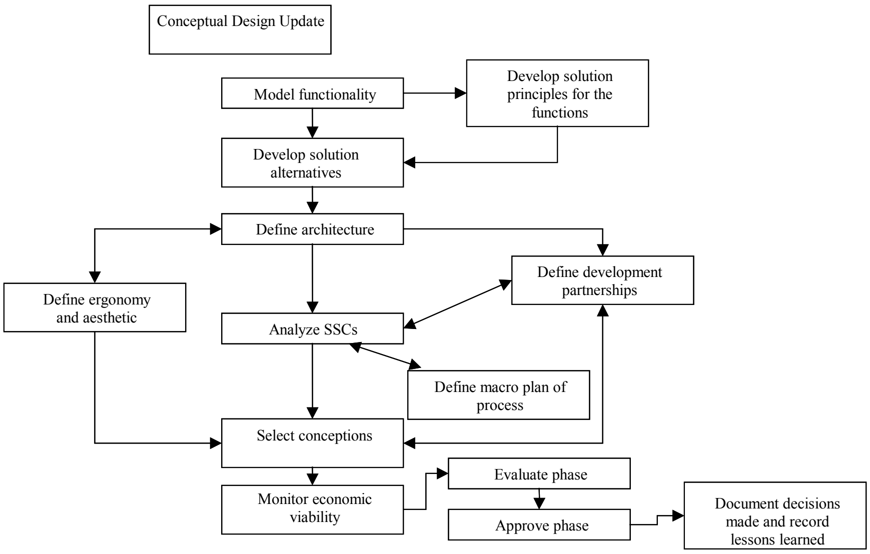

Figure 1. Conceptual Design phase [4]

Inside the conceptual design we can see some areas that still are needing of detailing like the interface design. The existing methodologies attend the interface design just in the Preliminar Design. This cause some troubles like the need of iterations due to connection fails between solution principles or the need of very complex interfaces among two principles. These troubles can cause late and increase the costs of design.

Moreover, the role of interface design is showed by Ullman [8] that consider the development of interfaces in the phase of Preliminary Design. The author point that the "functions occur in the interfaces between components". This is based on the following interface definition: "the boundary area between adjacent regions that constitutes a point where independent systems of diverse groups interact" or "the interconnection between two equipment that possesss different functions and that could not connect directly themself" [9].

The great advantage of the determination of the product interfaces is that the change of the abstraction level to the concrete level becomes less abrupt and uncertain, that is, instead of creating the solution principles directly from the structure of functions, we can reduce the possibility of problems in the posterior phases by the architecture determination of the product what includes the dfinition of its interfaces. Thus, parameters for the product development as the involved variable, flows of material energy and signal as well as the proper interfaces of the same, become more apparent for the designer.

In this direction, Ulrich and Eppinger [10] proposed a way to determine the product architecture by the mapping of interactions between functions and the possible product interfaces. However, the proposal of the authors is inserted in the Preliminary Design what indicates that for its application already exists a definite conception. Already Otto and Wood [11] describe the possibility of use of the method of Ulrich and Eppinger [10] still in the phase of Conceptual Design and, moreover, presents another proposal of generation of the architecture and determination of the possible modules that are executed by heuristical means. This proposal presents the advantage to use the specifications of design and the restrictions of the product as parameters for the development of the product architecture.

Looking for the definition of product interfaces in the literature there are some relevant proposals. Ullman [8] considers a systematics of interfaces development in the Preliminary Design in which presents some steps that go since the concern with the rocking of energy, material and information in the level of functions, passing to the most critical interfaces determination, the maintenance of the functional independence of subsystems and components and the care in separating the design in distinct components. Another proposal to interface development is made by Otto and Wood [11]. The authors point the necessity of initially to define the product architecture and, based on this, to define preliminary layouts. So, we can establish the product interfaces. However, the authors do not say as to make it.

Another work carried through in the direction to evaluate new techniques of development of concepts is of Sousa [12]. He made an analysis of the use of methods of Design for Manufacture and Assembly in the Conceptual Design. In this study the author points that the requirements of manufacture and assembly, beyond the functional requirements, are important for the evaluation of the product structures. Also he places that, for does not being made a correct evaluation of the product assembly and manufacture in the phase of Conceptual Design, there are unnecessary iterations when the design already meets in the Preliminary and Detailed phases returning to the Conceptual Design, also. These iterations finish for causing increases of costs, delays and reworks that could be prevented.

Ullman [8] and Linhares and Dias [13] places that CE must consider four basic elements: function, geometry, material and manufacturing processes. Moreover, they place that design and manufacture (including the assembly) must simultaneously be developed. Also point that the development of each part needs to be integrated to the funtions definition and refinement and its respective interfaces. Linhares and Dias [13] point too that the design must take in account two tasks in the individual conception of a part: (1) to design it like it was a product and (2) to consider that it is part of a realizable module and to take in account its interfaces. Siqueira and Forcellini [14] make the consideration that the requirements of the unions are excellent factors in the election of conceptions.

This way, we can see the role of the execution of the product interface design in the initial stages of the design process. This can to increase the knowledge of the design team about the designed product . However, its necessary to use methods and tools of support. So we will analyse some of them.

3 Support methods and tools to the interface design to the initial phases of the product development

In this topic the methods of DFA and DFM and the tool of FMEA will be boarded as auxiliary mechanisms in the product development process and especifically in the interface development in the early phases of the design process.

DFA e DFM

The methods of DFA and DFM aim to optimize the design in the phase of definition of processes and final shapes, searching lesser times and costs. These methods had been developed by Boothroyd, Dewhrust and Knight [15] and, initially, was used in set (DFMA). However, due to importance of each one of the processes and the possibility to be applied separately in agreement the case, them they had been branched in two methods: DFM and DFA. To have an idea of the relevance of such methods Boothroyd, Dewhrust and Knight [15] and Pereira and Manke [16] esteem that 50% of the manufacture costs are related to the assembly process and both represent a great parcel in the final cost of the product.

Moreover, the two methods are based on the last experience and search to expose and systemize the knowledge [17]. Thus, its role is observed as mechanisms not only of aid technician but, also, of support to the management of knowledge of the company.

However, for its application, it is necessary that there is an integrated product development environment, with processes and products engineers working in set in the early phases of design. This is another characteristic of the DFMA methods. It require the implementation of a CE environment with representants of different knowledge areas in the design team.

To Keys apud Valeri and Trabasso [18] the DFX methods can be defined as being “a set of techniques generally applied in the early phases of the integrated products development, to guarantee that the hole lifecycle will be considered in the product design”. In this definition the authors point that the DFM method is one “technic applied in design, aiming at definition of alternatives which optimize the manufacture system as a whole, identifying concepts of easy manufacturing products, help the design of these kind of products, facilitates the integration between the development of manufacture processes and the design of the product”. Therefore, Stoll apud Valeri and Trabasso [18] place a list of directives for the DFM:

- to minimize the number of parts;
- to develop modular designs;
- to minimize the variations of parts;
- to design multi-functional parts;
- to design parts for multipurpose;
- to facilitate the manufacture;
- to prevent the separate fixing use;
- to diminish the assembly directions;
- to maximize the of the assemblies;

- to minimize the handle;
- to evaluate the assembly methods;
- to eliminate or to simplify the adjustments.

Relative to DFA Lee and Hahn apud Valeri and Trabasso [18] define it as “a group of design techniques used in the product development to improve the assembly”. The authors divide the DFA in three boardings:

- general rules used by the designers as directives;
- measurelines of assemblability of parts and the product as a whole;
- revisions of design to combine the measurelines of assemblability with times of assembly and its costs with assemblability rules in order to assist in the revision of the design.

Because of this, it can be defined some basic lines of direction for DFA: minimize the number of parts and easiness of assembly to reduce the cost of the product [18].

Thus, Kuo et al apud Valeri and Trabasso [18] cite the criteria of DFA as being:

- to minimize: number of parts and elements of setting, variations of design, movements of assembly, directions of assembly;
- to provide: chamfers, automatic alignment, easy access, symmetrical or to evidence anti-symmetrical parts, simple manipulation and transport;
- to prevent: visual blockages to parts, entangled or hidden parts, necessity of posterior adjustments in the assemblies.

So, we can note the capacity to integrate the product development process that the presented methods possess. From this, we can think about the best use of the same ones, suggesting to apply them in the interface design in the Conceptual phase.

FMEA

The tool of Failure Modes and Effect Analysis (FMEA) were developed with the intention of assisting in the diagnosis and forecast of military and aeronautical equipment imperfections. However, due to its predictive character, it passed to be used in product design.

The FMEA is a standardized analytical tool used to detect and to eliminate potential problems by a systematic and complete way [17]. It uses the knowledge of the design team on quality, performance and process. Moreover, the FMEA allows the hierarquization of the causes of the problems and establishes parameters for the adoption of preventive or corrective actions [17].

Thus, when the FMEA is applied, we can to determine the design critical points. This will help the team to define the priorities of design. This tool, as well as the DFA and the DFM, is used in the Preliminary Design phase. However, like the FMEA implies in functioning preview it is useful in the Conceptual Design.

The application of FMEA in the Conceptual Design possesss the advantage to detect and correct problem earlier. However, it presents the disadvantage of, in this phase, to possess few available information. This lack of information can be a source of uncertainties, but this can be useful in the interface design to solve some of the uncertainities.

4 Conclusions

For the analysis of above displayed it can be evidenced that the interface design and CE are subjects that look at different aspects of the product development. Although this they converge to the reduction of the uncertainties in the design process. This is because they involve people of different areas of the product lifecycle. So, they can to map and forecast neglected product aspects.
However, there are barriers for use them.

Although sufficiently studied the CE still possesss a set of barriers to effectively be implemented. It cannot be used in many companies because is a work philosophy that must has a lot of information exchange and quarrels between different functional areas of the company. These experience exchange depends basically on the profile of the involved people in the design team. However, a difficulty can appear due to internal disputes or problems of relationship.

The interface design has another kind of implementation difficulty. There is not interface design methodologies for the conceptual design. There are proposals that suggest its use in the Preliminary Design. However, these keep the sequential status of the product development.

Based on these barriers, we perceive that there is a need to improve aspects of both the subjects. This improvement passes for the anticipation of the interface development to the Conceptual Design. This anticipation with concurrent application of the DFA, DFM and FMEA tends to add information of different areas of the product lifecycle facilitating the implementation of the CE environment.

This occurs because the DFx techniques can be considered as a knowledge base which objectives to design products maximizig characteristics as: quality, reliability, services, security, user, environment, time-to-market, at the same time that it minimizes costs of the product lifecycle and manufacture. Thus, the use of the DFx in the Conceptual Design can have a great role in the taking of abstract level decisions and in the product costs later phases of its development. In addition, they define the product performance in its lifecycle.

The use of DFA, DFM and FMEA in Conceptual Design is a new perspective in the field of integrated product development, therefore it can use all the advantages that those tools present in relation to the type of knowledge used in the generation and election of product concepts. This because, being the same exposers of the tacit knowledge, they can contribute for the diffusion of the experts knowledge for the whole organization.

Thus it is evidenced the viability of the use of the techniques with indicative for possible works in the Artificial Intelligence (AI) area. This is because AI permits to deal with the tacit knowledge of the human being transforming it to explicit knowledge. In addition, the AI is in a certain form, linked to the problems of heuristical nature as the election of the best conception for a product.

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Knowledge Engineering: Organization Memory, Ontology, Description logics and Semantics

Organizational Memory for Knowledge and Information Management in the Definition, Analysis and Design Phases of Civil Engineering Projects using an XML Model

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Abstract. An ontology of civil engineering services is created by combining knowledge of the phases of the life cycle of an engineering design product, the steps in the phases in an engineering service and the technical, technological, scientific, social, economic, organizational and legal aspects associated with an engineering service. The documents containing information and knowledge related to projects are tagged using ontological concepts. The annotated documents are stored in an XML-Database, and constitute an organizational memory that enables access to, and reuse of information and knowledge. A case study of an engineering service is used to illustrate the proposed approach to the construction of the organizational memory.

Keywords. Organizational memory, knowledge system, information system, ontology, XML model

1 Introduction

Organizational Memories (OM) are knowledge-based systems. Knowledge acquisition is a central aspect for developing this type of systems. In early systems knowledge was extracted from experts of domain and it was represented as a set of heuristic rules to solve problems. To find these heuristics is not easy. Reynaud in [9] argues that the difficulties arise, among others, from: the absence of a methodological guide for constructing heuristic knowledge bases, the fact that the heuristics are not directly expressed by the experts and that the ability to resolve problems depends directly on the existence of these heuristics.

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Active research about these difficulties began in 1980. The dynamic of research in this area has lead to approaches based on the construction of models in opposition to those centred on the knowledge extracted from the experts.

The knowledge of a study domain for developing an application, named "domain knowledge", has been differenciated from "reasoning knowledge", namely the knowledge obtained by reasoning, It describes abstractly the process of an application in terms of "task" and "methods".

Reasoning knowledge is abstract knowledge. It focus on the relationships to objects, tacking account of bject's roles in the reasoning model. The reasoning model is a frame of knowledge categories [12] supporting the interventions of the agents on the relationship between de agent and objects of the domain.

Domain knowledge is centered on objects, their associated semantic concepts, the relationship among these objects and physical interventions on domain objects. This knowledge expresses structured knowledge arising from well defined process and oriented to the communication. This characterization corresponds to the *information* concept.

The domain knowledge is currently structured in ontologies containing the domain objects and the relationships among them. Many domain ontologies are proposed in specific economical sectors. For example, [5] presents an ontology in civil engineering construction domain. Other ontologies are centered in phases or aspects of the construction work, for example, the definition phase of a project is considered in [14]. In [2] a project ontology is organized in terms of process, organization and product. We propose an enterprise ontology containing a project's ontology in the domain of studies and design in civil engineering for constructing an organizational memory, in order to store, manage, retrieve and reuse project knowledge.

In the domain of Interoperability for Enterprise Applications, the European project InterOp, www.interop-noe.org, envisions to facilitate the emergence of an interoperability research corpus through the fusion of three knowledge-components: *software architecture*, *enterprise modelling* and *Ontology*. These integration concepts are considered in that european project as requirements to interoperability. We introduce a model for integrating information and knowledge and a model of Organizational Memory for knowledge and information management related to definition, analysis and design phases of civil engineering projects.

Many definitions and interpretations of organizational memory exist in the literature. The concepts expressed, among others, in [1,6,13] are extend in [8] which considers the corporate memory as an *«explicit, disembodied, persistent representation of knowledge and information in an organization, in order to facilitate its access and reuse by members of the organization, for their tasks»*. Organizational Memory as a model for knowledge management concentrates the research work in particular domains in order to pay attention to specific knowledge and for developing an organizational culture favourable to an extended use of the Organizational Memory. In this way, recent studies in [7] and [3] highlight the handicap between the external diffusion of Organizational Memory models and the limited impact within the enterprises.

Knowledge and Information representation, storage and retrieval are central aspects which attract important efforts from Description Logic and XML communities. Our work proposes an Organizational Memory relating knowledge to information concepts, for an enterprise of studies and designs in civil engineering domain. This memory is structured using an XML model based on an enterprise ontology containing a project ontology.

We illustrate the approach with a case study in the company AREA INGENIEROS CONSULTORES, which considers the storage, retrieval and reuse of the content of a building structural design memory.

The remainder of this paper is organized as follows. A Knowledge meta-model for Knowledge and Information Systems is presented in Section 2. Section 3 is centered on constructing an Enterprise Ontology and Organizational Memory in domain of civil engineering studies and designs. An application example of the organizational memory is the object of Section 4. A discussion of results and future works are included in Section 5. Section 6 contains the biliography.

2 Meta-model of Knowledge

A first generation of knowledge systems was centered on the knowledge obtained from domain experts, while the second one is characterized by the use of models for supporting the stages of knowledge management. We use knowledge meta-model [4], in Figure 1, intending to integrate *knowledge* and *information* concepts as well as to construct structured reasoning models and ontologies representing knowledge of different nature.

Knowledge is considered, in our work, as all that may be known, understood and imagined about a subject, considering existent or created objects, agents, means, methods and agents' interventions. Equally, we define *information* as predefined communication-oriented knowledge arising from well structured processes from systematic intervention of existent agents, means and methods on existent or created objects, considering known and created relationships among these objects. We extend the concept of knowledge involved in a Knowledge Base and in Knowledge-based Systems, in order to incorporate and differentiate *information* and *knowledge*. The Knowledge-based Systems (KBS) change to Extended Knowledge based Systems (EKBS) including *knowledge* and *information*.

Our work takes *domain* and *context* concepts of [10,11] where the *domain* is an activity field characterized by the objects, while the *context* defines a space of agents' interventions including means, methods and the circumstances that complement the description of a phenomenon.

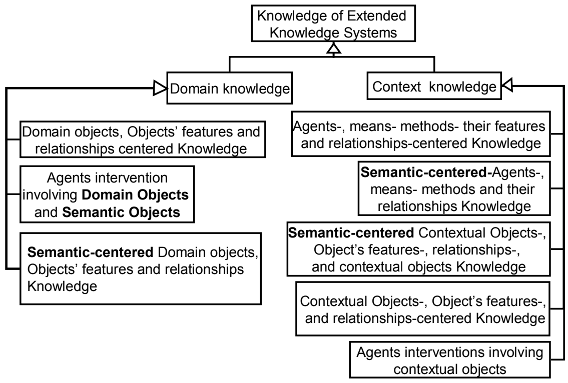

Figure 1. Meta model (domain knowledge branch)

Knowledge meta-model relates two categories of knowledge for extended knowledge-based systems: *domain knowledge* and *context knowledge*. The former involves knowledge centered on: features of existent and created domain objects and their relationships, existent and created semantic concepts of objects, and existent and created interventions (goals) of existent agents. These interventions may be physical and intellectual. *Domain knowledge* represents the three information types introduced in [4]: *predefined knowledge* corresponding to consolidated information treated by traditional information systems, *referenced knowledge* representing transitional information managed by evolving information systems, which uses knowledge techniques to manage the information, and finally, *discovered knowledge* denoting emerging information considered by prospecting information systems. Thus, *domain knowledge* is *information*. The latter considers knowledge focused on: existent and created agents, means and methods; existent and created context objects; existent and created semantic concepts of agents, means, methods and context objects and finally, existent and created interventions (goals) of existent and created agents involving features and semantic concepts of existent and created objects of the context. These concepts constitute the five sub-categories of *Context Knowledge* Category. This category is specialized according to three views. A first view presents three concepts: *Social Context Knowledge*, *Organizational Context Knowledge* and *System Context Knowledge*. A second view desegregates *Context Knowledge* in *Context Information* and *Context Expanding Knowledge*. The third view specialize *Context Knowledge* in *Specific Context Knowledge* and *Global Context Knowledge*.

Utilization Context knowledge is a hybrid concept which inherits its characteristics from *Domain Knowledge* and *Specific Context Knowledge*. In [11] *Utilization Context* delimitates the space of Intervention of system agents, the objects involved in interventions of these agents, as well as the circumstances affecting the involved objects. *Agent Intervention* represents an agent *action* or *interaction*. For sake of space we do not go ahead to explain more detailed concepts of Context knowledge.

The characterization of *Domain Information*, *Context information* and *Context Expanding Knowledge* aids to understand the interaction between Domain knowledge and Context knowledge. The proposed ontology aims to relate *knowledge* and *information* in the Organization Memory. Next section explains the Ontology and the Organization Memory construction.

3 Ontology Based Knowledge Memory

Our work of knowledge engineering presents an enterprise ontology in the field of civil engineering preconstruction services [4]. In this paper we take only a part of those, corresponding to *Engineering Services Ontology*, in Figure 2. The interdisciplinary study for arranging this ontology took acount of knowledge of definition, analysis and design phases of a civil engineering product, as well as knowledge of proper processes of each phase, and knowledge of technical, technological, scientific, social, economic, organizational and legal aspects associated with an engineering service. This ontology was validated applying an alternative construction method proposed in [10], based on the concept *utilisation context*.

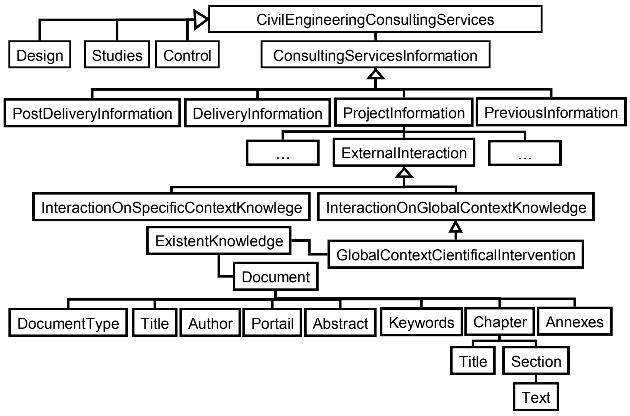

Figure 2. An ontology fragment

Offered Services as Top concept of the Engineering Service Ontology has two derived branches: *CivilEngineering*ConsultingServices and *InternalServices.* The first one generalizes the concepts *Design*, *Study* and *Control* which, in turn are specialized in particular Studies and Design Services. For example *Design* is specialized, among others in *StructuralDesign* and this last in *BridgeStructuralDesign, BuildingStructuralDesign, DamStructuralDesign, WallStructuralDesign, etc.*

The concepts *PreviousInformation*, *ProjectInformation*, *DeliveryInformation* and *PostDeliveryInformation* specialize the concept CosultingServiceInformation which is contained in *CivilEngineeringConsultingServices*.

PreviousInformation concept considers the necessary knowledge for defining, contracting and developing an engineering service and for managing the related project. *PreviousInformation* contains: *TechnicalInformation, Proposal and Contract.* This last concept is detailed in *Head, Clauses and FinalPart.*

The concept *ProjectInformation* is the central concept and covers seven concepts: *Record*, *Planning*, *Organization*, *Direction*, *Execution*, *EvaluationAndControl* and *ExternalInteraction*. The element *Execution* is desegregated in *Process*. In turn, *Process* encloses the concepts *Description*, *Activity* and *Decision*.

ExternalInteraction concept connects the domain concepts to elements of *Specific Context* and to *Global Context*. Two elements specialize *ExternalInteraction*: *InteractionWithSpecificContextKnowledge* and *InteractionWithGlobalContextKnowledge.* The former consider the interaction among Domain concepts and Specific Context concepts including the concepts: *CommercialInteraction*, *LegalInteraction*, *PersonalInteraction*, *InstitutionalInteraction*, *ClientInteraction*, *ScientificInteraction*, *TechnologicalInteraction*, *TechnicalInteraction* and *SocialInteraction.* The latter leads to relate the domain concepts to Global Context knowledge. This knowledge would be existent knowledge or created knowledge. Global Context knowledge includes:*GlobalContextScientificInteraction*, *GlobalContextTechnologicalInteraction*, *GlobalContextTechnicalInteraction* and *GlobalContextSocialInteraction*. A component of *GlobalContextScientificInteraction* is *ExistentLnowledge* having the concept *Document*, which is composed of: *DocumentType*, *Title*, *Author*, *Portal, Abstract*, *Keywords*, *Chapter* and *Annexes*. For sake of simplicity, in Figure 2, only the components Title, Section and Text of concept Chapter are depicted.

This described ontology's fragment is enough for illustrating, in next Section, the management of an ontology-based Organizational Memory.

4 Case Study of Knowledge Memory

Currently, project document repositories provide an enormous collection of engineering knowledge.


```xml
<GlobalContextCientificIntervention>
    <ExistentKnowledge>
        <Document>
            <DocumentType Name="Book Chapter"/>
                <Title>Monobe-Okabe Method</Title>
                <Author/>
                <Portal/>
                <Abstract/>
                <Keywords >
                    <Keyword>earth pressure</Keyword>
                    <Keyword>Monobe-Okabe</Keyword>
                </Keywords>
                <Chapter>
                    <Title>EARTH PRESSURE AND HYDRAULIC PRESSURE</Title>
                    <Section Name="9.1 Overview">
                        <Text>(1) Earth pressure and hydraulic pressure acting against structures such as exterior basement
 walls and retaining walls, which touch the soil directly, shall be considered. The buoyancy shall also be
considered for the structures below groundwater level.
(2) The earth pressure that permanently acts on exterior basement walls, etc. shall be assumed to be
the earth pressure at rest in general, and the influence the surcharge on the ground surface shall be
appropriately considered when it exists.
                        </Text>
                    <Section Name="9.2 Earth Pressure and Hydraulic Pressure that Act on Exterior Basement Walls">
                        <Text>The earth pressure and hydraulic pressure that permanently act on exterior
 basement walls shall be calculated according to Eq. (9.1) for above groundwater level, and shall be calculated according to Eq.(9.2) for below
Ground water level:
                        </Text>
                    </Section>
                    ...
                </Chapter>
            ...
        </Document>
    </ExistentKnowledge>
</GlobalConextCientificIntervention>
```


This knowledge refers essentially to engineering services organized as projects. Our enterprise ontology, in the field of studies and design in domain of civil

engineering, involves and deploys, among others, the concepts *civil engineering consulting service* and *projectInformation*. Thus, the ontology concepts are used to tag the documents related to the specific services and projects.
The tagged documents are incorporated in an XML file, which constitutes the Organizational Memory for the enterprise of Studies and Design. The little part of the XML file, in next paragraph, illustrates the storage and availability of the registered knowledge for retrieval and reuse. The concept *External Interaction* of the ontology links *Domain knowledge* (Information), related to the project, with knowledge of *Specific and Global Contexts*. There, the chapter "Earth Pressure and Hydraulic Pressure" of the book "Monobe-Okabe Method" is a scientific report required suddenly by the engineers for accomplishing projects activities.

Some conclusions and future works are presented in next Section.

5 Results and Future works

The proposed Enterprise Ontology provides the concepts for Modelling an Organizational Memory, which aims at covering technical and managerial aspects of a civil engineering enterprise in studies and design domain. In fact, this Memory constitutes an Organizational Memory meta-model supporting specific Organizational Memory models covering particular organizational aspects. These Memory models, based on parts of the ontology, fill only some particular segments of the total enterprise Organizational Memory represented in an XML model. The enterprise ontology incorporates a project ontology based on the life cycle of a civil engineering design product and on the processes executed in each phase.

Our work considers generic relationships between the *domain knowledge* and *reasoning knowledge* extending this last concept from reasoning domain existent objects to reasoning domain created objects and contextual objects, considering existent and created object relationships. In accordance with the characterization of the *information* concept in terms of: predefined, communication-oriented, arising from structured processes or from systematic intervention of agents, three knowledge types are found in the domain: *predefined knowledge* corresponding to consolidated information treated by traditional information systems, *referenced knowledge* representing transitional information managed by evolving information systems, which uses knowledge techniques to manage the information, and finally, *discovered knowledge* denoting emerging information considered by prospecting information systems. Thus, *domain knowledge* is *information*. While *Knowledge* is consider in our work as all that may be known, understood and imagined about a subject, taking account of existent or created objects, agents, means and methods.

In this total concept, three Knowledge Categories are identified: *Domain Knowledge (Domain Information)*, *Context Information* and *Expanding Knowledge*. Reflecting these three concepts on the ontology let us manage together *knowledge* and *information*. In fact, the concept *External Interaction* of the ontology relates the domains concepts to knowledge of the *Specific Context* and to *Global Context Knowledge*. Thus, the Organizational Memory based on the ontology manages *knowledge* and *Information* together. This aspect is verified with a case study in the studies and design area of civil engineering. Integration of

Knowledge and Information constitutes a contribution to interoperability of enterprise applications and enterprise knowledge in the sense claimed in the European Project INTEROP. The perceived trends “to Computerize knowledge”, that is, to convert *knowledge* into *information* contributes to capitalize enterprise knowledge and to develop an enterprise culture for knowledge reuse and exploiting the Organizational Memory.

Ongoing works aim at developing software support for knowledge and information storage, reuse, and retrieval, exploiting the enterprise and project ontologies and the Organizational Memory concept.

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Organizational memory supporting the continue transformation of engineering curricula

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Abstract. We consider seven knowledge components that constitute the pillars for building a document-based organizational memory for engineering curriculum design: epistemology, pedagogy, Philosophy, universal knowledge, internal academic knowledge, external academic knowledge and extra-academic knowledge. We present domain ontology for guiding access to, and management and retrieval of knowledge and information stored in annotated documents. The curriculum oriented organizational memory supports the construction, evaluation and continuous evolution of engineering curricula. The integration of knowledge and information for continuous curricular transformation is illustrated with a case study of an informatics curriculum.

Keywords. Knowledge management, organizational memory, ontology, curricula

1 Introduction

In early knowledge Systems, knowledge was extracted from experts of domain. Knowledge was represented as a set of heuristic rules for problem solution. The difficulty to construct heuristics based on the imprecise language of experts, without a methodological guide and a constrained space, delimited by the existence of heuristics, to solve problems, stimulated the use of models for knowledge acquisition and management. The approaches centred on the models construction dealt with different types of knowledge and differentiate knowledge explaining the system behaviour from knowledge related to implementation. Moreover, knowledge extracted form experts does not distinguish clearly Domain knowledge from Reasoning knowledge. Although this aspect has captured the interest of approaches oriented to models construction, the characterization of reasoning knowledge is not yet easy, as it remains constrained to reasoning about

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identified domain objects. We propose to extend the reasoning to consider created domain objects, additional semantic features, created agents from specific and global context, existent and created contextual objects and abstract interventions of existent and created agents. In this way, our work uses a meta-model of knowledge, in [4] in order to clarify the knowledge categories on the outside of domain knowledge. The concept Utilisation Context of a system, for example, is only a part of the Context and exceeds the scope of traditional reasoning models. In effect, Utilisation Context includes the existent and created agents, means and methods, as well as physical and abstract interventions of these agents, involving domain existent objects and created objects.

Knowledge meta-model presents two general categories: Domain Knowledge and Context Knowledge. Domain knowledge is currently represented as ontologies. In the last years a lot of ontologies have been proposed in different domains. For instance, enterprise ontologies are found in [10] and in TOVE project described in [8]. The work referred in [7] presents an ontology of organizational processes. An ontology of information systems is included in [11]. In European project INTEROP (www.interop-noe.org) ontology is a central concept in order to assure the interoperability of enterprise and software system. The same importance is recognized to the concept ontology in e-learning domain. Examples for ontologies in this domain are presented, among others, in [1, 2, 3, 5, 6].

We introduce the *Curricula Knowledge Ontology*, which is headed by concepts obtained from the two knowledge general categories of knowledge meta-model. The *Utilisation Context*, for exploiting curricula models, supports the definition of remainder concepts of the ontology.

Based on *Curricula Knowledge Ontology*, an Organizational Memory for curricula management is proposed. A study case centred on the construction, storage, retrieval, trace and transformation of a systems engineering curriculum, illustrates the application of the Organizational Memory.

After the Introduction, this paper is organized as follows. The selection of Knowledge and Information Areas corresponds to Section2. Ontology and Organizational Memory Structure is explained in Section 3. A study case in Systems engineering domain is presented in Section 4. Section 5 deals with the results and future works. Bibliography is the object of last Section.

2 Delimitation of knowledge and Information

Curriculum is, in general sense, a set of knowledge areas arranged, in space and time, for teaching and learning. Thus, curriculum relates knowledge, methods, resources, strategies, managerial concepts to facilitate teaching and learning. In this reference frame, it is necessary to delimit the scope in order to construct a curriculum model for engineering programs.

At first, knowledge general areas are conceptualized using the knowledge meta-model proposed in [4]. This knowledge meta-model contains two capital knowledge categories: *Domain Knowledge* and *Context Knowledge*. For sake of space, knowledge meta-model is not depicted.

The natural domain for curricula development encloses the part of the universal knowledge necessary to satisfy social needs belonging to the field of engineering. This fraction of knowledge feeds the curriculum model with knowledge arising from these two contexts. The two next paragraphs verify which categories of knowledge Meta-model provide the knowledge for engineering curriculum models.

Domain Knowledge includes knowledge centred on: existent and created domain objects, considering object's features and their relationships, object semantic concepts and Agent Interventions, which involve physical and intellectual treatments of objects. Agent intervention expresses actions and interactions of agents. It uses known and created relationships among objects. Thus, *Domain Knowledge* contains the knowledge associated to the domain objects, which represent the part of the universal knowledge necessary to satisfy social needs, belonging to the field of engineering.

Context Knowledge is focused on: existent and created agents, means and methods, contextual objects, semantic concepts and Agent Interventions involving existent and created context objects. Agents Interventions may be physical or intellectual. We consider three context types: Social, Organizational and Systemic. Context Knowledge is divided into *Global Context Knowledge* and S*pecific Context Knowledge*. Existent and Created agents, means and methods, their semantic characteristic and their relationships constitute the *Specific Context Knowledge*, while contextual objects, their semantic characteristics, their relationships and agent interventions involving the contextual object compound the G*lobal Context Knowledge*. Agent interventions, involving means, methods and domain objects determine the *Utilisation Context*, which defines the interactions of agents of the *Specific Context Knowledge* involving the part of the universal knowledge necessary to satisfy social needs, belonging to the field of engineering. This part of universal knowledge belongs to *Domain knowledge* and is found in particular knowledge areas constituting the support of engineering curricula models.

The problem at this point consists of determining knowledge general categories of engineering curricula models, leading to the construction of these models. Because of this, we construct the Utilisation Context of engineering's curricula, Figure 1, aiming to define knowledge general categories considering typical interactions of agents. From a pattern of typical interactions of commercial agents, presented in [9], we keep only two interactions: "Request and delivery of service and objects of information and knowledge" and "Request and delivery of information and knowledge: scientific, technological, technique, social, marketing, organizational, commercial, economic, legal and personal".

The agents related by the engineering curricula are introduced in the *Utilisation Context*, in Figure 1. By imagining the above proposed typical agent interaction, using the envisioned engineering curricula models as a means, the following general categories of knowledge are identified: epistemology, pedagogy, philosophy, universal knowledge, internal academic knowledge, external academic knowledge and extra-academic knowledge.

From these general categories of knowledge, the particular categories of knowledge are defined in next Section

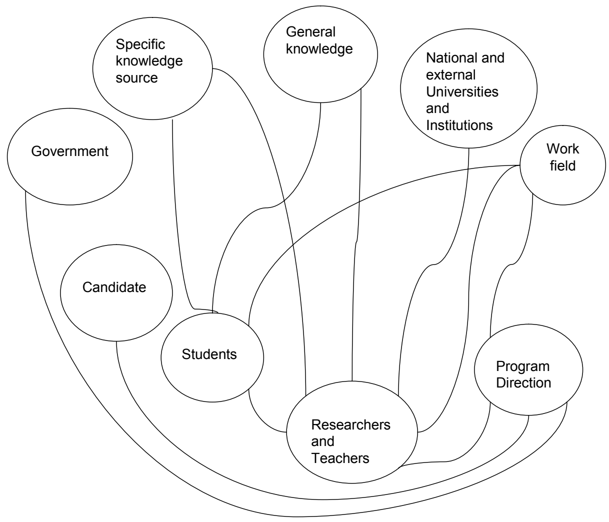

Figure 1. Curricula Utilisation Context

3 Ontology and Organizational Memory Structure

The elements and relationships presented in the Ontology of Curricular knowledge Categories constitute the resources to construct the curricula models. Moreover, the ontology contains the essential categories to organize and trace the knowledge related to the construction, application, evaluation and transformation of curricular models. This knowledge may be managed in an Organizational Memory structured according to concepts of the ontology.

3.1 Ontology of Curricular Knowledge Categories

Domain Knowledge and Context Knowledge specialize the top concept of the curricular knowledge ontology. The knowledge general categories of engineering curricula models, defined in the previous Section, constitute the second level of ontology depicted in Figure 2. Other ontology levels consider the particular categories of knowledge, which are essential meta-concepts to construct curricula models. Meta-concepts of the Ontology of Curricular knowledge Categories lead to define the concepts for constructing the engineering curricula models. For instance, the meta-concept Universal Knowledge leads to define the concepts Mathematic, Physic, Chemistry, Biology, Economy, Management, etc.

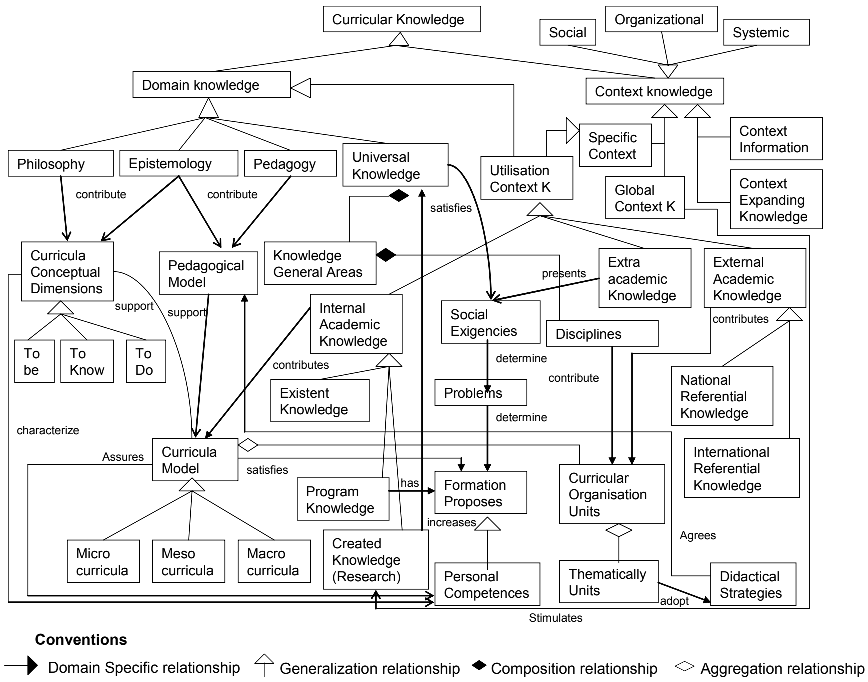

Figure 2. Ontology of Curricular Knowledge Categories

The ontology drive to define *what* Curricula models may do, *how* they do it, *why* they do it, *for what* they do it, as well as to construct pertinent and effective curricula. For assuring that curricula answer the mentioned questions, we propose a set of criteria that the curricula models of engineering have to incorporate:

a) Be focused on an undergraduate engineering curriculum adopting specific formation proposes.
b) Be based on solution of problems related to social needs.
c) Pertinence and effectiveness in the problems solutions
d) Be supported on pedagogical models centred on research. The students are directly related to knowledge.
e) Adaptability facing the social, economic, scientific, technological and technical changes
f) Be fed by scientific and technological developments
g) Be oriented to create open mind, autonomous and creative engineers
h) Integral formation of persons, considering three human dimensions.: to be, to know and to do.
i) Flexibility aiming to offer alternative formations and to develop vocational options for the students
j) Pertinence in contents according to specific areas of knowledge of other national and international institutions and to new knowledge trends.
k) Continuous revision and improvement of curriculum

Relating these criteria to the concepts of the second ontology's level, the remainder concepts of the ontology, in Figure 2, are defined.

Criterion a) drives to discover the concepts *curriculum model* and *formation purposes*. *Social Needs* and *Problems* arise from criterion b). From criterion c) arises the concept *extra academic knowledge*. Criteria c), d) and i) induce the concepts *knowledge general areas*, *curricular organization units*, *thematic units*, *didactical strategies*. *Personal competences* are a concept suggested by criterion g). Criterion h) provides the concept *Curriculum conceptual dimensions*. The analysis of criterion j) produces the concept *external academic knowledge*.

The predominant relationships among ontology concepts are: "is- a", "composition", "aggregation" and "specific of domain" relationships. These relationships leave from domain knowledge, in particular from the concepts expressing semantic characteristics of the domain objects.

3.2 Organizational Memory Structure

Considering that the ontology represents the essential concepts to construct curricula models, these concepts are pertinent to structure an Organizational Memory aiming to stores, retrieval, trace and transformation of curricula models. Ontology concepts constitute the tags to annotate their associated documents arranging an XML document. Thus, the Organizational Memory Structure is an instanceable hierarchy of tags containing the annotated documents related to ontology concepts. These concepts are complemented in the Organizational Memory, with characteristics such as class, type, subtype and attributes, in order to make possible the storage of nested instances of different document types. The new elements are created objects, important for referencing and representing structured documents. Created objects do not constitute, in principle, essential domain objects.

This characterization of created objects validates our classification of *Information* and *Information systems*, introduced in [4]. In this report, three categories of *Information* and *Information Systems* are considered. That is, the *Traditional Information Systems* involve Consolidated Information (Domain Predefined knowledge), while the *Evolving Information Systems* manage Transitional Information (Domain Referenced Knowledge). The third category corresponds to *Prospecting Information Systems*, which deal with Emerging Information (Domain Discovered Knowledge).

Here, we verify the transition from *Traditional Information Systems* to *Evolving Information Systems* (e.g. XML based systems, Web systems), by introduction of domain created objects and knowledge engineering techniques. In effect, the transition is marked by the introduction of new domain objects, created objects, in order to represent and manage the information by means of nested information structures. There, the information is not yet managed in predefined well established processes, but organized to be systematically dealt with knowledge engineering techniques.

Next Section illustrates the use of the Organizational Memory for managing knowledge that guides the construction, trace, evaluation and transformation of an engineering curriculum model.

4 A study case in Systems engineering domain

The ontology of curricular knowledge categories constitutes a meta-model of engineering curricula. Specific curricula of different fields of engineering are instances of ontology. The meta-concepts of the ontology are judged pertinent and sufficient for constructing, storing, retrieving, tracing and transforming of engineering curricula models. In effect, these meta-concepts allow us to identify and manage an extended gamma of knowledge of different nature.

The results of the study of curriculum model for the program of systems engineering at the University of Antioquia is a worthwhile model for testing the goodness of the Organizational Memory.

The Memory covering all the concepts of the ontology assures the quality of the knowledge required to make the engineering curricula evolve. For the sake of simplicity, we do not include the whole XML-model based Organizational Memory for a systems engineering curriculum. Next paragraph depicts some tags corresponding to problems arising from social context characterized as extra academic knowledge.


```xml
<?xml version="1.0" encoding="UTF-8"?>
<!--Sample XML file generated by XMLSPY v5 rel. 2 U (http://www.xmlspy.com)-->
<CURRICULA_KNOWLEDGE xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:noNamespaceSchemaLocation="C:\Documents and Settings\German Urrego\Mes documents\CE2007\ONTOLOGIA\CURRICULUM ONTOLOGIA_version_EJEMPLO.xsd">
    <CONTEXT_KNOWLEDGE>
        <UTILISATION_CONTEXT_KNOWLEDGE>
            <EXTRA_ACADEMIC_KNOWLEDGE>
                <SOCIAL_EXIGENCIES>
                    <PROBLEMS>El desarrollo de soluciones informáticas para la transacción (transmisión, consulta, almacenamiento y procesamiento) de información a través de amplias redes de computadores</PROBLEMS>
                    <PROBLEMS>El desarrollo de sistemas informáticos que apoyen la gestión organizacional moderna</PROBLEMS>
                    <PROBLEMS>El desarrollo de herramientas informáticas didácticas, que apoyen el proceso docente-educativo</PROBLEMS>
                    <PROBLEMS>Automatización y control de procesos</PROBLEMS>
                </SOCIAL_EXIGENCIES>
            </EXTRA_ACADEMIC_KNOWLEDGE>
        </UTILISATION_CONTEXT_KNOWLEDGE>
    </CONTEXT_KNOWLEDGE>
</CURRICULA_KNOWLEDGE>
```


5 Conclusions and Future Works

The delimitation of total Universal Knowledge for defining the domain of curricula models uses the knowledge meta-model, introduced in [4], where *domain* and *context knowledge* are considered. The characterization of *domain* and *context* concepts, introduced in [9] contributes to relate information engineering and knowledge engineering. The Knowledge General Categories for the domain ontology are extracted from the total universal knowledge, using the *Context Utilisation Model*. This model represents interventions of agents of the *Specific Context* involving *Domain objects*.

Knowledge General Categories constitute the second level of the ontology, which are subordinated to one of the first level concepts: *Domain Knowledge* and *Context Knowledge*. The remainder of ontology is fed with Knowledge Particular Categories arising from proposed criteria to define curricula models.

The elements of the Ontology of Curricular Knowledge Categories are meta-concepts. These elements cover the instances of curricular models in all fields of knowledge. In this work we are centred on engineering curricula models

The transition from the ontology to the Curricular Organizational Memory involved new domain objects, created objects, in order to represent and manage the information by means of nested information structures, e.g. XML models. That signifies the transition from Traditional Information Systems, centred on predefined information, to Evolving Information Systems, in which information is not yet managed in predefined well established processes, but organized to be systematically dealt with knowledge engineering techniques (e.g. XML based systems, Web systems).

The XML-based Curricular Organization Memory is illustrated in this work by a systems engineering curriculum. Only a small part of the instantiated Organizational Memory of Engineering Curricula is presented in this work.

Ongoing work searches to construct Curricula Organizational Memories for different engineering programmes and for other academic aspects. At the same time, we propose to apply Curricula Organizational Memories in e-learning fields using the web infrastructure..

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Development of an Ontology for the Document Management Systems for Construction

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Abstract. This paper describes the development of an ontology for the AEC/FM projects' documentation management that allows the classification of the documents along the lifecycle of AEC/FM projects. This ontology is aimed at reducing the interoperability and information exchange problems, inherent nowadays in AEC/FM projects, establishing a hierarchical structure of the different areas that conform the lifecycle of AEC/FM projects and an interrelationship system between them. Therefore, all the documentation created along a project could be classified in the different areas of the project lifecycle and related to them by this hierarchical structure. Moreover, metadata like identifier, creation date,… have been incorporated to documents in order to be completed and modified by the author to facilitate users' understanding. Therefore, this ontology is the first step to improve the Document Management Systems in AEC/FM projects and their interoperability limitations.

Keywords. Ontology, document management, interoperability, construction.

1 Introduction

The architecture, engineering, construction and facility management industry (AEC/FM) is fragmented due to the many stakeholders and phases involved in a construction project as well as to the complexity and diversity of their projects. This fact has led to a huge amount of organizational information formalized in unstructured documents.

Electronic Document Management Systems (EDMS) is an Information and Communication Technology (ICT) application that has started to be used in the construction industry as a tool to reduce some of the problems generated by fragmentation creating an environment that allows the centred stored of the documentation on a server. However, EDMS have also some limitations, most of them related to the interoperability, the ability for information to flow from one computer application to the next throughout the life cycle of a project, that

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becomes difficult to achieve because of its dependence on the development and use of common information structures throughout all the different EDMS users. In order to solve this problem, different standards, aimed at establishing internationally recognised information classification structures, projects based on them and ontologies, another kind of system of representation of the concepts that a domain contains and the relations that exist between them, are being developed. As example ISO 12006 [3] and Industry Foundation Classes (IFC) [4], standards that establish a structure for the classification of objects in AEC/FM sector, Lexicon [5], a project based on ISO 12006 that provides general information such as building regulations, product information, cost data and quality assessments in a common and standardized language, and eCognos [2], a project that establishes and deploys a domain ontology for knowledge management in the AEC/FM sector, between others. From the study of these different initiatives it could be observed that most of them are object-oriented and define an information classification structure in different fields of the domain of AEC/FM projects, however none of them are oriented to the document management.

2 Research objective, scope and methodology

The objective of this research is to develop an Ontology for the Document Management Systems used in AEC/FM with the aim of reducing the interoperability and information exchange problems from the establishment of a hierarchical structure of the different areas that conform the lifecycle of AEC/FM projects and an interrelationship system between them. Thus, it is claimed:

- To make a literature review of existing EDMS, the interoperability limitation, possible solutions, and existing Information Classification Systems in Construction sector.
- To make a literature review of ontologies' definitions, characteristics, applications, methodology, editors and languages.
- To develop the Ontology for the DMS for Construction, including the definition of a Concept Model of the Documentation Flow from the literature review of existing theories about projects lifecycle.

3 Background

Classification systems that attempt to organize the knowledge base of national construction industries have a long history. The Swedish SfB system has been under development since 1945 and although it has long been superseded in Sweden itself it remains the basis for many existing knowledge classification systems such as CI/SfB [6], which is widely used in the UK.

The growing experience with classification systems and the development of ICTs has led to the development of the ISO 12006 series [3], which is aimed at establishing internationally recognized classification principles. Projects such as Uniclass [1], Lexicon [5], etc are examples of adaptations of ISO 12006.

Currently, the technical committee ISO/TC59/SC13 is working on the development of guidelines connected to IFD (International Framework for Dictionaries)-object libraries based on ISO 12006-3 with the aim to improve the quality of object libraries and to link and integrate them with other libraries.

Other research projects developed basic conceptual structures in the building construction domain, for example, the e-Construct taxonomy and e-Cognos ontology process-centered system for knowledge management in construction [2].

4 Development of the Ontology for DMS for Construction

4.1 Classification of information

Along this paper an ontology is understood as a system of representation of a domain or area of knowledge, where a method is applied in order to obtain a formal representation of the concepts that it contains and the relations that exist between them.

The development of the ontology implies the previous definition of the domain, the important terms that it may contain and their classification system. Consequently, the Concept Model of concepts that may be included in the ontology and their classification system is defined.

The concepts that the ontology may contain are determined by its domain (*All the documents generated along a construction project*) and its future usage (*as an ICS in a DMS for Construction*). Therefore, concepts such as documents and construction project lifecycle must be analyzed.

Documentation Flows created along a construction project depend on the actors involved in it as well as the roles they play in the organization chart defined by the kind of contractual arrangement. Consequently, actors and contractual arrangement are considered basic specifications for the selection of the documents to study.

In reference to the type of contractual arrangement, the Traditional procurement arrangement is the one selected bearing in mind that is the most used for ordinary projects of moderate size and complexity, in which the owner wishes to retain the maximum amount of control for the design-construction process. On the other hand, three different actors, pretending to include all the possible actors involved in a construction project, are defined: Client, Designer and Contractor.

Up to this point, all the documents generated in a construction project can be identified. In reference to the ontology proposed, the documents included in it are the ones commonly created along Spanish construction projects, as well as the terminology used.

All this documentation identified is created along the lifecycle of a project as a result of an activity. Therefore, from the literature review the most useful and understandable way to classify documents is to locate them along the construction project lifecycle and as a consequence of an activity. Different theories and models have been studied and the construction project lifecycle has been divided in Phases, the period in the duration of a construction project identified by the overall character of the processes which occur within it, and Stages, defined as sub-processes of the project Phases. See Figure 1.

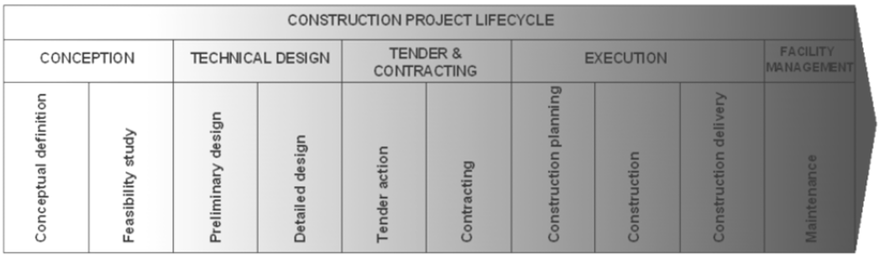

Figure 1. Phases and Stages of a Construction Project lifecycle

On the other hand, documents are a result of different activities and subactivities occurred along the project. By this way, Activities, defined as a working area of the project, and Subactivites, understood as the type of information of special importance in a project, are included in the Concept Model. Therefore, the Activities defined are: Advance, Changes, Contractings, Costs, Environment, Project, Quality and Safety & Health. And the Subactivities identified are: Communication, Documentation, Control and Planning.

As a result, with the Stages and Phases, that complete the lifecycle of the project, the documents listed and the Activities and Subactivities identified, all the relationships between them can be defined. These relationships will classify the documents along the lifecycle of the project bearing also in mind the activity and subactivity from where they come from. Therefore, the concepts and the relationships that constitute the Concept Model of the Documentation flow are already identified.

These concepts are classified in two kinds of metadata related to each document. Content-related metadata will be understood as the metadata that relates the documents with the phases, stages, activities and subactivities in order to situate them along the project lifecycle. This metadata is inherent in the document. On the other hand Content-properties metadata is related to what the document contains or is about, thus providing to users and applications useful hints to help document search and retrieval and to improve the reuse of documented information. This metadata is not compulsory and depends on the author needs. As example the name of the creator or the receiver, the type of format, the creation date, the version,… See Figure 2.

From the definition of this Concept Model of the Documentation flow, documents are classified as the result of the intersection of an Activity and a Subactivity that take place along one or more Stages that are part of a Phase. By this way documents are located along the lifecycle of the construction project basing on a three dimensional model. See Figure 3.

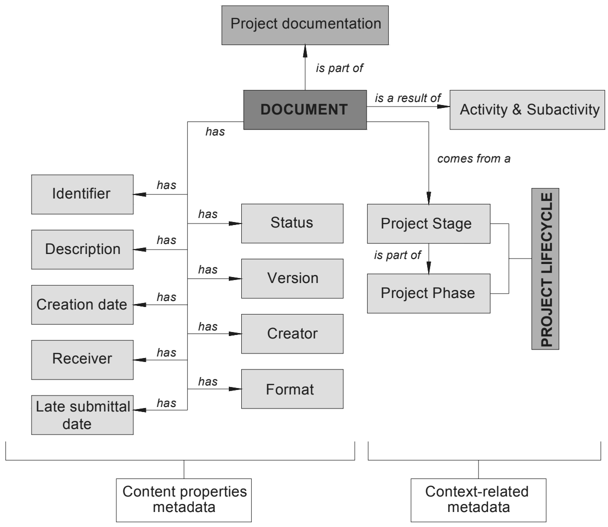

Figure 2. Concept Model of Documentation flow. Document metadata

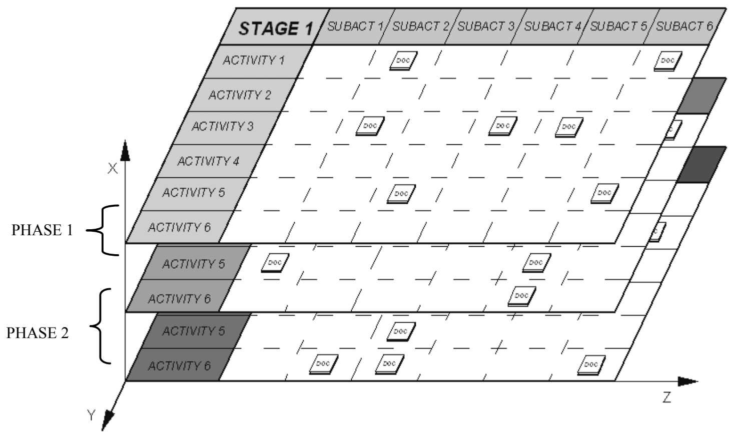

Figure 3. Representation of documents along the Construction Project lifecycle

4.2 Implementation

The implementation of the ontology has been carried out in Protégé editor, for its opened code, free access and simplicity, working with OWL DL language.

Reusing ontologies is an important point to bear in mind before the development of a new ontology. Taking into account that ontologies related to DMS haven't been found reusing has not been possible, however terminology to describe the phases, stages, authors, activities and subactivities in AEC/FM has been extracted from existing standards.

From the concepts identified in the Concept Model, classes, subclasses and properties are defined. Classes describe concepts in the domain and subclasses *kinds of* the already defined classes. In this proposed ontology the classes defined are shown in Figure 4. By the same way are represented the subclasses of each class.

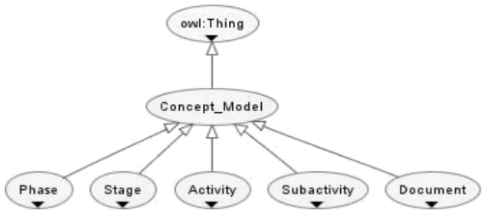

Figure 4. Classes of the Ontology for DMS for Construction exposed in Protégé

To classify the documents in the hierarchical structure created properties of classes and subclasses are defined. Three kinds of Protégé properties have been used:

- Object-properties to relate the class Document and their subclasses to the classes Stage, Activity and Subactivity. *is a result* property relates each document with the intersection of an Activity, a Subactivity and a Stage, *is part of* relates each Stage with its particular Phase, and finally, *is composed by* relates each Phase with all its Stages;
- Datatype-properties to add the content-properties metadata already defined such as the creator, the receiver, the format,… to each document;
- Annotation-properties that, in this case, have been used to provide multi-lingual names for ontology elements (Spanish, Catalan and English) and some comments to make easier their understanding.

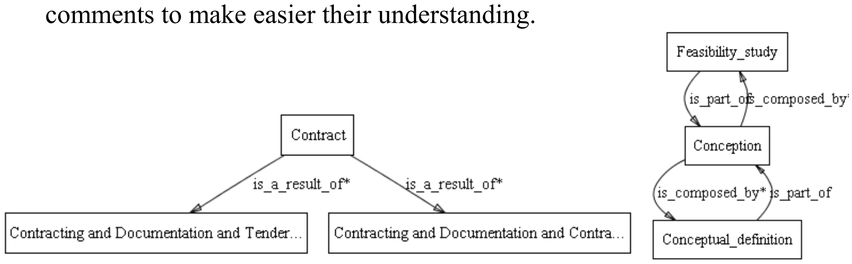

Figure 5. Examples of Object-properties

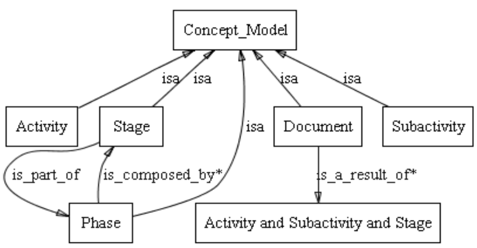

Figure 6. Concept Model and Object-properties

Documents are related to the Stages, Activites and Subactivites from which they come from by logic expressions such as *and* and *or*, that express intersection and union, respectively. Therefore, *and* expression is used to state that a document is a result of the intersection between an Activity, a Subactivity and a Stage (the Phase is already related with the Stage), and *or* expression is used to state that this document can be located in different locations (intersections) along the project lifecycle. See Figure 7.

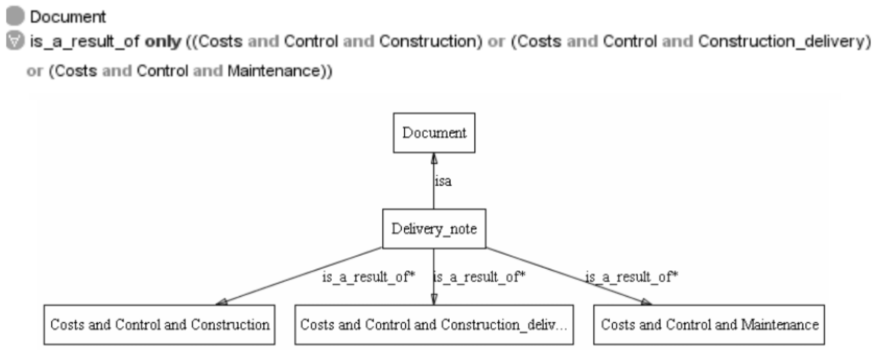

Figure 7. *and* and *or* expressions

Up to this point, the hierarchical structure that allows the documentation classification of a general construction project is defined. The following and the last step depends on the particular project and users that work with the DMS where the ontology is applied. This step consists on the definition of *individuals*, that are considered as particular classes. These individuals are created by the users, who add the information to the already defined properties of each document to facilitate its research and understanding. An example is shown in the Figure 8.

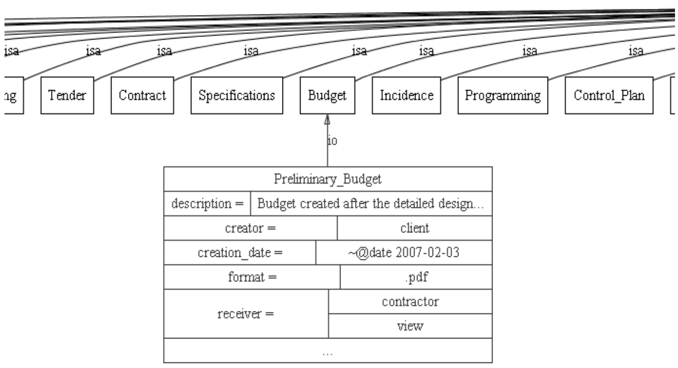

Figure 8. Example of an individual of the class *Budget*

5 Conclusions and future work

By the development of the Ontology applicable to a DMS for Construction all the documentation generated during a construction project is classified along its lifecycle as a result of the intersection between an Activity, Subactivity and Stage, improving, by this way, the existing indexing, search, retrieval and reuse of documents' limitations. This ontology provides a context-related metadata, that locate the documents along the project lifecycle, and a content-properties metadata, that add information to the document to facilitate its research and understanding.

The future work of this research would be the application of the developed Ontology as the internal information classification system of a tool such as BSC, a web page,… allowing users' interaction and the exchange of information by the web. Moreover, the creation of *Actors*, *Type of contractual arrangement* and *Related documents* classes would improve the classification of the documents and facilitate users' research. Finally, a more ambitious step would be to consider documents as a group of information and not as an entity.

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Some approaches of ontology Decomposition in Description Logics

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Abstract. In this paper, we investigate the problem of decomposing an ontology in Description Logics (DLs) based on graph partitioning algorithms. Also, we focus on syntax features of axioms in a given ontology. Our approach aims at decomposing the ontology into many sub-ontologies that are as distinct as possible. We analyze the algorithms and exploit parameters of partitioning that influence the efficiency of computation and reasoning. These parameters are the number of concepts and roles shared by a pair of sub-ontologies, the size (the number of axioms) of each sub-ontology, and the topology of decomposition. We provide two concrete approaches for automatically decomposing the ontology, one is called partitioning based on minimal separator, and the other is segmenting based on eigenvectors and eigenvalues.

Keywords. Graph partitioning, ontology decomposition, image segmentation.

Introduction

Previous studies about DL-based ontologies focus on such tasks as ontology design, ontology integration, ontology deployment,… Starting from the fact that one wants to effectively solve and reason with a large ontology, instead of integrating multiple ontologies we examine the decomposition of an ontology into several sub-ontologies that overlapping content. Some reasoning algorithms on the system of decomposed ontologies and the criteria for decomposition have been proposed in the previous paper [4]. In this paper, we resolve the problem of decomposing, more concretely, we delve into the techniques of decomposing an ontology into several sub-ontologies. Our principal goal is how select a "good" one? A decomposition is called "good" if it improves the efficiency of reasoning and guarantees the properties proposed in [4]. Our computational analysis for reasoning algorithms guides us to suggest the parameters of such a decomposition: the number of concepts and roles included in the semantic mappings between partitions, the size of each component ontology (the number of axioms in each

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component) and the topology of the decomposition graph. There are two approaches to be considered here. They are based on two presentations of the ontology. First, we present the ontology by a symbols graph, and implement decomposition based on minimal separator method. Second, the ontology is presented by an axiom graph, corresponding to the image segmentation method.

The paper is organized as follows. Section 1 describes two ways for transforming an ontology by an undirected graph (symbol graph or weighted graph). Section 2 defines the overlap decomposition of a TBox and the criteria for a good decomposition. In sections 3 and 4, we discus the methods and two partitioning algorithms of the graph representing an ontology corresponding to the above graphs. Section 5 presents some evaluations of the efects of the decomposition algorithms. Section 6 provides some conclusions and future work.

1 Representing ontology as the graph

A knowledge base (ontology) built by a concept language is generally composed of two component levels: intensional (called TBox) and extensional (called ABox). We are interested in the intensional level, the reasoning problem in a large TBox. A TBox is a finite set of general concept inclusions (axioms). Therefore decomposing an ontology is reduced to examining the set of axioms - we split the axioms into small groups following the proposed criteria in [4].

In this section, we present an ontology as an undirected adjacency graph. In particular, we examine two approaches for representing a TBox by graphs that deal with the problem of decomposition. The axioms are coded as follows.

Given an original TBox T with N axioms. Unfolding (expanding) all the axioms in the original TBox T into the expressions of primitive concepts and primitive roles (i.e. computing E*x*(A_i) as in [4], we recall that E*x*(A_i) is a set of primitive concepts and roles which occurs in A_i).

Let |E*x*(A_j)| = n_{ij} (the number of concepts and roles in A_i), |E*x*(A_i) ∩ E*x*(A_j)| = n_{ij} (the number of common concepts and roles in two axioms A_i and A_j), for i, j = 1,N, i,≠ j

Example 1. Given a TBox T presented in Figure 1, then N = 10 (there is ten axioms in T) and the axioms are unfolded as follows:

$Ex(T) = \{C_1, C_2, C_3, C_4, C_5, C_6, X, Y, H, T\}$; $|Ex(T)| = 10$

(A_1) : $C_1 \sqcap C_2 \sqsubseteq X$	(A_6) : $Y \sqcap T \sqsubseteq H$
(A_2) : $C_3 \sqsubseteq \neg C_2$	(A_7) : $C_3 \sqsubseteq X$
(A_3) : $X \sqcap C_4 \sqcap C_5 \sqsubseteq Y$	(A_8) : $\neg C_3 \sqsubseteq C_2$
(A_4) : $\neg C_4 \sqsubseteq \neg Y$	(A_9) : $\neg X \sqsubseteq \neg Y$
(A_5) : $Y \sqcap C_6 \sqsubseteq H$	(A_{10}) : $\neg C_5 \sqsubseteq \neg Y$

Fig. 1. TBox *T*

To simplify, we use the notation symbol instead of primitive concept (role), i.e., a symbol is either a primitive concept (role) in a TBox. A symbol graph will be introduced in the following section.

1.1 Symbol graph

Definition 1. *(Symbol graph) A graph G = (V,E), where V is a set of nodes and E is a set of edges, is called a symbol graph if each node* $v \in V$ *is a symbol in TBox T, each edge e = (u, v)* $\in E$ *if u, v* $\in V$ *and u, v occur in the same axiom.*

Construct a symbol graph G = (V,E) from a TBox *T* by taking each symbol (concept or role) in every axiom in *T* as a node and connecting each pair of concepts (roles) by an edge if this pair co-occurs in the same axiom. According to this method, each axiom is presented as a "clique" (see definition 7) in the graph.

Example 2. The above TBox *T* can be presented by a symbol graph as Figure 2.

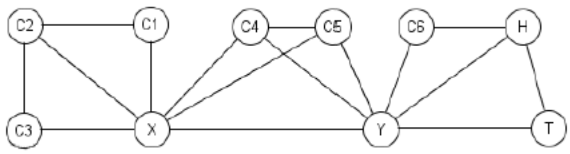

Fig. 2. Symbol graph of the TBox *T*

1.2 Axiom graph

Definition 2. *(Axiom graph) A graph G = (V,E), where V is a set of nodes and E is a set of edges, is called an axiom graph if each node v 2 V is an axiom in TBox T , each edgee = (u, v) 2 E if u, v 2 V and there is at least a shared symbol between u and v.*

Example 3. The above TBox T (Figure 1) is represented by an axiom graph as in Figure 3.

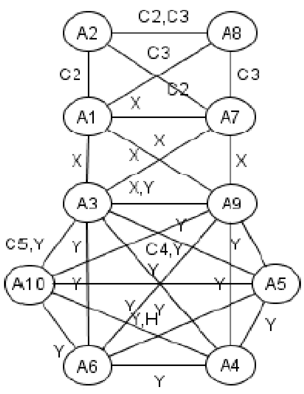

Fig. 3. Axiom graph of the TBox $\mathcal{T}$

From a point of view of graph, we present a TBox $\mathcal{T}$ by a weighted graph $G = (V, E)$, denoted the "connected axiom graph": each vertex v of V corresponds to an axiom in $\mathcal{T}$, and each pair of vertices in V is connected by an edge if they have some shared symbols. A weight is then assigned to each edge in E. This weight should be chosen such that it reflects the association degree between the linked vertices of that edge. Using just the common symbols between every pair of axioms, we can define the graph edge weight w_{ij} connecting the two nodes i and j that correspond to two axioms A_i and A_j as: $w_{ij} = \frac{n_{ij}}{n_i + n_j}$, where $i, j = \overline{1, N}, i \neq j$.

2 Ontology Decomposition

2.1 Definition

In this paper, the ontology is examined as a graph, therefore the notion of ontology decomposition is based on graph partitioning. Assume that a graph G is partitioned into m sub-graphs $G_{i,i\leq m}$, then partitioning G is defined as follows:

Definition 3. *(Graph partitioning) A graph partitioning $G_p = V_p, E_p$ is a connected graph (see definition 9) of the individual partitions G_i. Each node $v \in V_p$ is a partition (sub-graph) G_i, each edge $e_{ij} = (v_i, v_j) \in E_p$ is labeled by the set of shared symbols between G_i and G_j, where $i, j \leq m$ and $i \neq j$.*

This definition is equivalent to the overlap decomposing in [4], where G_i corresponds to component TBox T_i, the edge e_{ij} corresponds to the set of identical bridge rules B_{ij}.

2.2 What is a good decomposing

Our goal is to eliminate general concept inclusions (GCIs) as much as possible from a general ontology (presented by a TBox) by decomposing this ontology into several sub-ontologies (presented by a distributed TBox). In this paper, we only consider the syntax approach based on the structures of GCIs. Hence, the decomposition only implements the set of axioms (GCIs). All the concepts and

roles of the original ontology will be kept through the decomposition. As a result, we propose two techniques for decomposing based on graphs. In this paper, we examine only the simplest case, decomposing a TBox into two smaller TBoxes. The general case is presented in [7].
We defined the decomposition of a TBox as a distributed TBox consisting of sub-TBoxes and the semantic mappings between each pair of sub-TBoxes. Our decomposition approach is most related to the graph formulation and partitioning. A delicate aspect of decompositionbased logical reasoning is in the selection of a good partitioning of the ontology, and we also need to ask the following questions:

1. What is the precise criterion for a good decomposition ?
2. How can such a decomposition be computed efficiently ?

These questions have been also proposed for image segmentation and data clustering. In the general DL case, our purpose is not to reduce computational complexity, but the results for reasoning in decomposition suggest similar relationship between the decomposed TBoxes and the original TBox. The computation analysis of our decomposition-based reasoning algorithms provides a metric for identifying parameters of decomposition that influence our computation: the size of the communication part between component TBoxes, the size of each component, and the topology of the decomposition graph. Our goal is minimizing the disassociation between the component TBoxes and maximizing the association within the components. Moreover these component TBoxes must preserve the properties of decomposition that we proposed in [4]. These parameters guide us to propose two greedy algorithms for decomposing an ontology into sub-ontologies by trying to optimize these parameters. The decomposition algorithms depend on the representation graphs of ontology that will be presented in the following sections.

3 Partitioning based on the minimal separator

Starting from the symbol graph, we examine a decomposition method based on the minimal separators. Before describing details of the algorithm, we recall some notions in graph theory that can be found in [1,2,5].

3.1 Definitions

Definition 4. *(Neighbor) Let $G = (V,E)$ be an undirected graph, with $|V|=n$, $|E|=m$. For $x, y \in V$, the set of neighbors of x is $N(x) = \{y \neq x|(x, y) \in E\}$. For $X \subseteq V$, $N(X) = U_{\infty \in X} N(x)$.*

Definition 5. *(Minimum Vertex Separators) A set of vertices S is called an (a, b)-vertex-separator if $\{a, b\} \subset V \setminus S$ and every path connecting a and b in G*

passes through at least one vertex contained in S. A set S of vertices is called an (a, b)-vertex-separator if {a, b} $\subset V \setminus S$ and every path connecting a and b in G passes through at least one vertex contained in S.
Two vertices a, b are said to be adjacent if there is an edge connecting a and b in G. Let a, b are not adjacent vertices. If S is a minimal a, b-separator which contains only neighbors of a the S is called close to a.

Definition 6. *(Connectivity) Let N(a, b) be the least cardinality of an (a, b)-vertex-separator. The connectivity of the graph G is the minimum N(a, b) for any a, b $\in V$ that are not adjacent.*

Definition 7. *(Cliques) A clique (complete graph) is a graph with edge set consisting of all possible edges between the vertices of the graph. We denote by G[S] the clique built on vertices from S of the graph G.*

Definition 8. *(Maximum Cliques) A maximal clique in a graph G is a clique G[S] such that there exists no vertex set $S' \supset S$ for which G[S′] is a clique. The set of minimal cliques of G is denoted by K_G.*

Definition 9. *(Connected graph) A graph G is connected if for each pair u, v of its vertices there exists a path from u to v. If G is not connected, then a connected subgraph C of G is called a (maximal) connected component if there exists no connected subgraph C′ of G such that C is a proper subgraph of C′.*

Note that, the minimal vertex separator can be defined as: S is a minimal separator of the graph $G = (V,E)$ if and only if there are two different connected components of $G[V - S]$ such that every vertex of S has a neighbor in both of these components. This definition as a lemma that have been proved in [6]. If *S* is a minimal *a,b*-separator which contains only neighbors of *a* then *S* is called *close* to *a*.

3.2 Algorithm

In this section, we introduce a recursive algorithm using Even's algorithm [2], which takes a symbol graph $G = (V,E)$ (is transformed from a TBox *T*) as input and returns the set of separate sub-graphs of *G*. We briefly describe the algorithm as follows:
Input: $G = (V,E)$
Output: connected graph $G_p = (V_p,E_p)$

- Find the set of minimal vertex separators of graph *G*:
  + Chose an arbitrary pair *a, b* of non-adjacent vertices, and compute the set of minimal ab-separators.
  + Repeat this process on every possible pair {*x, y*} of non-adjacent vertices.
- Find the overall minimum vertex separator S^* between all vertices in *G*.

- Split G into the two subgraphs G_1, G_2 that are separated by S^*, with S^* included in both subgraphs.
- Create an undirected graph $G_p = (V_p, E_p)$ with $V_p = \{G_1, G_2\}$ and $E_p = S^*$

Figure 4 illustrates the connected graph of TBox T in Figure 2.
In this example, we have two minimum vertex separators $\{X\}$ and $\{Y\}$. If we chose $\{X\}$ to split T, then we collect two groups of symbols $\{C_1, C_2, C_3, X\}$ and $\{X, C_4, C_5, C_6, Y, H, T\}$.
Hence, we obtain two sub-TBoxes respectively:
$T_1 = \{A_1, A_2, A_7, A_8\}$ and $T_2 = \{A_3, A_4, A_5, A_6, A_9, A_{10}\}$. Similarly, if we chose $\{Y\}$, we obtain two sub-TBoxes $T_1 = \{A_1, A_2, A_3, A_4, A_7, A_8, A_9, A_{10}\}$ and $T_2 = \{A_5, A_6\}$.

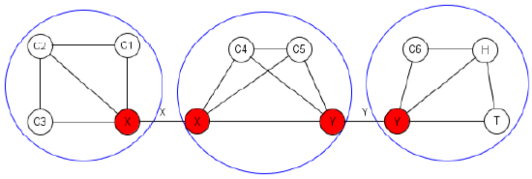

Fig. 4. Decomposing T 's symbol graph

We will take the first result, because there is a better balance between the number of axioms of the two sub-TBoxes. Thus, the axioms in the original TBox is distributed into T_1 and T_2 with the number of axioms respectively $N_1 = 4$, $N_2 = 6$.
The number of symbols in the minimum vertex separator is $|S^*| = |\{X\}| = 1$.

4 Decomposition based on image segmentation

This section describe a grouping method as image segmentation using eigenvectors. First of all, we assume that a graph $G = (V,E)$ has been partitioned into two disjoint parts with the two sets of nodes A,B respectively. The degree of association between these two parts can be computed as total weight of edges that have been removed from the original graph. In fact, these edges are equivalent to "bridge rules" in the ontology decomposition presented by a distributed TBox. The optimal partitioning of a graph not only minimizes this degree but also maximizes the degree of association within parts. In graph theory, these degrees are selected as [3]:

- $Ncut(A,B) = \frac{cut(A,B)}{assoc(A,V)} + \frac{cut(A,B)}{assoc(B,V)}$
- $Nassoc(A,B) = \frac{assoc(A,A)}{assoc(A,V)} + \frac{assoc(B,B)}{assoc(B,V)}$

where $cut(A,B) = \sum_{u \in A, v \in B} w(u,v)$, the total connection from nodes in A to nodes in B; and $assoc(A,V) = \sum_{u \in A, t \in V} w(u,t)$, the total connection from nodes in A to all nodes in the graph.
We can simply see that, $Ncut(A,B) = 2 - Nassoc(A,B)$.
We recall some notations from [3]: Let x be an $N = |V|$ dimensional indicator vector with $x_i = 1$ if node i is in A, and $x_i = -1$, otherwise. Let $d(i) = \sum_j w(i,j)$ be the total connection from node i to all other nodes. Let D be an NxN diagonal matrix with d on its diagonal, W be an NxN symmetrical matrix with $W(i,j) = w_{ij}$; $k = \frac{\sum_{x_i > 0} d_i}{\sum_i d_i}$, $b = \frac{k}{1-k}$, $y = (1+x) - b(1-x)$
They are used for computing the optimal partition by solving $(D-W)x = \lambda Dx$.
The algorithm is implemented by the following principal steps [3]:

1. Transform a given ontology into an undirected graph (as the above section).
2. Find the minimum value of NCut by solving the eigenvectors with the smallest eigenvalues of the system

$$(D - W)y = \lambda Dy \tag{1}$$

The generalized eigensystem in (1) can be transformed into a standard eigenvalue problem of

$$D^{-\frac{1}{2}}(D - W)D^{-\frac{1}{2}}x = \lambda x \tag{2}$$

3. Once the eigenvector are computed, we can decompose the graph into two partitions using the second smallest eigenvector. In the ideal case, the eigenvector should only take on two discrete values and the signs of the values can tell us exactly how to decompose the graph. However, our eigenvectors can take on continuous values and we need to choose a "good splitting point" to decompose it into two parts.

4. After the graph is broken into two partitions, we can recursively implement our algorithm on these two decomposed partitions.

Figure 5 illustrates the NCut obtained (denoted by the blue line) in the example of Figure 2, and result graph of decomposition is shown in Figure 6. This result is the same in the method based on minimal separator.

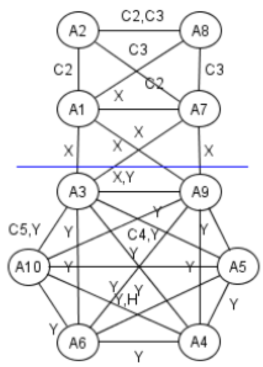

Fig. 5. Axiom graph of $\mathcal{T}$ and its NCut

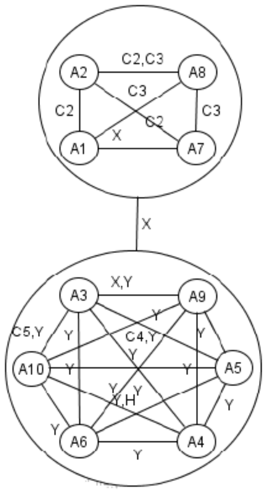

Fig. 6. Decomposing $\mathcal{T}$'s axiom graph

5 Effect of the decomposition algorithms

We have been applied two graph partition algorithms based on minimal separator and image segmentation for decomposing an ontology. These two methods return the same result that satisfies the proposed decomposition properties. All the concepts, roles and axioms are preserved over the decomposition implementation. The relations between them are expressed by the edges in symbol, and connected axiom graphs. The set of axioms in the original TBox is then reduced by regular distribution into sub-TBoxes. Decomposition techniques focus on finding a good decomposition. The approach based on minimal separator minimizes the number of symbols shared between partitions and tries balancing the number of axioms in the partitions. However, we have to regroup the axioms based on the cliques in the symbol graph after decomposition. However, in reality there exists some cliques in symbol graph which do not represent axioms.

The possible advantage of an approach based on image segmentation is that it conserves the axioms. Furthermore, the NCut measure is normalized, it expresses the disassociation between partitions and the association within partitions. However, to implement this technique effectively, we must propose a proper weight function for the edges between nodes of the axiom graph.

6 Conclusion and future work

In this paper, we have presented two algorithms for ontology decomposition in DLs using graph partitioning. By treating the grouping problem in graph theory, we proposed two methods for representing the ontology by a symbol graph and a weighted graph. Each graph type is applied corresponding to a decomposition algorithm. Two graph partitioning algorithms are independently implemented. We see that two approaches are sufficient for our purpose in requirements of decomposed ontologies. However, the choice of decomposition method depends on the structure of the original ontology. For example, with an ontology that consists of a large number of symbols then one can chose the weighted graph method. And for an ontology contains many axioms, one can use the symbol graph method. These proposals are only suggestions for future work. We also propose some essential properties of a good decomposition that influence the reasoning performance as provided in [4]. The graph transformations of an ontology again depends on having an effective (and cheap) method for analyzing the likely characteristics of a given test ontology.We are also performing more experiments with very large KBs (as UMLS,...) for decomposing. Preliminary results in the decomposed ontologies suggest similarity between both methods. We are embarking on optimizing these decomposition algorithms and effectively treating large ontologies.

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Modeling ORM Schemas in Description Logics

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Abstract: In recent years, there has been a growing interest in integration of semantics into the Semantic Web environment, whose goal is to access, relate and combine information from multiple sources. With regard to this tendency, our work studies a mechanism to model ORM schemas in the Description Logic language SHOINK (D), the underpinning of a Web ontology language. This mechanism meets the key feature required by ORM schemas (i.e. identi¯cation and functional dependency constraints). It can be applied to integrate information not only from systems described in ORM schemas but also from relational databases into the Semantic Web environment.

Key words: Information integration, object role modeling (ORM), description logics (DLs), web ontology language, semantic web.

1 Introduction

In recent years, the problem of interoperability and semantic integration of heterogeneous information sources in the Semantic Web environment has triggered various research [2, 11, 15]. Besides the universal environment of the WWW (World Wide Web), this is thanks to the expressivity of Web ontology languages that deals with the problem of heterogeneity of sources and to their well-formalized annotations which can be used in automated reasoning [9].

These features are provided by underlying description logic (DL) languages, a family of knowledge representation formalisms based on First-Order Logic (FOL) [17], e.g. *SHOIN*(D) [7, 8].

One of the most popular information modeling approaches nowadays is ORM (Object Role Modeling) [4, 5]. It facilitates modeling, transforming, and querying information using *facts* and *constraints*, which may be verbalized in a close-to-natural language. This increases the ease of use, specially toward non-technical users. Unlike Entity-Relationship (ER) modeling [19] and Uni¯ed Modeling Language (UML) [16], ORM is attribute-free. The latter avoids the problems caused by instability in ER and UML as clearly shown in [3].

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Moreover, for information modeling, ORM graphical notations are far more expressive than those of ER and UML. It provides procedures for mapping to other database schemas (e.g. ER, UML). ORM has been fully formalized in FOL [4], so that its semantics is very close to that of DLs.

Hence, with the aim of integrating information systems into the Web Semantics, we introduce a formalization of ORM schemas in terms of a DL.

In particular, we show how ORM schema semantics can be captured in Web Semantics thanks to the expressivity of the DL *SHOINK*(D) [14, 12], which in its turn is the underpinning of a Web ontology language [13].

Several formalizations of ORM schemas have been proposed in the literature [10, 18]. They have been proved very useful with respect to establishing a common understanding of the formal meaning of ORM schemas. However, to the best of our knowledge, none of them has the explicit goal of building a framework to integrate information into the Semantic Web environment.

The rest of the paper is organized as follows. Section 2 brie°y introduces the *SHOINK*(D) language. In section 3, we show how ORM schemas can be formalized in this DL. Section 4 will conclude the paper with some future perspectives.

2 Description Logic *SHOINK*(D)

2.1 Concrete Datatypes

Concrete datatypes are used to represent literal values such as numbers or strings. They compose a *concrete domain* **D**, as introduced for *SHOQ*(**D**) [7]. Each datatype $d \in \mathbf{D}$ is associated with a set $d^{D} \subseteq d_{D}$, where d_{D} is the domain of interpretation of all datatypes. For example, a datatype $\geq_{21}$ in **D** defines a set ¸$\geq_{21}^{D}$ of *integer* values greater than or equal to 21.

2.2 *SHOINK*(D) Syntax and Semantics

SHOINK(D), presented in [14, 12], is an extension of *SHOIN*(D) with a decidable inference by adding identi¯cation constraints (ICs), which are one- to-one relations between an identifying and the identi¯ed part.

As a DL language, the basic syntactic building blocks of *SHOINK*(D) are atomic *concepts*, atomic *roles*, and individuals (constants). Concepts are interpreted as sets of individuals (subsets of the interpretation domain) and roles as sets of pairs of individuals. Expressions are then built from these basics by using several kinds of constructors. For example, the *conjunction* $C \prod D$ denotes the set of individuals obtained by intersecting the sets of individuals of C and D. In FOL, this expression can be described as $C(x) \wedge D(x)$, where the variable ranges over all individuals in the interpretation domain and $C(x) \wedge D(x)$ is true for those belonging to the concept C and D.

Syntax and Semantics of *SHOINK*(D) can be seen in table 1, where *C;D* are concept descriptions; *o* is nominal, i.e. singleton concept; *R, R*1*,...,;R*$_n$, *S* are roles; $\mathbf{R}_+$ is the set of transitive roles; # denotes cardinality; *I* is the interpretation function; Δ^I is the interpretation domain disjoint from $\Delta_{\mathbf{D}}$, the concrete interpretation domain. Further details of *SHOINK*(D) can be found in [14, 12].

Table 1. *SHOINK*(D) Syntax and Semantics

Construct name	Syntax	Semantics
atomic abstract role	R	$R^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}} \times \Delta^{\mathcal{I}}$
concrete role	U	$U^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}} \times \Delta^{\mathcal{I}}_{\mathbf{D}}$
transitive role	$R \in \mathbf{R}_+$	$R^{\mathcal{I}} = R^{\mathcal{I}+}$
inverse abstract role	R^-	$\{\langle x, y\rangle \vert \langle y, x\rangle \in R^{\mathcal{I}}\}$
role hierarchy	$R \sqsubseteq S$	$R^{\mathcal{I}} \subseteq S^{\mathcal{I}}$
atomic concept	A	$A^{\mathcal{I}} \subseteq \Delta^{\mathcal{I}}$
datatype	d	$d_{\mathbf{D}} \subseteq \Delta^{\mathcal{I}}_{\mathbf{D}}$
concrete value	v	$v^{\mathcal{I}} = v^{\mathbf{D}}$
negation	$\neg C$	$\Delta^{\mathcal{I}} \backslash C^{\mathcal{I}}$
conjunction	$C \sqcap D$	$C^{\mathcal{I}} \cap D^{\mathcal{I}}$
disjunction	$C \sqcup D$	$C^{\mathcal{I}} \cup D^{\mathcal{I}}$
exists restriction	$\exists R.C$	$\{x \in \Delta^{\mathcal{I}} \vert \exists y.\langle x, y\rangle \in R^{\mathcal{I}} \wedge y \in C^{\mathcal{I}}\}$
value restriction	$\forall R.C$	$\{x \in \Delta^{\mathcal{I}} \vert \forall y.\langle x, y\rangle \in R^{\mathcal{I}} \rightarrow y \in C^{\mathcal{I}}\}$
concrete exists restriction	$\exists R.d$	$\{x \in \Delta^{\mathcal{I}} \vert \exists y.\langle x, y\rangle \in R^{\mathcal{I}} \wedge y \in d^{\mathbf{D}}\}$
concrete value restriction	$\forall R.d$	$\{x \in \Delta^{\mathcal{I}} \vert \forall y.\langle x, y\rangle \in R^{\mathcal{I}} \rightarrow y \in d^{\mathbf{D}}\}$
atleast restriction	$\geq nR$	$\{x \in \Delta^{\mathcal{I}} \vert \sharp\{y.\langle x, y\rangle \in R^{\mathcal{I}}\} \geq n\}$
atmost restriction	$\leq nR$	$\{x \in \Delta^{\mathcal{I}} \vert \sharp\{y.\langle x, y\rangle \in R^{\mathcal{I}}\} \leq n\}$
nominal	o	$\sharp\{o^{\mathcal{I}}\} = 1$
subsumption	$C \sqsubseteq D$	$C^{\mathcal{I}} \subseteq D^{\mathcal{I}}$
identification constraint	$(R_1, ..., R_n$ $\mathbf{Idfor}\, C)$	$\mathcal{I} \models (R_1, ..., R_n\, \mathbf{Idfor}\, C)$ iff $\forall s, s' \in C^{\mathcal{I}}$ and $\langle s, t_i\rangle, \langle s', t'_i\rangle \in R_i^{\mathcal{I}}\, \forall 1 \leq i \leq n$, $t_i = t'_i\, \forall 1 \leq i \leq n$ then $s = s'$

As shown in table 1, *SHOINK*(**D**) concept descriptions can be specified as logical combinations (conjunction, disjunction, or negation) of others, as nominals or as restrictions on a particular role so that all the values filling the role have to belong to a certain concept (or datatype); or at least one value must come from a certain concept (or datatype); or there is at least or at most a certain number of distinct values. Concept descriptions and roles can also be organized in a subsumption (subclass) hierarchy. *SHOINK*(**D**) can also state whether a role is transitive, or the inverse of another.

3 Modeling ORM in *SHOINK*(D)

Example 1 is an illustration of modeling ORM schemas in *SHOINK*(**D**). We use the ORM formalization and syntax as found in [4, 5, 6], but, limiting it to binary predicates[2]. In this work, we consider the critical constraints that are indispensable

[2] It has been proved that n-ary predicates can be transformed to binary ones [20] in designing ORM schemas and we do not support nested-fact types and derivation constraints (the latter are not part of the ORM graphical notation).

Example 1. Fig. 1 describes in ORM graphical notation [6] the information of the students who attended an International meeting of the best students in the world. Each country, coded by CountryId, had only one student per subject (which is coded by SubjectId) who was elected to represent his/her country in this discipline. For social events, each student could attend many groups, each of which has only one topic. Different groups can share the same topic, but the student can only attend groups having different topics. These descriptions can be expressed in *SHOINK*(**D**) as shown in Table 2.

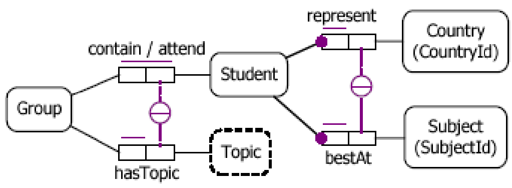

Fig. 1. ORM schema example

The principle components of ORM are object types, which include entities (e.g. Student, Country) and values (e.g. Topic, CountryId), and roles (e.g. contain, represent). Object types are connected by the roles they play, composing the fact types. Two roles in a fact type make up its binary predicate. Constraints are applied to roles to create the population of a database and restrict the data permitted in it. We here focus on the representation of the mandatory (•), internal uniqueness (-) and external uniqueness (θ) constraints.We briefly explain the formalization shown in Table 2, where $C_1, C_2, ..., C_n$ are entity names; $R_1, R_{2,...,}R_n$ are role names; $(CR_i{=}R_{inv(i)}C_i)$ are fact types, $R_{inv(i)}$ is the inverse of R_i, C is an entity name and $1 \leq i \leq n$; C(Id) is the reference scheme of C; R_{id} is a role name used to translate a reference scheme; C_{fd} and R_{fd} are respectively an entity and a role name used to translate a functional dependency.
The basic process is to go through a given schema, just as an automated system would do, looking for the following descriptions in the schema:

1. Object types (entities and values)
2. Reference schemes
3. Roles
4. Constraints

a) Identification constraints on one role
b) Identification constraints on many roles
c) Functional dependencies on many roles
d) Other constraints

It is obvious that this mapping is polynomial w.r.t the number of elements in the schema.

3.1 Mapping Fact Types

Since constraints are applied to fact types, frist of all, object types and roles must be formalized. Values are object types that cannot be defined by others. They are either strings or numbers, which exactly correspond to datatypes in *SHOINK*(**D**).
Entities can be defined by other entities and/or values. When defined by values, they can be seen as atomic concepts in *SHOINK*(**D**). Otherwise, constraints must be used to describe them (see section 3.2).
A role can attribute a value to an entity (attributive role, e.g. has Topic) or connect one entity to another (e.g. represent). The former corresponds to a concrete role while the latter corresponds to an abstract role in *SHOINK*(**D**). In any case, the instances assisting a given fact compose a set subsumed by their entity. So that we can model the context of the role they play as an axiom where the set generated by *atleast* restriction by 1 on the role is subsumed by the entity playing the role (e.g. ≥ 1hasTopic $\subseteq$ Group). Besides, whenever the entity plays its role, the object it plays with is defined by the role. So we can formalize this expression by an axiom specifying that the *value* restriction on the role subsumes the universe (e.g. T $\subseteq \forall$ hasTopic.Topic). In binary predicates, one role needs to be the inverse of the other. Hence, for a given fact type, two predefined non-attributive roles are mapped as the inverse of each other (e.g. attend $\equiv$ contain$^-$).

3.2 Mapping Constraints

A mandatory constraint (MC) on a role species that all instances of an object type must play the role. For example, it is applied on the role represent in Example 1 to show that every student must represent some country. This constraint is equally expressed by the existence restriction in *SHOINK*(**D**).
Uniqueness constraints (UCs) are used to express that each instance of an object type plays a set of roles at most once. These constraints make think of *atmost* restrictions in *SHOINK*(**D**). However, *atmost* restrictions are applied to a single role only. UCs in this case (e.g. on represent, bestAt) can thus be described by *atmost* restrictions by 1.
In case UCs are applied to a set of two roles of the same predicate (e.g. contains/attend), the two objects are in a n-n relationship (in Example 1, the objects are Group and Student). Implicitly, a binary relation is n-n without condition. So that there is no need to make a translation for this case.
In Fig. 1, we also see entities as so called *reference schemes*, e.g. Country(CountryId). The latter species that CountryId identifies uniquely Country. Essentially, reference schemes can be explained by adding an attributive role, imposing an MC and two UCs on both the two roles in the predicate (see Fig. 2). However, the inverse of an attributive role cannot be represented in *SHOINK*(**D**)

(see Table 1). Nevertheless, ICs in *SHOINK*(**D**) allow us to represent this ORM formalization, e.g. (idForCountry IdFor Country).

Table 2. Modeling ORM schemas in *SHOINK*(**D**)

ORM	$\mathcal{SHOINK}(\mathbf{D})$	**Example**
Value C_i	Datatype C_i	Topic
Entity C_i	Concept C_i	Group
Role R_i	$\geq 1R_i \sqsubseteq C$	$\geq$ 1contain $\sqsubseteq$ Group
	$\top \sqsubseteq \forall R_i.C_i$	$\top \sqsubseteq \forall$contain.Student
Inverse role $R_{inv(i)}$	$R_{inv(i)} \equiv R_i^-$	attend $\equiv$ contain$^-$
MC on R_i	$C \sqsubseteq \exists R_i.C_i$	Student $\sqsubseteq$ $\exists$ bestAt.Subject
IUC on R_i	$C \sqsubseteq \leq 1\ R_i$	Group $\sqsubseteq$ ≤ 1 hasTopic
Reference scheme	$\geq 1\ R_{id} \sqsubseteq C$	$\geq$ 1idForCountry $\sqsubseteq$ Country
C(Id)	$\top \sqsubseteq \forall\ R_{id}$.Id	$\top \sqsubseteq \forall$idForCountry.CountryId
(simple IC)	(R_{id} **Idfor** C)	(idForCountry **Idfor** Country)
EUC on (R_1^-,..., R_n^-) (IC for C)	(R_1,..., R_n **Idfor** C)	(represent, bestAt **Idfor** Student)
EUC on	$\geq 1R_{fd} \sqsubseteq C_{fd}$	$\geq$ 1specGroup $\sqsubseteq$ StudentTopic
(R_1^-, R_2^-, ..., R_n^-)	$\top \sqsubseteq \forall R_{fd}$.C	$\top \sqsubseteq \forall$specGroup.Group
(FD for C)	$C_{fd} \sqsubseteq \leq 1R_{fd}$	StudentTopic $\sqsubseteq$ ≤ 1 specGroup
	(R_1,...,R_n **Idfor** C_{fd})	(contain, hasTopic **Idfor** StudentTopic)

Fig. 2. Description of the reference scheme Country(CountryId)

In Fig. 1, we also see entities as so called *reference schemes*, e.g. Country(CountryId). The latter species that CountryId identifies uniquely Country. Essentially, reference schemes can be explained by adding an attributive role, imposing an MC and two UCs on both the two roles in the predicate (see Fig. 2). However, the inverse of an attributive role cannot be represented in *SHOINK*(**D**) (see Table 1). Nevertheless, ICs in *SHOINK*(**D**) allow us to represent this ORM formalization, e.g. (idForCountry IdFor Country).

This combination of constraints can also be described explicitly in ORM schemas as ICs. In such cases, the same mapping mechanism is applied.

The UCs discussed above are applied to roles in a single predicate. They are called *internal uniqueness constraints* (IUCs). In case applied to the roles in different predicates, these constraints, the so-called *external uniqueness constraints* (EUCs), are used to express unique identification and functional dependency (FD) relationships:

- *Using EUCs to describe unique identifications.* In Example 1, the EUC on the two inverse roles of represent and bestAt, combined with the IUCs and the MCs on the two latter roles, describe that students are uniquely identified by their country and their subject at which they were the best.

Hence, the combination of these constraints can be interpreted as an IC in *SHOINK*(**D**), i.e., (represent; bestAt Idfor Student).

- *Using EUCs to describe FDs*. Except the case described above, the application of EUCs results in FDs. For example, the EUC on attend and the inverse of hasTopic species that Group is functionally dependent on the couple (Student,Topic). Note that in *SHOINK*(**D**), constructors, except for ICs, are applied to one role only. In that way, it is not capable of ex-pressing FDs nor ICs on many roles [1]. However, observe that an FD of an object A on two objects B and C can be described as an FD of A to an object A', which is uniquely identified by the couple (B,C). Hence, we make use of this idea to formalize this kind of EUCs. For example, modeling the given EUC on attend and the inverse of hasTopic, we create an entity StudentTopic which is uniquely identified by the couple (Student,Topic). A new role, specGroup, is created to set the functional dependency of Group on StudentTopic. The two ORM schemas in Fig. 3 are equivalent.

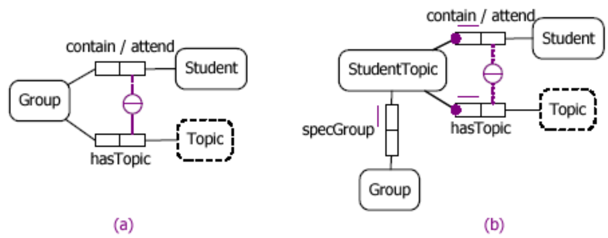

Fig.3. Equivelent schemas for an FD in Example 1

4 Conclusion and Perspectives

We have proposed a new formalization of ORM schemas in the DL *SHOINK*(**D**), which meets the key feature required by the schemas (i.e., identification and functional dependency constraints). Exploiting such a formalization, one can integrate information into the Semantic Web environment from systems described in ORM schemas as well from relational databases. Furthermore, the DL used here is decidable [14, 13]. So this formalization allows for automated reasoning on ORM schemas as well (e.g., detecting constraint conflicts or implications).
Our future work will include the mapping of other types and constraints in ORM to *SHOINK*(**D**) and the implementation of the formalization. With the perspective to construct a methodology of integration of information sources into the Semantic Web environment, our next phase will be the automated translation of requests from a DL to SQL by using this formalization.

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Semantics-based Reconciliation of Divergent Replicas in Advanced Concurrent Engineering Environments

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Abstract. A novel method for semantics-based reconciliation of long-lived transactions in concurrent engineering environments is described. The reconciliation is a key element of recent optimistic replication technologies facing the challenges of diverging replicas, conflicts between concurrent operations and disturbing consistency. The research presented addresses the general problem of semantically consistent and functionally meaningful reconciliation and enables significant simplification and formalization of its solution. The advantages of the method are strong guarantees of semantic consistency of the convergent representation, capabilities to use it in autonomous and user interactive modes as well as avoidance of combinatorial explosion peculiar to many other methods. The particular application is presented to illustrate how the method can be effectively applied for collaborative software engineering in the scope of the emerging UML-driven methodology.

Keywords. Concurrent engineering environments, optimistic replication, reconciliation, EXPRESS, UML/OCL

1 Optimistic replication

Optimistic replication is the key technology in advanced distributed systems intended for effective collaboration of various stakeholders involved in joint engineering activities to be conducted concurrently [1].

Sacrificing underlying ACID (atomicity, consistency, isolation, and durability) principles the traditional database management systems rely on, optimistic replication enables higher availability and performance [2]. The advantages are achieved through reduced latency by letting users and applications share data simultaneously as well as through increased throughput by avoiding centralized query processing and remote network access. Instead of synchronous replica coordination deployed in pessimistic transaction models, optimistic methods let data be accessed without a priori blocking based on the assumption that occasional conflicts can be always fixed after they happen.

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Often, human activities like cooperative engineering or software development require people to work asynchronously in relative isolation. It is better to allow them to update data independently and repair occasional conflicts after they happen than to lock the data out while someone is editing it [3]. CVS, Lotus Notes, Synergy, subversion [4] are some applications that exploit optimistic replication for collaboration purposes.

These benefits, however, come at a cost, since there is a principal trade-off between data availability and consistency common for all distributed systems. Optimistic replication faces the challenges of diverging replicas, conflicts between concurrent operations and disturbing consistency. These issues are especially critical for advanced multi-modal collaborative environments enabling long-lived transactions, supporting semantically rich operations and managing complex scientific and engineering data [5] like those defined by ISO 10303 — Standard for Product Data Representation and Exchange (STEP) [9] and by Model Driven Architecture initiative by Object Management Group (OMG MDA) [10].

Such data are usually multidisciplinary, highly scaled, and too complicated the diverged replicas to be managed and agreed manually. Being specified in the EXPRESS [11], the Unified Modeling Language and Object Constraint Language (UML/OCL) [12], the data models may contain definitions of hundreds and thousands of data types and constraint sorts. This makes realization of the reconciliation and replication approach in whole a nontrivial task. Creation of application-specific solutions is not satisfactory because of complexity and variety of the actual product models.

The circumstances above inspired us to develop a systematic semantics-based reconciliation method that would incorporate three basic principles making it quite universal and constructive for a lot of problems and applications:

— *support of emerging STEP and OMG MDA standards* to use general and popular object-oriented modeling languages like EXPRESS, UML/OCL as well as to employ standard product models developed by wide academy and industry communities for key engineering domains;

— *formal semantic analysis of concurrent transactions* covering both underlying model data structures and algebraic constraints imposed upon them;

— *logic (poly-syllogistic) deduction* targeted on construction of most promising reconciliation schedules that would incorporate as many as possible operations from concurrent transactions and would maintain consistency, correctness, and meaningfulness of the resulting convergent data representation.

This paper focuses on basic principles of the reconciliation method. Section 2 presents a general organization of a reconciliation process and shortly concerns a classification of data and constraints occurred in practice. In section 3 explanations how formal analysis of data models can facilitate establishing relations among operations in concurrent transactions and how logic deduction can be applied for their consistent and meaningful reconciliation are provided. Section 4 presents an application developed for the reconciliation of UML diagrams in the scope of the emerging model-driven software engineering methodology. In conclusions we mention some adjacent problems and outline promising directions for future investigations.

2 General reconciliation process

According to the optimistic replication, applications running within distributed systems are either in isolated execution phase or in the reconciliation phase. At isolated phase applications proceed on local replicas of the shared data bringing them to some tentative states. All the actions undertaken are sequentially recorded in transaction logs. Actions are assumed to be deterministic and reversible. Replaying a log against the initial state results in the same final state and, vice versa, being reversed the log reproduces the initial state from the final one. We suggest that transaction logs are correct in that sense they can be correctly replayed and correspond to consistent and meaningful tentative states. It is a rather reasonable assumption motivated by correctness of the applications running on local machines and proceeding on local data replicas.

A typical repertoire of the actions for the object-oriented data involves operations with extended read/write semantics like creation of new object, changing an object class, modification of object attributes, reassignment of object associations and aggregations, and deletion of an object. Object-oriented modeling languages like EXPRESS, UML/OCL provide a wide range of declarative and imperative constructs to define both data structures, derived properties and algebraic constraints. In particular, strings, enumerations, collections, object types, and classes can be defined within the specified data model. The constraints can restrict acceptable widths of binaries and strings; cardinalities of collections; multiplicities of associations and compositions; non-mandatory attributes; uniqueness of attributes and their aggregate groups; value domains of separate attributes, objects and whole object populations.

We suggest that general reconciliation process incorporates following seven stages presented by the figure 1.

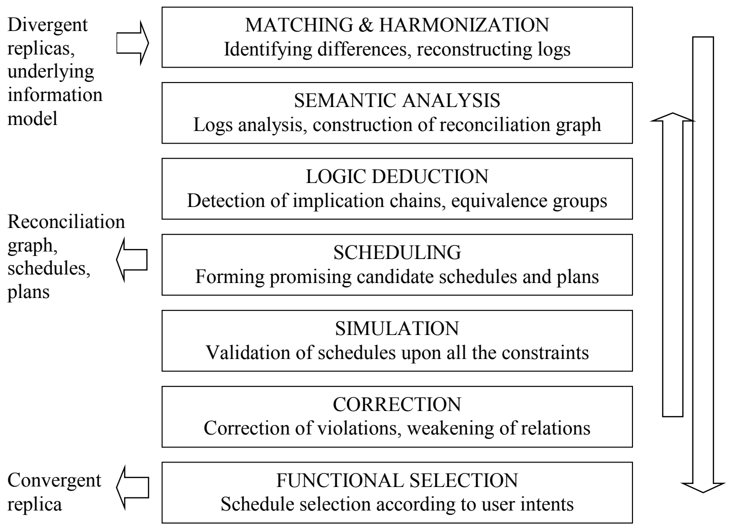

Figure 1. Basic phases of the general reconciliation process

At the *matching and harmonization* stage the divergent data replicas are compared with each other to identify and to harmonize differences and to correctly reconstruct logs. The actions contained in transaction logs are joined at the *semantic analysis* stage and analyzed against all the preconditions and constraints defined by the data model. Dependence and precedence relations are established among the actions. *Logic deduction* is applied to determine transitive closures of the relations and to form implication chains and equivalence groups for the actions. At the s*cheduling* stage alternative solutions are explored to satisfy the representativeness requirement for the consolidated schedule and the consistency requirement for the convergent data representation. The *simulation* stage is necessary to verify whether the built schedules really satisfy all the conditions. If no acceptable schedules have been found, *correction* may be constructive to weaken the established relations and to bring the resulting data representation into consistent state. Correction can be executed iteratively in feedback cycle as shown in the figure 1. Finally, at the *functional selection* stage the schedules being successive simulation outcomes are chosen in accordance with functional requirements and user intents.

3 Semantic analysis of concurrent transactions

Reconciliation should combine the initial logs in some way to produce a new log, which can be replayed to bring the replicated data from its last common consistent state to a new common consistent state. Ideally, the reconciled schedule would contain all the actions and satisfy all the constraints and user intents. Nevertheless, careful analysis of semantic relations among actions of concurrent transactions has to be conducted to guarantee that in general case.

The tentative log $T = T' \cup T''$ is a set of actions formed by union of the reconciled transactions T', T''. In other words, if x is an ancestor state of the data and x', x'' are the divergent replicas of the data, then $x' = T'(x)$ and $x'' = T''(x)$.

The dependence relations D are defined using boolean operations as follows. For actions $t_1, t_2 \in T$, if $t_1 \rightarrow t_2$ then the schedule must contain t_2 on condition that it contains t_1. If $\neg t_1 \rightarrow \neg t_2$ then the schedule must exclude t_2 on condition that it doesn't contain t_1. The relations are non-symmetric, reflexive and transitive. We find also reasonable to utilize the symmetric implication relations $t_1 \rightarrow \neg t_2$, $\neg t_1 \rightarrow t_2$ as well as the relations induced by equivalence operation $t_1 \sim t_2 \equiv t_1 \rightarrow t_2 \wedge t_2 \rightarrow t_1$ and by exclusive disjunction operation $t_1 \oplus t_2 \equiv t_1 \rightarrow \neg t_2 \wedge \neg t_1 \rightarrow t_2$.

In some cases multiple dependency relations should be employed for the comprehensive semantic analysis. They can be represented in a general form by characteristic boolean functions $D(t_1, t_2, t_3, \ldots)$ and corresponding truth tables [13].

As an example, the relation $D^{(n:m)}(t_1^+, \ldots, t^+_{I+}, t_1^-, \ldots, t^-_{I-})$ should be taken into account if some cardinality constraint is imposed upon a collection and transaction actions are capable to insert new elements in the collection and remove the elements from it. The relation takes place if only $n \leq card(T^+) - card(T^-) \leq m$, where $T^+ = \{ t_i^+, i \in (1, I^+) \mid t_i^+ = true \}$, $T^- = \{ t_i^-, i \in (1, I^-) \mid t_i^- = true \}$, and the function $card()$ returns the cardinal number of action subsets T^+, T^-.

The characteristic functions of the cardinality relations $D^{(0:0)}(t_1^+, t_2^+, t_1^-, t_2^-)$, $D^{(1:1)}(t_1^+, t_2^+, t_1^-, t_2^-)$ and $D^{(2:2)}(t_1^+, t_2^+, t_1^-, t_2^-)$ are given by trivial truth tables [8]. The functions of derived cardinality relations can be expressed using the following recursive identities:

$D^{(n:m)}(t_1^+,\ldots, t_1^-,\ldots) \equiv D^{(-m:-n)}(t_1^-,\ldots, t_1^+,\ldots)$,

$D^{(n:m)}(t_1^+,\ldots, t_1^-,\ldots) \equiv D^{(n:n)}(t_1^+,\ldots, t_1^-,\ldots) \vee \ldots \vee D^{(m:m)}(t_1^+,\ldots, t_1^-, \ldots)$

Often, if some constraint $c(x_1, x_2,\ldots)$ is given by a predicate function of several variables and it is required to satisfy it, the algebraic dependence relation $D^c(t_1', t_2', \ldots, t_1'', t_2'',\ldots)$ can be set among the transaction actions, which modify the variables of the given constraint. The relation takes place if the resulting schedule contains all the modification actions belonging either to one or another transaction $D^c(t_1', t_2',\ldots,t_1'', t_2'',\ldots) \equiv t_1' \oplus t_1'' \wedge t_1' \sim t_2' \wedge t_2' \sim t_3' \wedge\ldots\wedge\ t_1'' \sim t_2'' \wedge t_2'' \sim t_3'' \wedge\ldots$ Being established the relation guarantees the algebraic constraint will be satisfied.

The precedence relation P is defined as follows. For actions $t_1, t_2 \in T$, if $t_1 \angle t_2$ then action t_1 must appear before (not necessarily immediately before) action t_2 in any schedule that contains both t_1 and t_2. The precedence relation is non-symmetric, non-reflexive, but transitive.

Once the relations are established among actions, the logic deduction can be applied to form a resulting schedule that would satisfy all the action preconditions and the semantic constraints. Early we presented a method exploiting a graph representation for the introduced semantic relations and a poly-syllogistic deduction on the graph to form consistent schedules. The method enables to determine implication chains, equivalence groups, and conflicts by transforming of the semantic relations into logic ones and by computing their transitive closures. An important feature is that the method tends to consolidate within the final schedule as many actions as possible (see the published works [7, 8]).

4 Reconciliation of UML models

For illustration let discuss the developed reconciliation method in conformity to collaborative software engineering in the scope of the emerging UML-driven methodology [10]. The UML has been widely accepted throughout the software industry and is successfully applied to diverse domains. The UML provides a variety of diagram types for describing dynamic behavior of software being developed, its static structures, functional requirements, and implementation features. The OCL is its textual extension intended for specifying constraints.

Using visual and textual notations provided by the UML/OCL languages, software engineers (e.g. analytics, architects, requirement engineers, designers, developers, testers, etc.) can effectively collaborate by sharing and exchanging the models. But possible conflicts in the model replicas caused by asynchronous work on them must be identified and resolved consistently. Because of high complexity of the underlying UML/OCL metamodel, it cannot be done manually without a risk to disturb the consistency. Nevertheless, the presented semantics-based reconciliation method can be employed for such purposes.

The class diagram in the figure 2 presents a partial, simplified fragment of the metamodel responsible for visual representation of the UML state chart diagrams.

The class diagram illustrates a simple visualization scenario describing the generalizations, compositions and associations among Diagram, DiagramElement, Symbol and Line classes. The scenario indicates that Diagram instances consist of elements of Symbol or Line types. The concrete classes StartSymbol, TaskSymbol, DecisionSymbol, CommentSymbol and some other allied classes are specializations of the abstract Symbol class. The classes FlowLine and CommentLine are specializations of the Line class. The associations From and To established at abstract level are inherited by the concrete classes in which the referenced association types and multiplicities are redefined.

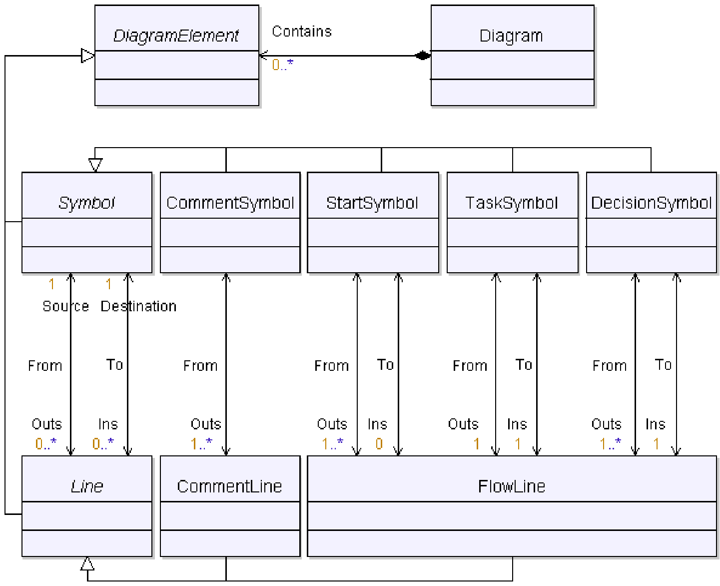

Figure 2. The metamodel representation of the UML statechart diagrams

The figure 3 presents replicas of the concurrently developed state chart diagram — common ancestor version (a), versions obtained in the first and the second transactions (b), (c), and a resulting version (d). In the version (b) new transition chain has been added consisting of Signal3 ∈ InputSignalSymbol, Task1(i = 20) ∈ TaskSymbol, State2 ∈ StateSymbol and connecting them Line1(Idle -> Signal3), Line2(Signal3 -> Task), Line3(Task -> State2) ∈ FlowLine. The previous State1 ∈ StateSymbol has been deleted, and output of the Task (i = 10) ∈ TaskSymbol via Line4 ∈ FlowLine has been reconnected.

The first transaction log can be represented as follows: $T' = \{t_1' =$ *new* (Signal3), $t_2' =$ *new* (Task1), $t_3' =$ *new* (State2), $t_4' =$ *new* (Line1), $t_5' =$ *new* (Line2), $t_6' =$ *new* (Line3), $t_7' =$ *wr* (Line4.Destination, State2), $t_8' =$ *del* (State1)$\}$, where symbols *new*, *wr*, *del* denote creation, modification and deletion actions. Here action $t_4' =$ *new* (Line1) implicitly assumes the setting of mandatory Source and Destination associations: *wr* (Line1.Source, Idle), *wr* (Line1.Destination, Signal3).

Then the following relations can be established among actions. Implications $t_1' \rightarrow t_4'$, $t_1' \rightarrow t_5'$ take place as the signal3 must have input and output. In fact, stronger, equivalence relation takes place because of Source and Destination associations for newly created flow lines must be set. Thus, to guarantee the semantic correctness $t_1' \sim t_2' \sim t_4' \sim t_5' \sim t_6'$ must be satisfied. In order to be able to reply the log, the partial ordering $t_1' \angle t_4'$, $t_1' \angle t_5'$, $t_2' \angle t_5'$, $t_2' \angle t_6'$ must be kept.

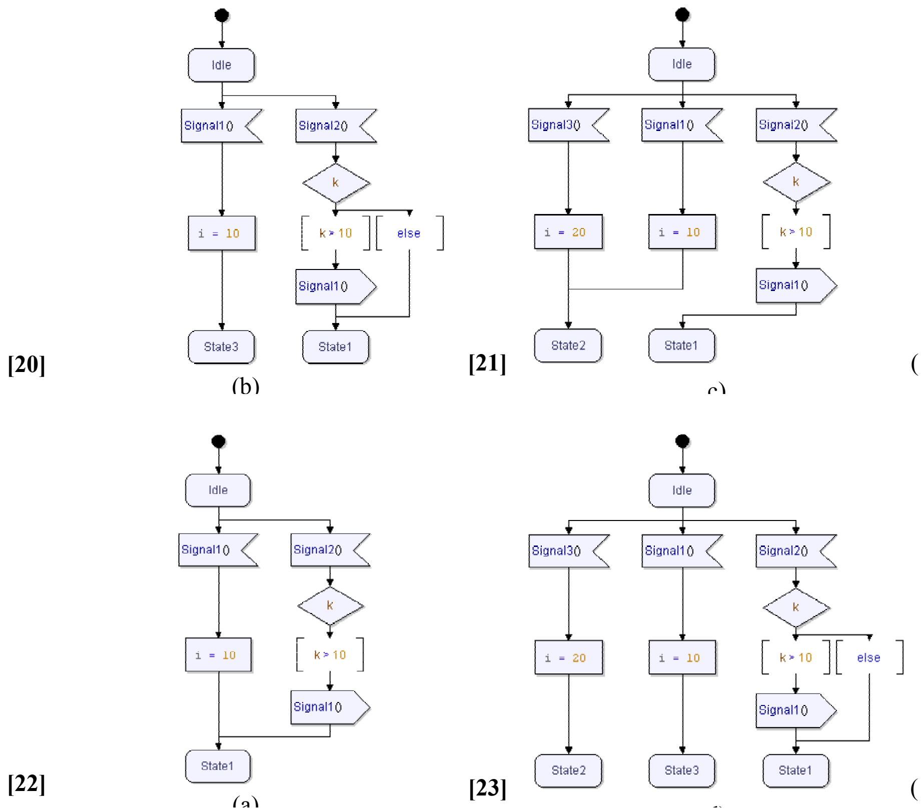

Figure 3. The original, divergent and resulting replicas of the statechart diagram

Similar semantic analysis can be performed for the second transaction and across concurrent transactions to detect possible conflicts. So, in the example considered there is a conflict between the actions *wr* (Line4.Destination, state2), *wr* (Line4.Destination, state3) in the first and the second transactions respectively. If the conflict is resolved by taking changes made by the second transaction, the result looks as shown at the figure 3. It is important that the semantically consistent and functionally meaningful result has been derived in a completely formal way using underlying data model and applying logic, poly-syllogistic deduction. Certainly, the example is not exhaustive. Nevertheless, it outlines the essential advantages of the developed method.

5. Conclusions

Thus, the method for semantics-based reconciliation of divergent replicas in advanced concurrent engineering environments has been presented. Its main advantages are a significant formalization making possible to employ it for sophisticated data models and applications, mathematically strong guarantees of the result correctness and meaningfulness, capabilities to use it in autonomous and user interactive modes as well as avoidance of combinatorial explosion peculiar to many other methods. In the future, some adjacent problems will be investigated. These are semantics-based matching of divergent replicas, building well-balanced reconciliation plans, adaptive correction of transactions as well as application-specific reconciliation solutions.

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Controlled Vocabularies in the European Construction Sector: Evolution, Current Developments, and Future Trends

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Abstract. In the last 40 years, the development of Controlled Vocabularies (CVs), such as dictionaries, classifications, taxonomies, and of course the "appealing" ontologies, has been the focus of many research projects around the world targeting the Construction sector. Being involved in several pan-European initiatives, the authors of this paper show milestones on the path of evolution (what has happened so far), the current situation (where we are now) in terms of development and adoption of results, the main problems found regarding both development and adoption of the CVs, and finally, present some speculative and provocative ideas about the future of CVs in the European Construction sector.

Keywords. Controlled Vocabularies, Ontologies, Taxonomies, thesaurus, Construction.

1 Introduction

In the last 40 years, the development of Controlled Vocabularies such as dictionaries, classifications, taxonomies, and of course the appealing ontologies, has been the focus of many research projects in Europe. A non-exhaustive list of well known efforts in this are is the following: ISO12006 parts 2 and 3, LexiCon (the Netherlands), Barbi (Norway), bcBuildingDefinitions taxonomy (e-Construct Project), ICONDA terminology (Fraunhofer IRB), BS6100 and UNICLASS (British Standards), e-COGNOS ontology (e-COGNOS project), Standard Dictionary for Construction in France (SDC). It is worth recalling that in other continents similar efforts were also conducted, such as the SI/SfB, Masterformat, Omniclass, and the Canadian Thesaurus, just to name a few.

Even a brief review of the above listed projects/initiatives allows us to imagine how much effort has been devoted to this area around Europe[54], (likely) guided by

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a single aim: to put the Construction sector at the leading edge for the best advances of semantic-related ICT resources. Preliminary thoughts were about developing useful e-Commerce/e-Business related tools and resources to help construction companies publish their own catalogues using their own languages and, at the same time, become actors in the European arena.

Based on the results achieve so far, however, a quite pragmatic question arises: after one decade (or more) investing on this topic, what is the reality in Europe nowadays? Are Controlled Vocabularies really used in a daily basis by Construction actors or are they still remaining a piece of art contemplated and admired behind the security protection provided by the 'research walls'?

If Controlled Vocabularies are fully adopted and used on a daily basis, what might we do with them in the future, and what are the trends currently observed in the research area? What are the domain(s) of work where Controlled Vocabularies will likely play an important role? What is the future of e-business and e-commerce related activities in Europe, a very fragmented market where the national (sometimes regional) norms and regulations impose a strict control on products and services construction-oriented? And a more ambitious question, what Construction can do in order to place itself properly regarding the business exploitation of the Semantic Web?

This paper discusses the questions raised above, based on the experience gathered by the authors through their involvement in several European initiatives related to the subject. Section 2 presents the main reasons behind the development of CVs in Construction (why). Section 3 discusses very briefly a selected set of European/International initiatives on this area. Section 4 draws a picture about where we are now, preparing the ground for the speculative and provocative discussion in Section 5, about where we are going *versus* where we could/should go. Finally, some conclusions close the paper.

2 Major reasons behind the development of Controlled Vocabularies in Construction

Well, why develop controlled vocabularies for any field of activity? Here are some unquestionable reasons for this necessary activity:

- **Vocabularies give names to things that have meaning at a certain level of detail.** Vocabularies provide a convenient shorthand for exchanging information. For example, "dog" means "a domestic carnivorous animal with four legs that typically has a long muzzle, pointed ears, a fur coat, a long fur-covered tail, and whose characteristic call is a bark". It is certainly different to "elephant" or "bicycle". So, if somebody says, "Where is my dog?" we know the kind of thing to look for. But there are many dogs. We could add adjectives like "small", "long", "short-legged", "drooping eared", "German" (which adjectives must have agreed meaning in the dog context) or we could

[54] Not only Europe, but for the context of this paper the discussion will remain inside European borders.

simply use another name “dachshund” or “sausage dog”. These need to have agreed meaning, not least because to the English or French the word dachshund is foreign and the other is a descriptive nick-name. The deeper we need to go with meaning to add detail or to differentiate, the more control there needs to be in the use of the language. Between specialists in one discipline there can be quite precise understanding of words (in this case zoologists who might even use Latin names) but between experts and non-experts and different kinds of expert there can be misunderstanding. To change to a construction example, what is the difference between a “brick pillar” and a short length of thick wall made from brick? A bricklayer and a cost estimator might use different terms. The answer (in UK at least) is that the difference is defined by rules related to the dimensions.

- **Vocabularies are important to conveying human thought in a concise way and with precision in a given working context.** Vocabularies must be controlled to achieve this or we have the Humpty Dumpty situation (from Alice in Wonderland) pictured in Figure 1. There must be as much preciseness as possible although in human exchanges we sometimes say that something is like something else e.g. the dog is like a dachshund but with longer legs. We can then ask questions to refine meaning and (perhaps finally) identify the breed of dog.

Figure 1. About the meaning of words (from Alice in Wonderland)

- **Controlled vocabularies are even more important to electronic information exchange in any form.** Whilst humans can ask clarifying questions based on their experience and knowledge, computers do not have that as a general capability (though in limited contexts artificial intelligence may enable that). So there needs to be precision built into the language of computer communication used. There is much less possibility for confusion if an object is referred to by say its catalogue/part number and as a buyer I use that to describe my need to the supplier. But not everything can be conveyed that simply. Architectural details, a building frame, a plumbing system etc. are usually designed to result in requirements that facilitate choice of components to satisfy the need. So generic types like wall, pump, foundation are used that are then specialised according to properties (such as dimensions, material, colour, strength etc) which themselves must have precise (i.e. agreed) meanings. Although codes could be used to identify components and systems, it is far more convenient that the codes take the form of the names we humans use. “Pump” not A254GHT7 unless we are buying from a catalogue!

9. **With control of vocabulary (including between natural languages) being so important, who should control it for the Construction Industry**? The answer is the practitioners and ICT providers through standardisation processes of one kind or another. The struggle of the past decade or more has been to put in place the national, European, international and cross discipline organisation for that to happen. The Construction Industry is hugely fragmented in terms of disciplines involved, their locations and skills and often undertakes major projects as international consortia. Such consortia are temporary alliances for the duration of a project, perhaps no more than a year or so in a design phase. Project lead times can be exceedingly short with teams from different disciplines (and within disciplines) put together at quite short notice. The need for standardised, controlled vocabularies in such a work environment is crucial. But where has the resource come from to cover the cost of vocabulary development and control? The industry is highly cost competitive and not noted for its research investment by virtue of the small size of the vast majority (80%+) of companies. Progress has largely been made through efforts arising from collaborative research projects, initiatives and developments such as those listed below. Finance for effort has been contributed to by funding programmes (national and EU) and the participating organisations themselves.

3 State of the Art on CVs for Construction in Europe

As previously indicated, a large effort has been devoted to the creation and use of CVs around the world. This section briefly summarises a suite of relevant research projects, and pan-European & international initiatives (Figure 2). It is worth noting that this broad scene is not presented as exaustive or complete. It simply provides inputs to the brainstorming and discussion presented in the next section.

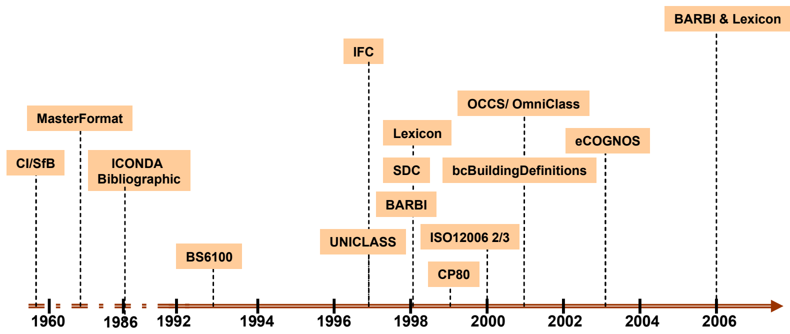

Figure 2. Some examples of CV-focused initiatives in Europe and worldwide

We start with the CI/SfB (Construction Index/*Samarbetskommitten for Byggnadsfragor*), a Scandinavian system of classification originally set up in 1959 and specially designed for the construction sector. It is claimed to be now in use worldwide for any technical and trade literature in the broad construction area. The CI/SfB was used in North America as the basis of the MasterFormat™, which is the specification-writing standard for most commercial building design and construction projects.

MasterFormat is a master list of numbers and titles intended for use in the organizing of specifications, and contracting and procurement requirements initially started with 16 *divisions* coded with 5 digits. In order to cope with the changes required by the modern Construction industry, in 2004 MasterFormat was heavily updated; new sections were added (the initial 16 were extended to 50) and the number codes are composed now of 8 digits (instead of the initial 5). MasterFormat targets the standardised communication of projects for all actors involved.

MasterFormat works together with Uniformat. Uniformat is an arrangement of construction information based on physical parts of a facility called systems and assemblies, aiming to: (I)achieve consistency in economic evaluation of projects; (ii) enhance reporting of design program information; and (iii) promote consistency in filing information for facility management, drawing details and construction market data. Masterformat tells **what** the construction item is, whilst Uniformat says **where** the construction item is.

Beginning in the 90's there is the British Standard 6100 (BS6100, the pioneer in UK); this is a glossary of the terminology used in the UK Construction sector, aiming to provide *a comprehensive list of terms that will promote better understanding between various sections of the construction industry, facilitate trade and provide better tools for improving handling of information*.

The use of **BS6100** was combined with the Unified Classification for the Construction Industry (UNICLASS, published in 1997 as a substitute for the widely accepted but increasingly out of date CI/SfB), which is a Construction-specific information classification system that covers information generated from all phases of a construction project. Uniclass is structured with a faceted classification system rather than a hierarchical one.

The **ISO 12006**[55] family (part 2 and part 3) came from another level of concern: the International Organisation for Standardisation. ISO was also targeting the development of standard CVs for the Construction sector in a world-wide scale. On one hand, ISO12006-2 targeted the definition of a model for classification systems (it is not a classification system in itself); rather it sets out an approach whereby particular classification systems that meet regional or national requirements can be developed according to a common international approach. On the other hand, the ISO 12006-3 defines a schema for a taxonomy model, providing the ability to define concepts by means of properties, to group concepts, and to define relationships between concepts. Objects, collections and relationships are the basic entities of the model.

The ISO foundation work was adopted and used by some institutions around the world. Among them, we can cite Stabu (Netherlands), Edibatec (France), and the Norwegian construction industry, which respectively started their own implementations of ISO-based tools, namely the **LexiCon, SCD, and BARBI**. In other words, the three of them are independent implementations of dictionaries that are compliant with the specification given in ISO 12006-3.

Next we talk about the International Alliance for Interoperability (IAI) and its Industry Foundation Classes (IFC). The IFC model has been progressively developed by the IAI since 1995 through several releases implemented in software for data exchange and sharing across applications. Since the IFC.2x release (October 2000), a core part of the model has been protected against change and formally accepted as ISO PAS 16739 in November 2002 under the external “harvesting” procedures of ISO TC184/SC4. IFC is the IAI vehicle aiming to promote and support the implementation of the concept of a Building Information Model (BIM) to increase the productiveness of design, construction, and maintenance operations within the life cycle of buildings.

The IFC model is rooted in approaches initially developed within the work of ISO TC184/SC4; most particularly in the development of the ISO 10303 series of standards (STEP q.v.). In particular, IFC has adopted and/or adapted certain parts of the STEP standards including: formal specification of IFC is in the EXPRESS language from ISO 10303 part 11; encoding of files for data exchange is undertaken using ISO 10303 part 21; and the IFC model uses schema that have been adopted from the resource standards within ISO 10303, particularly parts 41, 42, 43 and 46. Despite the fact that from a “semantic perspective”, the IFC model per se cannot be considered ontology/taxonomy, part of it has been used to support reasoning and to exchange meaningful pieces of information among different software tools.

Many others European projects (research-oriented, standards-biased, etc.) were performed after this. A brief xlist includes: eConstruct [1], e-COGNOS [2], CEN/ISSS eConstruction series of Workshops [3], FUNSIEC [4], and the on-going CONNIE [5], and SEAMLESS [6] projects.

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[55] It is worth noticing that both standards were officially relased by 2001, after the normal “evolution” through the standardisation channel (PAS-Publicly Available Specification, DIS-Draft International Standard), altough they have started been used before that.

The eConstruct project developed the *Building and Construction eXtensible mark-up Language* (*bcXML*), which supports the eBusiness communication process needed between clients, architects and engineers, suppliers and contractors for the (e)procurement of products, components, and services. The *bcBuildingDefinitions*, the taxonomy developed by eConstruct to show the power of bcXML, contains nearly 3000 terms specifically related to *doors*, expressed in six languages[56]. Such taxonomy can be instantiated to create catalogue contents or the actual requirements (queries) and solutions (answers) messages.

The e-Cognos developed a KM-oriented software infrastructure enabled by a semantic pillar: an ontology server (and its respective ontology). Such ontology focuses on construction concepts as they were related to e-COGNOS main objective: **consistent knowledge representation of construction knowledge items**. The e-COGNOS ontology is composed of two taxonomies (concepts and relations). The taxonomy of concepts is grounded on the IFC model, which was used to form its highest levels, according to the following motto: *In the context of a* <u>*Project*</u>*, a group of* <u>*Actors*</u> *uses a set of* <u>*Resources*</u> *to produce a set of* <u>*Products*</u> *following certain* <u>*Processes*</u> *within a work environment (*<u>*Related Domains*</u>*) and according to certain conditions (*<u>*Technical Topics*</u>*)*.

The CEN/ISSS eConstruction series of workshops worked towards the standardisation (or as close as possible since CEN means *European Committee for Standardisation*) in which the required semantic themes were also formulated. This initiative recognised that it is not possible to propose standardised *Semantic Resources* (SRs – i.e., ontologies, taxonomies, dictionaries, thesauri, and the related resources) for the construction sector but that it was possible to recommend what organisations could do after deciding to use SRs to support their business activities. Additionally, this initiative emphasised the need to take into account two key parameters, namely *purpose* and *application* areas when considering development and/or use of SRs.

The FUNSIEC project worked with the following question: is it possible to establish semantic links (mappings) between different SRs? And if yes, is it possible to evaluate how good are they? The first answer is yes, it is possible, which was demonstrated through the results of such projects: the OSIECS Kernel, and both OSIECS meta-model/model. The former is a software tool built to identify and propose semantic mappings between two SRs. OSIECS meta-model/model are the mapping tables produced by the OSIECS Kernel.

The CONNIE project tackled the problem of exploitation of multi-lingual content representing norms and regulations for the European Construction sector. It produced a software infrastructure to help organise, index, classify and use (in a pan-European way), the contents (regulation/norms) currently available within the CONNIE environment. This infrastructure strongly relies on the use of CVs in order to index and share the use of multi-lingual contents in an efficient way.

The SEAMLESS project targets the deployment of a seamless infrastructure to help SMEs to participate more easily in the e-business world (i.e. providing e-

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[56] : English, French, Dutch, German, Norwegian, and Greeklish (Greek language written with Latin characters). Additional information about e-Construct can be found at (Lima 2003).

services to support business needs, such as procurement, production follow-up, etc.). The SEAMLESS infrastructure has been developed in a sector-independent way, but in order to demonstrate its potential two vertical sectors were selected: Textile and Construction. The knowledge-related side of SEAMLESS is based on a hierarchy of ontologies covering three levels of representation, namely: the global level (the whole SEAMLESS environment), the mediator level (the intermediate level providing a mapping between the global level and the SMEs), and the local levels (the lowest level where the SMEs are placed with their small CVs). In order to support the operation of the SEAMLESS environment, a sector-specific hierarchy of ontologies is being developed.

Currently, North America is attempting to bring classification within a single, multi-facetted approach called Omniclass, which started under the name of Overall Construction Classification System (OCCS) in 2001 and was renamed to Omniclass in 2002. It is based on ISO12006-2 as a framework and it uses MasterFormat for work results, UniFormat for elements, and Electronic Product Information Cooperation (EPIC) for structuring products. First version of Omniclass 1.0 was officially released by March 2006.

Last but not least, we complete the picture by referencing the ICONDA Terminology and the Canadian thesaurus. The former is the CV supporting the operation of the whole ICONDA@ family of products (e.g. the ICONDA database holding technical information on Construction problems). The latter is a bi-lingual thesaurus specifically created to represent construction terms in English and French. The enrichment of this thesaurus has been re-launched and new developments and improvements are expected in the near future.

4 Where we are now and where we could/should go

The work and initiatives described in the previous section allows us to say that we are in a good position but we have not achieved what we have been looking for. Companies are not yet sufficiently capitalising on the results provided by the research world and standardisation still needs to find its place in this arena. However, we should not be pessimistic: very good work has been produced, and solid results are now available. Education is the key word behind what needs to be done in order to push things forward.

The assessment of the results produced by FUNSIEC emphasised the importance of **education** (in the large sense) of the practitioners from Construction regarding the use of semantic resources. CEN/ISSS eConstruction workshop suggested the same approach. Education here means providing good practice examples to the final users showing how they can benefit from the use of CVs in their daily business, how they can expand their capabilities and potentialities in terms of market, what are the tangible benefits/improvements CVs can offer to them.

The authors keep working on this field and the latest experiences show that although good and powerful contributions are already in place, every time new research starts, people want to develop new things and to break with the past is a way to show innovation. This is a very natural human behaviour and, to the best of our knowledge, quite difficult to change. For instance, in a new IST project[57], where CVs are required, the development team finds arguments to justify the development of 'yet another' ontology editor and a new tool to produce semantic mappings. What is behind this behaviour? Is it the need to differentiate the from previous ones? The need to leave 'fingerprints' on this area? Authors do not know; what they know is that recommendations from standards-related initiatives, like the CEN/ISSS eConstruction workshops, are not really being taken into account. These recommendations talked about 'analysing what is available', 'reusing current results', etc., which is definitely relegated to a second place. What matters is to propose new ideas, develop new things and try to be innovative & revolutionary, even when only keeping pace and going nowhere!

Business initiatives, even supported by less advanced solutions, are pushing things forward. IFCs have catalysed the adoption of the BIM concept and, considering the fact that part of the IFC model can be considered as an ontology, new experiments on the area have been launched and we can wait for solid results very soon. Other more modest initiative but also very useful (e.g. ICONDA family, CSTB products) are making money using very dedicated CVs, which for some people is more than enough. But it is not for some others. ICONDA is trying to push their 'semantic side' to something more modern and supported by new technologies and CVs. For instance, the ICONDA agency has started agreements with several countries around the world in order to enrich its terminology; CSTB has started an internal project to extend the capabilities of dictionaries and taxonomies supporting the search process of content-based products, such as their CD-REEF and I-REEF), and so on. Both examples are also looking very closely to the standard-related initiatives aiming at capitalising on them.

5 Conclusions

Communication is about exchanging signs. Humans are able to use words, body gestures, images, etc.. Jargon is often used inside a given community and those not belonging to this community *will* have problems to communicate. If we are to be clear and unambiguous, we must 'control' the vocabulary we are using in communication. Only parties knowing the words and their meanings are equipped to engage in communication free from misunderstanding. When it comes to computer-based communication, this is even more crucial since computers cannot establish dialogues in order to know elucidate precisely 'what is meant by that'. The conceptual approach to handle this situation often relies on the adoption of formal CVs (as much as possible) which help define the universe of discourse (the working context) of those involved in the communication process.

Several examples can be found around the world, coming from very different initiatives ranging from industrial support to feasibility projects funded by research programs. Results are emerging; education is gaining a new status in the European scene for several reasons, including European policies, businesses profit, and natural evolution of the area. LexiCon and BARBI (two implementations of ISO

[57] Authors are intentionally avoiding to identify the initiative, for obvious reasons.

12006) have joined forces; IFCs are becoming the standard supporting the inevitable BIM concept; IFD is attracting worldwide attention, and governments have published policies that directly or indirectly enforce the adoption of shared CVs and semantic-related resources. This is the future path we are called to – with no acceptable excuses and no other choice in moving forward.

Recalling McGuiness (and adapting her sayings to our context), *an ontology (or CV) is required when there is a need to communicate/exchange (transfer and/or share) various sorts of information where the meaning is fundamental. Ontology (CV) is also useful when the reuse of existing knowledge is required. From a non-exhaustive list of uses, an ontology (CV) can be used for simple kinds of consistency checking, interoperability support, validation and verification testing, configuration support, help to perform structured, comparative and customised search as well as to exploit generalisation/specialisation of information* [7]. This means whenever we must communicate precisely, our vocabulary must be controlled, our jargon must be shared and meaningful, and our semantics must be refined for the sake of the communication process. This is the mission behind the development and use of CVs in the Construction sector. This is the justification for proposing, developing, and assessing CVs. This is the quest that keeps the authors of this paper involved in this field. Results are still in their infancy, but they are promising and exciting, and hold the key to the future.

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Technology for Collaborative Engineering

Supporting Collaborative Engineering Using an Intelligent Web Service Middleware

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Abstract. Collaborative Engineering tasks are difficult to manage and involve a high amount of risk – as such, CE tasks generally involve only well-known pre-established relationships. Such collaborations are generally quite static and do not allow for dynamic reactions to changes in the environment. Furthermore, not all optimal resource providers can be utilised for the respective tasks as they are potentially unknown.

The TrustCoM project elaborated the means to create and manage Virtual Organisations in a trusted and secure manner integrating different providers on demand. However, TrustCoM focused more on the VO than on the participant. The BREIN project enhances the *intelligence* of such VO systems to support even providers with little business expertise and provide them with capabilities to optimise their performance.

This paper analyses the capabilities of current VO frameworks on the example of TrustCoM and identifies the gaps from the participant's perspective. It then shows how BREIN addresses these gaps.

Keywords. Virtual Organisations, TrustCoM Project, BREIN Project, Service Oriented Architecture, Artificial Intelligence, Grid

1. Introduction

Modern day engineering tasks typically demand a complexity not supported by individual companies – accordingly, enterprises join in collaborations to outsource and distribute tasks according to the tasks that need to be fulfilled. Such collaborations are normally difficult to manage considering their size and complexity.

In recent years, the concept of Virtual Organisations has been developed to describe such collaborations *on basis of resources exposed to the internet*. Following the grid concept, such organisations allow for managed and dynamic collaboration between different resource *types*, or in other words to enable transactions between different companies in a coordinated manner.

The TrustCoM project has delivered a framework, as well as a reference implementation that enables organised and contract managed collaborations in a secure and trusted manner. Even though TrustCoM principally allows for dynamic on-demand creation of Virtual Organisations, as well as their autonomous management according to predefined collaboration description, the project does not support all issues to ensure full uptake by the eBusiness community.

This paper examines TrustCoM in view of one its particular application scenarios, namely the "CE scenario", in which different companies participate in a Virtual Organisation to adapt an airplane according to a specific customer's personal requirements. Basing on this scenario, we will examine in how far TrustCoM actually supports the individual participants in their task of supporting the VO requirements and thereupon elaborate the gaps that the recently started IP project BREIN is addressing.

2. An Assured Environment for Collaborative Engineering: The TrustCoM Approach

The main goal of the TrustCoM project consisted in providing a framework that would allow integration of any type of resource provider to form collaborations that meet specific business needs and goals. The framework makes extensive use of web service standards so as to allow common uptake from both larger and smaller companies, respectively individuals.

The framework ensures that all transactions within the Virtual Organisation are secured and that confidentiality issues are fully respected so that partners may remain anonymous, if so desired. Furthermore, as shall be detailed below, it allows participants to maintain their own infrastructure and their own means to realise the "products" they provide to a collaborative engineering task.

As one of the first projects, TrustCoM also extensively researched the influence and relationship of *legal* and *trust* issues on framework specific structures and its implementation. As such, TrustCoM allows for contractual support as well as selection of partners on basis of their performance in other collaborative tasks.

Contractual performance is enforced through means of Service Level Agreements that monitor behaviour and evaluate it with respect to the contractual agreements. Accordingly lacking performance can be identified in time and dealt with accordingly – depending on the overall requirements, this can consist in applying fines or even complete replacement of the partner, if lacking performance is considered critical for the full execution of the collaborative tasks.

For more details on the framework structure as realised by the TrustCoM project, please refer to [1].

2.1 "Abstract Entities"

TrustCoM's main achievement in bringing Virtual Organisations closer to modern day business needs consisted in particular in introducing the concepts of "abstract entities" to the Grid and Web Services community. As opposed to the classical approach, where each actual resource as maintained by the individual enterprises is exposed as a service of its own, be it humans, printers, computers or actual applications and utilities, the "abstract entities" approach foresees that each participant in a Virtual Organisation is actual a *conglomeration* of individual resources that are executed and linked in a coordinated manner.

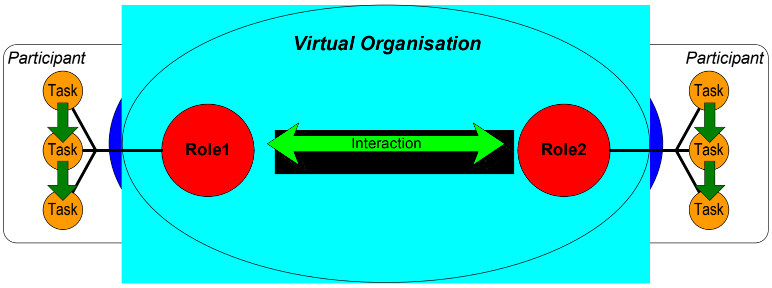

Figure 1. Abstract Entities in TrustCoM's Virtual Organisations

This way, participants are considered *real* business entities, with their own existing typical workflows to generate the "products" they sell and with an infrastructure they do not want to expose to, let alone be controlled by external bodies. From the TrustCoM perspective, enterprises participate in a Virtual Organisation according to the *roles* they bring in rather than according to their *resources*. This respects the first main issues in (electronic) business: the confidentiality of providers' infrastructure and leaving complete control over this in their hands.

2.2 Managing the Virtual Organisation

Classical Grid VO approaches described the whole collaboration as a series of task executed by the individual resources as exposed by the participants. With actual enterprises participating in the Virtual Organisation, i.e. with them representing abstract entities that do not allow manipulation of their individual resources, such an approach is obviously not feasible anymore. Instead, TrustCoM describes the collaboration as interactions between roles in a choreography across organization boundaries as defined e.g. by WS-CDL.

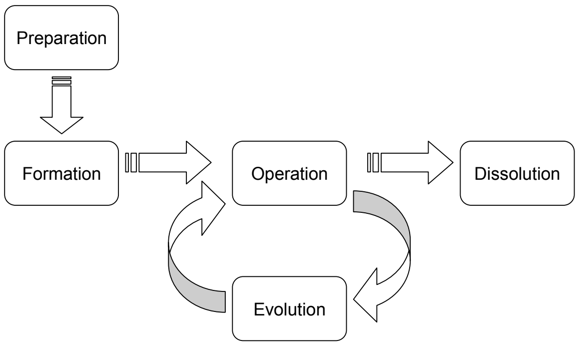

Figure 2. Typical Phases in the VO Lifecylce

Since Virtual Organisations may lose individual participants during execution, be it due to actual loss of connection, due to violation of the contractual terms etc., such a choreography and the according list of role providers needs to be carefully maintained by the Virtual Organisation. To this end, TrustCoM provides the VO

Management structures that manages participants in the collaboration and enacts the relevant tasks to maintain the VO structure, which includes the typical VO lifecycle phases as described by [2] (cf. figure 2).

3. Applying Virtual Organisations: The Collaborative Engineering Scenario

One particular application scenario of the TrustCoM project consisted in an engineering consortium (here "CE VO") collaborating with a team of airplane analysts ("Analysis VO") to support the tasks of an airline manufacturer that e.g. wants to extend the capabilities of an airplane to host internet capabilities on-flight to fulfil customer demands (cf. figure 3). It has to be noted here, that the so-called VOs in this scenario are actually the "abstract entities" as described in the preceding section, i.e. (smaller) collaborations that exist prior to the actual VO as supported by the TrustCoM framework and that only adapted minimally to the according customer needs. For more details on the legal impacts of such an approach, please refer to [4].

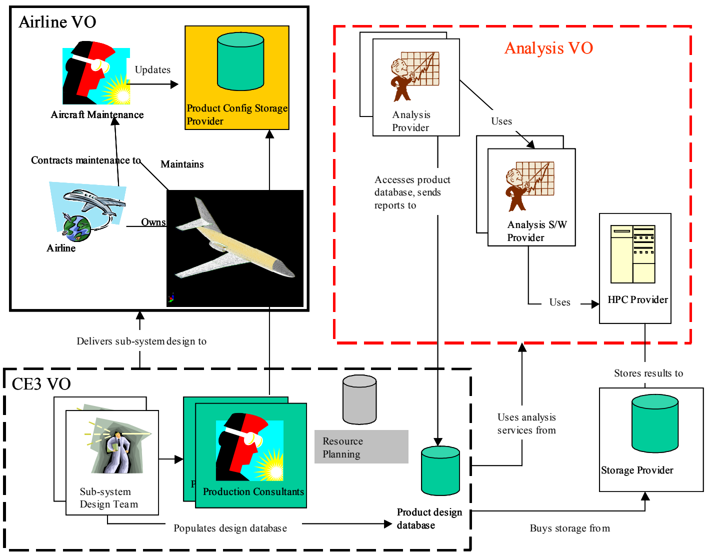

Figure 3. Actors in TrustCoM's CE Scenario

Beside the support to manage the lifecycle of a VO the main issue here is that the TrustCoM framework allows for such collaboration by providing a secure and contract managed middleware that enables the individual participants to expose "virtual" resources that reflect the capabilities of the respective "local" and private business processes. The framework provides participants with a means to host such an interface that secures message exchange, controls access according to the overall collaboration description and ensures that the according transaction requirements are met and automatically updated. From the individual participant's perspective, interactions take place as with a single entity, non-regarding the changes in the VO structure. What is more, none of the participants needs to take over responsibility for any other entity, but itself.

This reduces the management overhead typically associated with such scenarios greatly. This scenario has also been thoroughly discussed in [3].

4. Ready for eBusiness 2010?

TrustCoM provides all the relevant features to relieve business providers from the burden of complex and in particular costly adaptations of the infrastructure to meet individual customer's demands and to maintain security and accress right restrictions. It also ensures that dynamicity is maintained without impact on the individual participants and that the risk of participation is reduced through means of contractual binding, sensible responsibility distribution and SLA support.

However, TrustCoM can not relieve the participants from the burden to *understand* the system and to prepare their infrastructures so as to meet the TrustCoM requirements. As such, business ("role") providers need to understand the Service Level Agreement language, as well as describe the link between those and their resource capabilities. They need to be capable of reading and understanding the policy descriptions they subscribe to as part of their contracts. They need to describe and set up their infrastructure so that it can interface a business process engine which in turn is exposed to the VO. Furthermore customers wanting to exploit the TrustCoM framework need to have great knowledge about collaborations so as to form the initial collaboration description and specify the requirements with respect to the individual participants.

Since furthermore the TrustCoM system does currently not support any intelligent matching, it takes a unique way of describing service capabilities to ensure that the exposed functionalities match the ones described in the collaboration description.

As such TrustCoM must be regarded as a great step towards providing business providers with a framework that supports their business needs from a *technical* perspective, yet as such it could not cater for specific needs that would allow "business agnostic" providers easy integration into the system. With smaller to medium enterprises in particular focus of the Virtual Organisation goals, the TrustCoM middleware runs the risk of being yet too complicated for fast uptake, non-regarding the simplifications achieved by this project.

TrustCoM can hence only be an intermediary step towards reaching the actual end-user, be it SME "role provider" or customer.

5. Filling in the Gaps: The BREIN Approach

The BREIN project is loosely coupled to TrustCoM and extends the achievements of the latter with a particular focus on the *human* behind the system. It pursues three main goals:

- supporting the business providers in all tasks related to exposing and integrating his/her capabilities into a Virtual Organisation.
- supporting the customer in getting the capabilities and services he/she needs.
- optimising the behaviour of both the whole VO *and* the individual partcipant in a way that respects everybody's demands without disrespecting according corporate policies.

As such, BREIN is one of the first IP projects to address the *whole* requirements of enterprises to participate in Virtual Organisations (cf. figure 4), i.e. by enhancing the pure technical level according to *human* needs. As opposed to TrustCoM, the project does *not* look into the legal aspects involved in VO enactment and does not intend to extend the issues related to measuring individual participant's trustworthiness. With this respect it builds upon existing results (such as by TrustCoM).

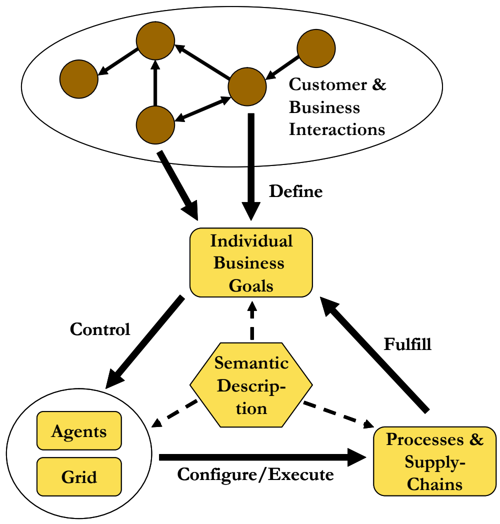

Figure 4. An overview over the technologies in the BREIN project

5.1 The BREIN Framework

The BREIN framework builds strongly upon Web Service technologies and incorporates existing VO middleware solutions, as well as communication standards and specifications that promise or already found wide acceptance by the research and eBusiness community. Thus, it will realise a Service Oriented Architecture that integrates the most relevant aspects related to supporting and realising Virtual Organisations.

With a significant relationship between Grid and Agent technologies [5] the BREIN project focuses on extending common grid technologies with the autonomy and negotiation capabilities of Multi-Agent approaches and thus implicitly extending Multi-Agent technologies with the stability and reliability of the Grid. With respect to modern day eBusiness requirements, the BREIN consortium identified in particular the following technical areas as most important for future VO middleware needs (cf. figure 5):

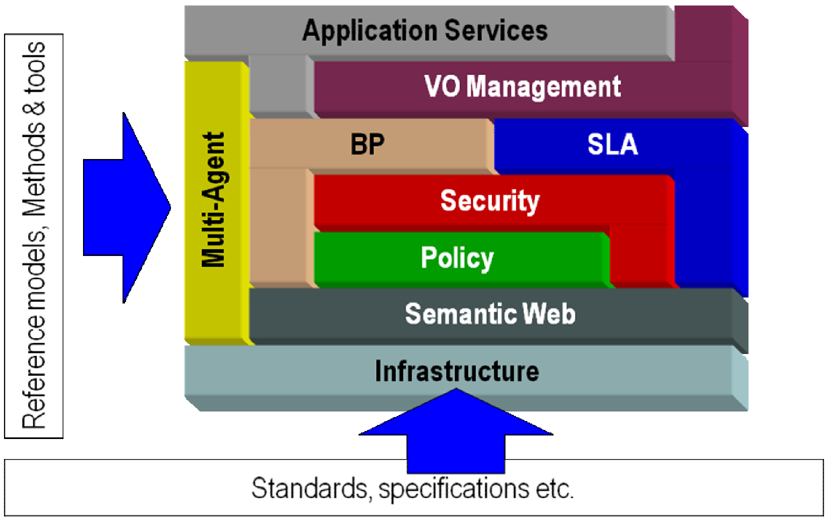

Figure 5. Framework structure of the BREIN project

Infrastructure capabilities represent the most classical Grid functionalities, namely to allow for standardised messaging in different formats, as well as the encapsulation and publication of service capabilities (cf. section 2.1 “Abstract Entities”). The full VO middleware is based upon such infrastructure capabilities to provide a common messaging platform.

Semantic Web technologies ensure that information *about* participants and their products are commonly understood, even though their details (such as capabilities) are defined by humans and as such subject to great variations between each other. This also allows more flexibility in defining and understanding terms. Semantic Web technologies are therefore part of the common middleware basis.

The term *Policies* is generally defined in different ways – in the context of VO capabilities, it covers general behavioural policies for the VO on the one hand, as well as the individual participants on the other. This involves issues such as business goals, but also event-condition-actions to allow for the respective dynamicity. In addition to this, a policy may state access right details, i.e. which entities to admit and which to reject.

Accordingly, *Security* builds partially upon the policy capabilities but also covers aspects related to authentication (to enable access right policies) as well as message encryption to ensure integrity and privacy. Obviously, security capabilities are crucial to most collaborations.

Business Processing covers aspects related to executing individual (“private”) workflows [6], as well as the coordination of the overall workflow execution, i.e. the main collaborative tasks.

Service Level Agreements (SLA) describe terms and conditions related to contractual clauses with a particular focus on monitoring and enforcing these. SLAs map between common contractual terms and verifiable status information.

VO Management represents basically the supervising capabilities of the Virtual Organisation, such as ensuring that all contact points are up-to-date, that the contractual basis is maintained etc.

Multi Agent technologies serve mostly as a conceptual input as the respective technologies have not (yet) found wide uptake in the eBusiness community. For the BREIN project they serve as means to making the individual components more capable of taking decisions (such as protocol usage) autonomously (cf. above).

5.2 CE Scenario Revisited

With the enhancements as pursued by the BREIN project, scenarios such as the Collaborative Engineering one described above will profit very much from both provider as well as customer perspective:

- customer and provider may describe their requirements, respectively their capabilities in a more abstract way
  This way, no additional background knowledge about the underlying common language model needs to be acquired and participants can expose and make use of functionalities in their own way. This allows in particular integrating providers according to their capabilities, rather than having to respect interoperability issues.
- business processes and collaboration may be described in a more intuitive manner with only limited business expertise, collaboration details are derived automatically from capabilities and requirements
  Since complex engineering processes are difficult to design and require expertise in particular to optimise the execution, such an approach allows providers to implement and realise new services more effectively. Given the business processes and the requirements / capability descriptions, the BREIN framework furthermore supports the design process in a way that allows customers to define complex collaborations more easily
- contract details are (more) human readable
- the collaboration is capable to adapt to changes in the environment in a more autonomous manner
  With the intelligence to monitor and integrate environmental information, participants in the VO are enabled to react more quickly and effectively. This may involve both changes on the local infrastructure side (such as limited resources) as well as external effects (such as additional customer requirements).

Given the capabilities, the BREIN framework will allow participants to generate and integrate their services more efficiently with less effort. From the CE perspective, this allows in particular to realize more complex engineering tasks without the additional effort of having to “understand” the system first.

6. Summary & Conclusion

The paper has shown that the Collaborative Engineering scenarios can gain much from the current progress being made in Virtual Organisation research: not only does it allow to reduce risk and adaptation cost, it also allows more flexibility and easier integration into collaborations.

Great progress has been made over the recent year to achieve this goal by such projects like TrustCoM which furthermore laid the basis for integrating legal and trust aspects. Reference implementation and demonstrations have shown that the vision of dynamic Virtual Organisations on an internet / network basis *are* possible indeed and will form the future of eBusiness.

However, the approaches so far still show great inflexibility with respect to human specific needs, in particular where such complex issues such as business objectives are concerned. And even though deployment and administration of such middleware becomes more and more easy, the actual usage is still restricted to technically educated engineers with the according knowledge.

One step in overcoming these obstacles is taken by the BREIN project which integrates Agent, Semantics and Web Service technologies with VO middleware to provide the necessary flexibility that brings eBusiness closer to the modern market.

Acknowledgements

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Research on Concepts and Technologies of Grid Collaborative Designing to Supporting Cross Enterprises Collaboration

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Abstract. The original Cross Enterprises Grid Collaborative Designing System could not meet industrial demands on dynamic sharing of various and transient manufacturing resources and collaboration due to their inherent weakness. The concept of collaborative designing technology under the guidance of Grid theory based on the principle of facing to business users, supporting "Integration on Demands" and "Instantaneous Integration." During application integrating process, Business-driven Grid technology breaks the barriers between computer experts, domain experts, business designers and business executants, and supports instantaneous integration. Unlike traditional network collaborative design technology, Resources is integrated instantly according to the directives of its business users, and thus comes the concept Grid Collaborative Designing. This paper analyzes the different between manufacturing and computing resources, gives the definition, connotation and the problem which Grid Collaborative Designing attempt to solve, discusses the differences and similarities between Grid Collaborative Designing and other related technologies, analyzes the limitation of traditional technology supporting cross-enterprise collaboration. At last an architecture of WSRF based OGSA is yielded, it encapsulate manufacturing resources into services using WSDL description, services mapping and deploying method, and the core research issues in Grid Collaborative Designing are submitted and the related technologies are summarized.

Keywords. Grid Collaborative Designing ,Grid Computing, Web-based Manufacturing, Web Service.

1 Instructions

The modern complicated products are an achievement of using multi-field knowledge, usually involve the knowledge in fields such as electromechanics, hydraulic pressure, control, information,etc.. In today in high development such as information technology, how about be under the assisting of computer, integrate the design knowledge in the multi-disciplinary field effectively, it is the key point that the products succeed in designing. And single enterprise rely on oneself only

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resource and ability meet its product design's demands alone while being very difficult, with the increase collaboration among enterprises, more and more enterprises have already realized that realize the necessities of information sharing, resource-sharing among enterprises through Internet, on the basis of to design with manufacture system because of inherent weakness their in coordination Web a traditional one, make it unable to deal with the environment of the dynamic change, especially can't deal with the sharing of instantaneous resources.

Appearance of Grid, design, exploits resources, innovate and design offering new theory and infrastructure. Grid can realize the virtualization of many kinds of distributedly computing resources, such as handling the course, memory capacity, data and network broadband, thus establish a single fictitious system, offering for users and applications to a large number of IT functions visiting that has not sewn. The concept of the Grid has already been applied to a lot of fields such as calculation, astronomy, biology information, and intensive in calculation, intensive application of data, such as Globus[1], SETI2@home[2],Global Grid Forum[3], European Union (EU)DataGrid[4], so many research projects have got application. In order to satisfy and realize fundamentally the demand of solving in dynamic resource-sharing and question among the cooperative enterprises of the dynamic change, the concept of the Grid Collaborative Designing rises in the field of product design. In order to explain the feasibility of the Grid Collaborative Designing in the manufacturing field, this paper is yielded an architecture of WSRF based OGSA, it encapsulate manufacturing resources into services using WSDL description, services mapping and deploying method, and the core research issues in Grid Collaborative Designing are submitted and the related technologies are summarized.

2 The characteristic of the manufacturing resource

Manufacturing resources is that enterprises finish the general name of the physical elements of activities in production of whole lifespan of the products, can include material resource, information resources, technological resource, human resources, fund resource,etc. comprehensive resource inclusive, for instance the apparatus, processing tool, extensive application software, design resources bank,etc.. On design phase, manufacturing resources including various design tools, for instance various application software such as CAD, PDM, FEA; Products data existing with various forms; And other various relevant information,etc. such as customer's demand. Computing resources include CPU, Memory, Data, Software, and distributed system,etc[5].. Manufacturing resources in the form of existing, management style, etc. have characteristic that is different from computing resources.

There are a large number of physical resources in manufacturing resources. These resources must solve the virtual problem at first□if they want to share through the Grid. The virtual source of so-called resource means that releases the functionality and handles these functions from the particular physical apparatus, include a lot of mechanism and technology which slacken those frameworks and users and perceive behavioral from physics realizing of resources of software and hardware [6]. On the manufacturing field, realizing the foundation facing integration of enterprise served virtually of resources, through fictitious to turn Web service realize in resource of environment entity[7].

On the management style, manufacturing resources have the same characteristics with computing resources. If distributed in different organizations of different regions, the owner of resources has top administration authority to their resources, all dispersible resource owner determine according to one's own condition whether to share his resource at the Grid, make dynamic change of quantity of resources at the whole net, meanwhile, because the fast changes of market and the change of peripheral economy, the political environment, dispersible resource requirement person's demand for resources in the region is dynamic change too, this causes resources shared to have very obvious distribution and dynamic characteristic.

3 Definition of Grid Collaborative Designing and key problem

3.1 Grid Collaborative Designing

It means under computer support, every member focus on a design object to design in coordination, undertake the design task of the corresponding part, carry on the design work alternately, get the design result design method according with designing requirement finally. The basic goal of the Grid Collaborative Designing is that the intelligence share, resource-sharing, aim at based on resource-sharing of material, for instance resource-sharing of software, resource-sharing of apparatus,etc.; Be distributed in different fields through the network, the organization stand up organically on the intelligence resources of different trade or different specialty, synthesize each side's advantage, improve the whole design level of the products. Collaborative Designing has characteristic that cooperates on a large scale, i.e. the disperse of the mutual colony's region range, the different constructing of the environment, the extension of business and discipline domain, variety of information,etc.. So the research on Grid Collaborative involve a lot of respects, mainly include system integration and information sharing, the negotiation and clearing up of the conflict question, collaborative and exchange, organization and management of knowledge,etc.

The Grid Collaborative Designing regards the Grid as the infrastructure, it based on the principle of facing to business users, supporting "Integration on Demands" and "Instantaneous Integration." It collaborates and organize a lot of design units, business-driven Grid technology breaks the barriers between computer experts, domain experts, business designers and business executants, and supports instantaneous integration. It fully utilize the computing resources of the Grid, data resources, the service,etc., resources is integrated instantly according to the directives of its business users, and thus comes the concept Grid Collaborative Designing, use field knowledge to make policy in coordination, output the comprehensive course of the products. Supported by Grid. Users use the resources on Internet like using local resources synthetically. Users will design the task to be referred to the door, the task will be assigned to corresponding resources to finish through the course of task decompose and resources mapping.

3.2 Key problem of Grid Collaborative Designing.

The Grid Collaborative Designing utilizes net and relevant advanced computers and information technologies, to realize the resource-sharing in the net and the collaborative designing question to ask and solve. In order to realize this goal, on the basis of grid computing research, fully consider the characteristic of the manufacturing industry, study and solve the key technology of the manufacturing operations characteristic, design the grid framework suitable for manufacture resource sharing and product collaborative designing, develop one the middle the application facing manufacturing field, construct the grid collaborative designing system which meets the demand characteristic of manufacturing operations.

Grid framework

After several years of research and practice, the grid technology system structure has been already mature day by day. In the abstract structural level, the most important and most representative one is the structure of five layers of sand filters[8]; In 2002, GGF propose Open Grid Services Architecture[9] [10]. In OGSA frame, it make everything abstract into service, including the computer, the procedure, the data, instrument and equipment,etc.. this kind of idea help to manage and use the grid by unified standard interface[11].

But traditional computing grid or general service grid framework can't be totally competent at manufacturing grid. First of all, manufacturing resources is disperse, mutual and complicated, and its operation is not always automatic, which make it more complicated and challenge to set up the grid of manufacturing service. Second, the traditional computing grid lays particular emphasis on solving computing question on a large scale, it is often a comparatively simple calculation task that its homework is submitted. There is a lot concrete complicated business treatment not computing in the grid to deal with, which have the characteristic of long periodicity, complexity, flexibility and cross-organizing collaborative with,etc.; Third, the nodal institutional framework of manufacturing grid is complicated, consider fully considering nodal autonomy in the design, the sense of organization, adapt to the need of the construction of the grid, expand and the business operate.

Manufacturing resources modeling and encapsulation of resources

Manufacturing resources modeling is an important basic work in manufacturing grid research. It needs to study and manufacturing grid resource-sharing implementation method, especially the systems approach to realize resource-sharing under facing the service framework at first, show resources, resources encapsulate and the resource scheduling are made into the whole consideration; Need to study the expression model which makes resources emphatically, can contain different types of manufacture resources, solve the problems of the various types and different shapes, at the same time considerate the demands on resource find and match; Study the encapsulation of resources and virtual on this basis, solve the manufacture resources of a large number of physics, encapsulate in appropriate form, become the problem that can visit resources on the network.

Deployment and job management of the Grid Service

The main business form of the grid collaborative designing is cross organizations collaborative homework of fictitious enterprise's modes ,except what a resource that deployment dispersed in different organizations is needed to consider, and to the procedure dynamics of the homework and uncertain support among them; Meanwhile, it designs to be one trends and confirmed course in coordination, it carry out course distribute until by different to construct and among the distributed environment that independent enterprise form, customer's enterprises need to control and coordinate the manufacture process. Consider the characteristic of application of net, study how to provide convenience, the modeling tool of flexibility, dynamic choice is served and tied and served definitely to combine, make resource noumenonn, come on, solve and serve and make the dynamics problem up, design and realize the net homework administrative system, deployment of resources while supporting the homework to carry out.

4 Grid Collaborative Designing And other Network Technology

The grid collaborative designing system can be regarded as the distributed system finished the particular task through cooperating each other by a lot of independent nodes. And the grid computing system is a kind of information technology infrastructure formed by hardware and software, in a dynamic and distributed virtual organization, offering reliable, coordinate, expanding and low-priced resources sharing and collaborative. Dispersible all kinds of construct resources differently and serve as fictitious whole through the grid in geography, realize computing resources, store resources, the resources of the data, information resources, knowledge resource, overall sharing of expert resources. The grid service has broken the traditional sharing or collaborative restriction, the sharing to resources often stayed in the level of file transfer of data in the past, and the sharing of net resource allows to directly control other resources, and each side of the shared resource can exchange information in many ways while cooperating, utilize grid technology to well solve the dynamic deployment of the design task in the design, questions such as the sharing and analyzing and calculating collaborative of distributed knowledge,etc., help to further accelerate the design process of the products.

Grid collaborative designing offer an integration sustain environment for the integration and share for the enterprises and social resources, collaborative designing among enterprises and management. Through integrating and encapsulating the dynamic design information dispersed in different enterprises, resources of production and products all other information and resource in lifespan, hide these details of manufacturing resources, and present it to users in form of operating. Collaborative grid designing share and optimize belong to the manufacture resources of different organizations, utilize the standard, open, common agreement and interface come to meet single enterprises demands on resources share and collaborative designing question. Its' core question is to coordinate the manufacturing resources share and designing solve. The sharing here is not the file exchanging in the past, but visiting the computer, software, data and other devices more directly, on the demands of collaborative designing question ask and resources agent policy which appear in the fields of the enterprises ,science and project.

Web service passes standard Web agreement in a manner to independent of the platform, is logic unit of application program[12], that can be visited by the procedure. Outwardly, Web service is a application program, it exposes one API that can be transferred to the external world through Web, the programmer transfers this application program by Web. Meanwhile, because Web services structure is consider extensively one contractual mutual method of the distributed software, Web service offer the standard working technique[13] each other while operating different application software on various platforms and/or frames. It can use Web service to solve the distributed computing problem of nonstructural differently.

The grid service is a kind of special Web services. It including lasting service and instant service, joining the dynamic information at the same time, to meet grid system's demands. With the constant development of grid technology and Web service technology, especially the introduction of Web services resources frames (WSRF), have accelerated the integration of grid technology and Web services. Resources are defined as the one with the state in WSRF, but the service is no state. For manufacturing resources, each resource regard as one reliable service that can be added or deleted in grid at any time. The essence difference of collaborative designing grid with the web service in the past lies in dealing with dynamic resource in coordination. The grid technology not only can share permanent resources, but also share instantaneous resources, which has solved the sharing problem of manufacturing resources dynamically fundamentally.

5 The system of Across Enterprises Grid Collaborative Designing

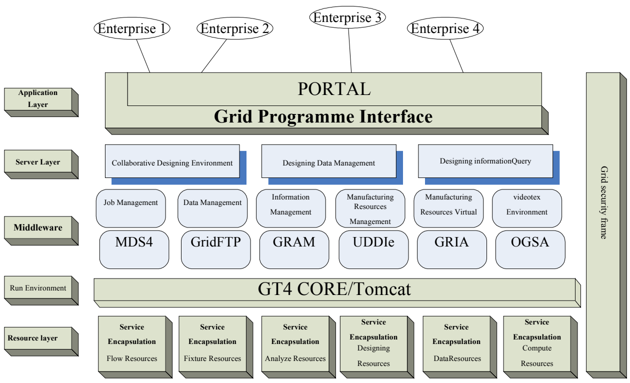

Fig. 1. The system of Across Enterprises Grid Collaborative Designing

This paper provides a kind of support across the grid system structure which enterprises design, as shown in Fig. 1. This structure is adopted on the basis of facing service , follow OGSA normal hierarchical structure set up. Encapsulate for Web service and register and form its storey of resource in the net from dispersible manufacture resources. Utilize GT4 CORE / Tomcat / Axis put up environment operate, it waits to be comparatively ripe one under grid as the foundation at present with piece to GRIA that industrial circle employ, dispose MDS4, GridFTP, GRAM, OGSA-DAI, UDDIe,etc. construct the back-up environment of ground floor based on kernel service, offer resource management, data transmission, scheduling of resource, different core of constructing nets such as the access to data,etc. to support the function; Under the support of a technology between the design, shield the different resources that constructed of ground floor, support the realization that the net of design employed in coordination of the fictitious organization's mode.

Resource layer

The resource layer is gathering layer of all kinds of resources, including the organizations of all kinds of data, knowledge and some logic deal with, even including relevant designers and apparatus. These manufacturing resources are offered by the enterprises participated in the grid collaborative designing, these resources carry on the packaging in form of serving, ones that finished resources are virtual, to the resource type of manufacturing field and characteristic of describing, offer different kinds of encapsulation models to encapsulate them.

Resource of physics can be used by grid only after encapsulating. So main job of resource layers is virtual. Resource can have two way while being virtual, first to express as resource standard Web service by provider of resource, until sharing of resource use, turn into to request that Web serve correctly, resource taken to serve dispose at resource night host computer of provider. Another kind of encapsulate, accord with WSRF normal service (abbreviate as WSRF serve) as one, concrete manufacture as a resource registration that WSRF serve this resource, and the WSRF serve, can register get net service registration center too, equivalent to one " container" of resource; Each kind of resource has offered one to encapsulate the template, the resource provider can download this model, use it to encapsulate a kind of manufacture resource, it can already be in order to register the resources containers that entered to encapsulate good resources on the resource provider's local constellation host computer, can pass the net Portal to public resource container registration too.

Grid Middleware

Distributed because of different constructing and wide area manufacturing resources, these resources belong to different enterprises at the same time, it is difficult to apply in net directly, so it need the corresponding software system to dispel the difference between the systems joint differently, realize the unified management of the whole net resource. Each research institution in the world has carried on a large amount of research in such aspects of system structure of grid , Grid middleware, agreement, programming running environment. And it has developed some middleware tools and frame, such as Globus, Condor-G, Storage Resource Broker, DataCutter, Legion, Cactus and common framework. These research results establish the foundation for designing the implementation of grid collaborative designing intermediate.

Design Middleware

The upper strata of one the middle the net are to face each the middle the design that is designed in coordination, include some special-purpose services that are developed in the middleware, core to the manufacturing field on a foundation among them, in order to support the application that is designed in the net together, among them mainly include setting up in job management, data management, grid information management, manufacturing resources management, virtual tool of resource and visual environmental foundation of grid, in coordination with the design environment, designing data management, designing the information management,etc.

Application Layer

Employ layer offer interface of contents of grid, which is the aspect that ordinary users can perceive. It including the door entry based on Web and application interface using the interface of the net service to develop among other systems. Application layers of user needn't understand that design the structure of ground floor of the net in coordination.

6 Conclusions

Through integrating and sharing of manufacturing resources, grid technology will bring the prominent advantage to manufacturing industry. Design research and application of the grid present the good development trend in coordination. However, grid collaborative designing is still a new developing field, its research is at the starting stage at present, no matter theoretical research or application is not ripe. This paper encapsulate manufacturing resources into services using WSDL description, services mapping and deploying method. It give a reference model of grid collaborative designing, to solve the main problem of the research on the grid collaborative designing, make the net widely used in the business circles in coordination with designing technique.

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PEGASE: a prototype of software to manage design system in a collaborative design environment

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Abstract. The control of the design process requires to take into account three narrowly overlapping dimensions relating to the product, as an object to be defined, the process, as a generator of this object and finally the organization. Within the framework of the work undertaken during the IPPOP project, an integrated model was proposed with a view to development of a prototype of software. We are interested here in the software tool which can be brought to the actors to manage design process by correlating the organization of the company and the definition of product development process with the structure of the design projects and the control of the real process. This tool is materialized by the development of the PEGASE software for which we present an application inspired of an industrial case study in SME.

Keywords. Design organization, design control, performance management, prototype of software.

1 Introduction

Today, to increase performance in design, companies must not only control the design process but also manage the design system. Finalities of design management are to improve the performance of the company and to bring it reactivity to the evolutions of customers' waiting and to the constraints of the market. Control of the design system obliges to be able to understand and evaluate the design process, in particular the activities which make it up but also the context of the design. Thus, the evaluation of the design must propose a whole of elements of measurement, identified thanks to a model of the system, to provide relevant information to ensure a coherent decision-making in comparison with the real state of the system. Difficulty will be in the modelling of the system for its evaluation. Concerning the design process, it is necessary to be focused on the definition of the product and its evolution, on the objectives of design constrained by the

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organization of the company [1] but also on the factors that influence the system as technologies, human resources and physical implementations [2]. Considering this viewpoint and the integrated model defined during the IPPOP project [3], Robin *et al.* proposed a model to evaluate the design system [4], a methodology to implement this model and a prototype of software to assist design actors (PEGASE) to make operational this methodology [5]. In this paper, we present some results of the IPPOP project and we focus more particularly on the software application PEGASE. The first part of the paper describes the integrated product – process – organization model of IPPOP project. On the basis of this model we propose then a detailed presentation of PEGASE, a prototype of software supporting actors all along design project. We show how the prototype makes it possible to model and to follow-up the evolution of the design system but also to create a project and to follow-up its progress.

2 The IPPOP integrated product–process–organization model

Our propositions to manage the design process are based on the results obtained during the IPPOP project (Integration of Product, Process and Organization to improve the Performance in design) [3]. This RNTL project (Reseau National des Technologies Logicielles) has been financed by the French Ministry of the Economy, Finances and Industry, between December 2001 and June 2005. It regrouped five academic partners (LAPS and LMP, University Bordeaux 1; L3S, INP Grenoble; LASMIS, UT Troyes; CRAN, University Nancy 1) and four industrial partners (EADS-CCR, ALSTOM Motors, Open CASCADE, ESTIA-Innovation). One of the principal objectives was to formalize a model integrating three complementary dimensions: the modelling of the product, the modelling of the design process and the modelling of the organization where this process proceeds [6] (Figure 1). This model constitutes the core of a collaborative environment having to make it possible to the actors to control the design process and to be inter-connected with the existing applications (XAO tools, PLM systems...). In this context a methodology and a prototype of software supporting the methodology (PEGASE) were developed [5]. Prototype makes it possible:

- to correlate the organization of the company and the structure of the project,
- to structure the project and to plan the design process by integrating performance indicators concerning product, process and organization,
- to ensure the follow-up of the project thanks to this integration and these performance indicators.

To implement this model and to allow the effective control of the design projects, the company, its organization and its resources have to be described. Following section details the development phase of PEGASE based on an analysis of the design process and of the mechanisms of decision-making throughout the product development. A presentation of the prototype of software is also provided.

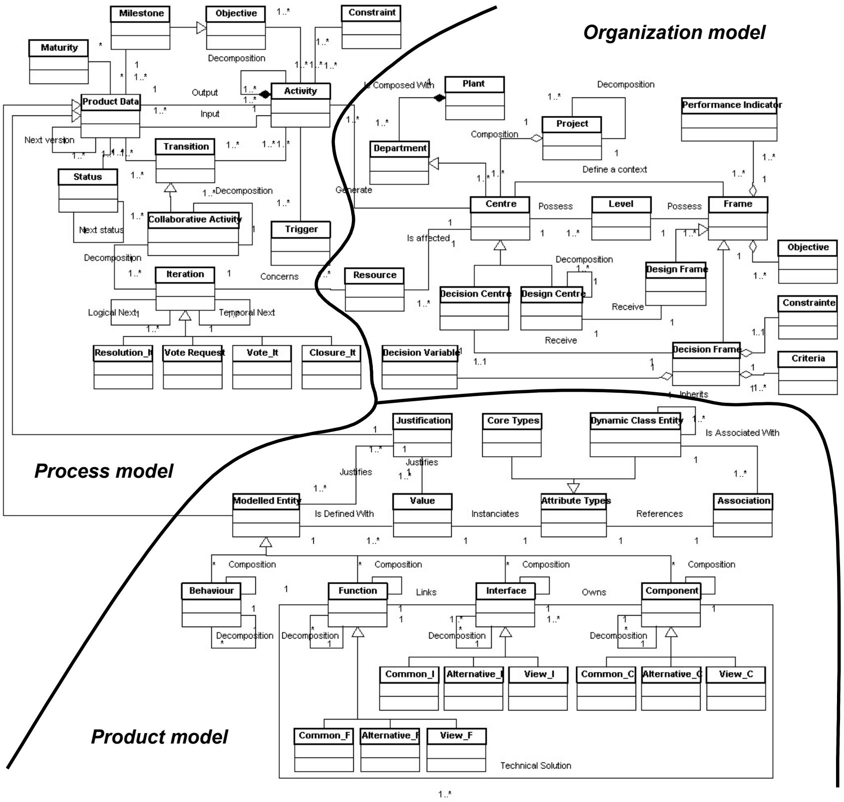

Figure 1. Integrated product – process – organization model of the IPPOP project

3 PEGASE: a prototype of software to control design project

3.1 Presentation of PEGASE

According to the concepts and the models suggested in the IPPOP project we developed a prototype of software to support actors during a design project: PEGASE. To ensure that our prototype respects criterion of conformity, reliability, safety, dimensioning and maintainability [7], the design phase was based on concepts proposed by the creators of UML language [8]. This choice is justified by the fact that this method is very structuring. Moreover, as we wished that the application either based on the open source principles and easily and quickly usable in network of actors, the Graphical User Interfaces were developed in PHP language. This language is used in the development of Internet websites and offers the advantage of being a script language, not compiled, directly interpreted. Finally, the great number of data to be stored and handle implying the use of a data base. MySQL was retained to manage the data base. The initial objective to which PEGASE must answer is to ensure the connection between the structuring of the organization of the company relating to the design and the control of a design project, such as it is considered in IPPOP project.

3.2 Control the design process thanks to PEGASE

The detailed analysis of design processes and of the mechanisms of decision-making throughout the product development allows identifying elements that have to be managed to control design process [4]. PEGASE has been developed to integrate and manage all these elements. The integration phase concerns the implementation and the configuration of the data base. It is dedicated to the administrator of the system. To manage evolution of the design process, projects have to be structured, planned and resources have to be allocated. This phase is realized by the project manager. Finally, PEGASE controls project evolution by managing the realization of the designers' activities and helping managers to follow-up the project.

In a nutshell, control of the design process thanks to PEGASE results in several actions from the genesis of the project to its closure:

- implementation and configuration of the data base,
- structuring and planning the projects and allocated resources:
  - after the project was initialized and the objectives of the company were specified, the head of project structure his project in order to achieve his goals,
  - he defines several sub-projects for which he specifies the objectives and the persons in charge (as local decision centres),
  - he associates input technical data necessary to the designers to achieve their goals, and output technical data corresponding to the achievement of these objectives,
  - he defines a planning of the activities to be carried out by specifying their technical objectives and their data,
- realize the activities and follow-up the design projects:
  - to allow the follow-up of the project, the designers generate the awaited technical data and valuate the required performance indicators.

These actions associated with the integrated model ensure that the organization of the company, the multilevel management of the projects, the differentiation between the decisions and the transformation of product-process knowledge, the synchronization of informational flows and finally the follow-up of the projects are taken into account.

3.2.1Implementation and configuration of the data base

Within the framework of GRAI R&D approach [9], the modelling of a company makes it possible to formalize its organization (functional decomposition and decisional system) and its technological system (design process). Via an administrator access, the organization is seized within PEGASE (Figure 2). The structure of the decisional system is defined thanks to GRAI R&D grid. Decision centre are identified and their temporal range, their nature and information flows connecting these centres are identified too. This structure is deployed in PEGASE by associating each element of the organization (plant, department, service...) and the corresponding decision centres and by connecting them between specifying information flows (Figure 2). So, the administrator configures information flows which will have to be implemented in the course of project by the various local coordinators implied in order to ensure the coherence of their communication and their decision-makings.

The administrator access also permits to define the whole of the resources: human, material and software. Humans' competencies are also managed and are specified according to competencies matrix of the company. Through the management of their competencies, human resources could be selected during the design projects.

Finally the administrator deploys the design process modelled in the organization by associating to each decision centre the sequences of tasks. This process could be formalized according to the quality procedures of the company. When configuration is completed, PEGASE is operational in order to ensure the control of the design. So, the administrator creates and initializes a project by sending the decision frame and associated design frame to the decision centres concerned in the organization.

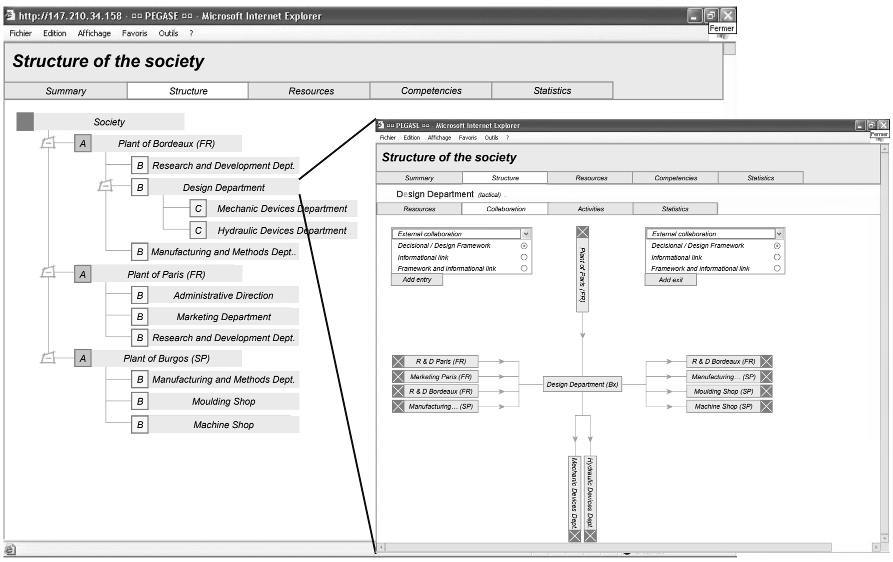

Figure 2. Functional and organizational structure of the company

3.2.2 Structure, plan and follow-up a design project

When the project is initialized, PEGASE systematically informs the users of the new events which relate to them. So each coordinator is informed of his new statute when he is connected. He has information about the organisational structure of the company in order to know the other coordinators with whom collaborations will be established. He is able to reach directly the details of the new project and to reach the decision frame that is sent by the upper decisional level (Figure 3).

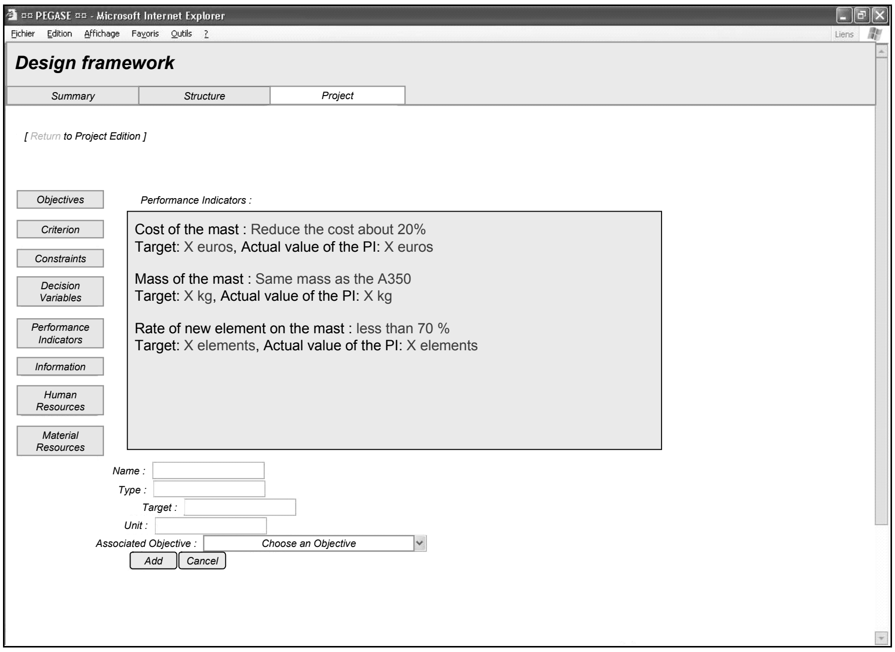

Figure 3. Graphical User Interface to consult the decision frame

The decision frame enables him to know his context of work: his objectives, his criterion and decision variables, his constraints, his performance indicators and the resources which are allocated to achieve his goals regarding to performance indicators. He is then able to begin the phase of control previously structured, assigned and planned. The coordinator has the opportunity to create sub-projects which will be automatically associated to decision centres for the lower decisional level. He defines finally the tasks to be carried out by completing whole or part of the tasks specified by the administrator, or by introducing new tasks depending on the needs for the project. It guarantees the flexibility of the design process evolution during the project. By using the preset informational links, PEGASE informs each new local coordinator of sub-projects and each designer affected to specific tasks of their objectives. Project managers and the designers have the same GUI (Figure 3) to understand the context in which they must carry out their tasks. Difference is that project manager create performance indicators and designer could just complete these indicators. They must, at the end of their task, indicate the values of the performance indicators.

The coordinator is informed of the new values to his next connection. If the indicators don't correspond to the attended values, he analyzes the situation and then could decide: to start new activities, to modify some elements of the decision frame (objectives, constraints, resources...), etc.

4 Synthesis and conclusion

Work reported here constitutes a specific application of the results from IPPOP project in order to make effective the control of the design. The approach suggested is based on an integrated product - process - organization model and on a methodology modelling the design system and structuring, planning and following-up the design projects. This methodology remains however to be validated by an experimentation in a company. PEGASE is a prototype whose first version only takes into account organization and process dimensions. Influences of each element of the design context are considered since functional and decisional structures of the design system are identified and external environment (subcontractors, competitors, customers, etc) is integrated. PEGASE takes part in the project management from the creation of the project to its closure. All the projects of the company could be managed and controlled through the prototype which provides and capitalizes information on the project, on the resources (competencies, availability, etc.) to follow-up evolution of the design system.

Despite, the prototype is perfectible and must be sophisticated. Thus, the product dimension has to be implemented in order to be able to define performance indicators related to the evolution of the technical data. The prototype currently only makes it possible to define indicators manually and it is envisaged thereafter to enrich this functionality by automatisms that permit to identify indicators along the evolution of the process, the product and the organization. Moreover, the taking into account of the material resources for their management is not effective yet and the integration of CO²MED tool [10] – tool for management of collaborations between actors – is also under study. Lastly, the management of the activities only concerns sequential process. The use of workflows technologies such as those existing within the PDM tools should allow a great variety of specification for the managers while providing mechanisms of multilevel synchronization [11].

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A New Ant-based Clustering Algorithm on High Dimensional Data Space

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Abstract. Ant-based clustering due to its flexibility, stigmergic and self-organization has been applied in a variety areas from problems arising in commerce, to circuit design, and to text-mining, etc. A new ant-based clustering method named AMC algorithm has been presented in this paper. Firstly, an artificial ant movement(AM) model is presented; secondly, the new ant clustering algorithm has been constructed based on AM model. In this algorithm, each ant is treated as an agent to represent a data object, each ant has two states: resting state and moving state. The ant's state is controlled by two predefined functions. By moving dynamically, the ants form different subgroups adaptively, and consequently the whole ant group dynamically self-organized into distinctive and independent subgroups within which highly similar ants are closely connected. This algorithm can be accelerated by the use of a global memory bank, increasing radius of perception and density-based 'look ahead' method for each agent. Experimental results show that the AMC algorithm is much superior to other ant clustering methods. It is adaptive, robust and efficient, and achieves high autonomy, simplicity and efficiency. It is suitable for solving high dimensional and complicated clustering problems.

Keywords. Ant-based heuristic, clustering, high-dimensional data space.

1. Introduction

Clustering analysis is an important method in data mining. It is a discovery process that groups a set of data such that the intra-cluster similarity is maximized and the inter[60]-cluster similarity is minimized. Clustering of data in a large dimension space is of a great interest in many data mining applications[10].

Clustering has been widely studied since the early 60's. Some classic approaches include hierarchical algorithms, partitioning method such as K-means, Fuzzy C-means, graph theoretic clustering, neural networks clustering, and statistical mechanics based techniques. Recently, several papers have highlighted

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the efficiency of stochastic approaches based on ant colonies for data clustering [2,3, 5,8].

Ant-based clustering and sorting was originally introduced for tasks in robotics by Deneubourg [3]. The entomologists who observe societies of ants found that larvae and food are not scattered randomly about the nest, but in fact they are sorted into homogenous piles. Deneubourg et al. proposed a basic model that explains the spatial structure of cemetery forms as a result of simple, local interactions without any centralized control or global representation of the environment[3]. Holland et al. applied related model to robotics to accomplish complex tasks by several simple robots[9]. Lumer and Faieta modified the algorithm to extend to numerical data analysis by introducing a measure of dissimilarity between data objects[5].Kuntz et al. applied it to graph-partitioning[11], text-mining[7] and VLSI circuit design[12]. Note that Monmarché has introduced an interesting AntClass algorithm, a hybridization of an ant colony with the k-means algorithm, and compared it to traditional k-means on various data sets, using the classification error for evaluation purposes[8]. However, the results obtained with this method are not applicable to ordinary ant-based clustering since it differs significantly from the latter.

The research presented here proposes a new Ant-based Clustering algorithm(AMC) which is enlightened by the behaviors of gregarious ant colonies. Firstly, an artificial ant movement(AM) model is presented; secondly, the new ant clustering algorithm has been constructed based on AM model. In this algorithm, each ant is treated as an agent to represent a data object, each ant has two states: resting state and moving state. The ant's state is controlled by two predefined functions. By moving dynamically, the ants form different subgroups adaptively, and consequently the whole ant group dynamically self-organized into distinctive and independent subgroups within which highly similar ants are closely connected. This algorithm can be accelerated by the use of a global memory bank, increasing radius of perception and density-based 'look ahead' method for each agent.

2. Clustering algorithms based on ant colony

Ant-based clustering was inspired by the clustering activities of corpses observed in real ant colonies[4]. The algorithm's basic principles are straightforward: Ants are modeled by simple agents that randomly move in their environment, a square grid with periodic boundary conditions. Data items that are scattered within this environment can be picked up, transported and dropped by the agents. The basic model proposed by Deneubourg et al and its extended clustering algorithms have three fatal problems: firstly, there are so many useless random movements for the agents before they picking or droping the data items; secondly, the parameter value of these algorithms are sensitive to be set initially, and result the clustering algorithm has no robusticity; thirdly, there are two kinds data to be stored and managed through the whole running time, one is ant agents and another is data items to be clustered. That's meaning that it needs more storage space and more complexity methods. Although Handl et al have made some effort to improve the clustering performance[6], the clustering effect should be reformed through another side.

2.1 The Ant Movement Model（AM model）

Enlightened by the behaviors of gregarious ant colonies, an ant movement model has been proposed. The AM model simulates the demeanor of gregarious ant of seeking a comfortable environment to stay, defined the ant agent and two states for them, resting and moving. In the AM model, an artificial ant means a simple agent. It has a simple behavior that, when it has no comfortable site to be rest, it always moving; if it has find a appropriate site, it will stay there until it fills not comfortable again. Such and such, until all these agents find their site and stay there. Not similar with former methods that the ant agent want to carry data object to destination site, the artificial ant has been treated as an agent to represent a data object in our AM model. Thus, the moving of ant agent means the moving of data object.

In the AM model, the environment for ant agent to move about is mapped to a toroidal grid. In a toroidal grid, all the site have same neighborhood, have no difference of center, corner or border. We can defined a state variable q_i to describe the state of an ant agent o_i : $q_i=(x_i,y_i,c_i,s_i)(1\le i\le n)$, which n is the number of data object, (x_i,y_i) is the coordinate of the agent's site, c_i is the cluster ID and s_i is the state sign for resting or moving. The neighborhood can be defined as *Moore* neighborhood in which there are 8 neighbors for each site. For an ant agent, to determine resting or moving at time t , needs to calculate the fitness function $f(i)$ which also can be called similarity function.

2.2 Similarity and Distance

Let us assume that an ant o_i is located at site r at time t. The local density of objects similar to o_i at the site r is given by

$$f(i)=\begin{cases}\dfrac{1}{\sigma^2}\sum\limits_{o_j\in Neigh_{\sigma\times\sigma}(r)}\left[1-\dfrac{d(o_i,o_j)}{\alpha}\right] & f(i)>0\\ 0 & \text{otherwise}\end{cases} \qquad (1)$$

Where, $f(i)$ is a modified version of Lumer et al.'s[5] neighborhood function. It is a measure of the average similarity of ant o_i with the other ant o_j present in its neighborhood. And $Neigh_{\infty}(r)$ is the local region. It is usually a square of $\sigma\times\sigma$ sites surrounding site r . $d(o_i,o_j)\in[0,1]$ is the distance of data object O_i with O_j in the space of attributes. It is usually Euclidean distance or Cosine distance. The parameter α is defined as similarity coefficient. It is a key coefficient that directly affects the number of cluster and convergence of the algorithm. Large values of α will result in making the similarity between the objects larger and forcing objects to lay the same clusters. When α is small, the similarity will decrease and may in the extreme result in too many separate clusters. The parameter α also determines the cluster number and the speed of convergence. The bigger α is, the smaller the cluster number is, and the faster the algorithm converges.

2.3 Probability Activation Function

Probability activation function is the function which active an ant agent from a state to another state, resting or moving. Obviously similarity is one of its variables. The value domain is [0, 1]. There are two situation for an ant agent to exchange its state, and we defined two function for them to determine whether to exchange. The probability of an ant agent resting to moving will be calculated by $p_M(i)$:

$$p_M(i) = \left(\frac{k^+}{k^+ + f(i)} \right)^2 \tag{2}$$

and the probability of an ant agent moving to resting will be calculated by $p_R(i)$:

$$p_R(i) = \left(\frac{f(i)}{k^- + f(i)} \right)^2 \tag{3}$$

Where commonly $k^+ = 0.1$ and $k^- = 0.3$.

2.4 Basic Clustering algorithms based AM model

Based on the AM model, a basic generic algorithm is described in Algorithm 1.

Algorithm 1. Basic ant algorithm

```
procedure BASIC_ALGORITHM
/*INITIALIZATION PHASE*/
data preprocess and initialize parameter
for each Agent do
   Randomly scatter Agent on the toridal grid
   let c_i =data item ID
   let s_i=moving
 end for
while(not termination)
 for each Agent do
   if s_i=moving  calculate p_R(i)
   if s_i=resting  calculate p_M(i)
turn state based on p_R(i) or p_M(i)
 update c_i
 if s_i=moving select next site
end for
end while
output cluster information of all Agents
```

3 Algorithm Optimization

In data clustering, many algorithms (like K-means and ISODATA [1]) require that an initial partition be given as input, before the data can be processed. This is the one common drawback of these methods, for it is not easy to specify a proper number of clusters for a set of data in advance. Moreover, these methods are often led to locally optimal by using a deterministic search, which is another major drawback of these methods.

Contrasting with those methods mentioned above, ant-clustering boasts a number of advantages due to the use of mobile agents, which are autonomous entities, both proactive and reactive, and have the capability to adapt, cooperate and move intelligently from one location to the other in the bi-dimensional grid space. These advantages are□

Autonomy**:** Not any prior knowledge (like initial partition or number of classes) about the future classification of the data set is required. Clusters are formed naturally through ant's collective actions.

Flexibility: Rather than deterministic search, a stochastic one is used to avoid locally optimal.

Parallelism**:** Agent operations are inherently parallel.

While many of those advantages look prefect, two important defects remain. The first one is that there may be some data objects which have never been assigned to ant when the algorithm is terminated. This is due to the fact that each time when an ant is assigned a new data object to inspect, the selected data object is randomly selected. Un-assigned objects lead to a high misclassification error rate of the algorithm, for they have never taken part into the clustering loop. The second defect is the long time consumption of clustering. Due to the random motion of the ants, ant-based clustering algorithms have a slow convergence rate.

To improve the performance of traditional ant-clustering algorithm, we have made some effort in it. We treat each data object as an ant agent to be sure that every object should be visited in the iteration. This method also can save memory because there are no additional agents beside data object themselves. Otherwise, we also adopt technologies such as memory bank, "look ahead" methods and so on.

4 Experiment results and analysis

We have applied the new algorithm AMC to several numerical databases including synthetic ones and real databases from the Machine Learning repository□Machine Learning Repository□http://www.ics.uci.edu/~mlearn/MLRepository.html□. Synthetic database include: ANT1(75,2,4)□ANT2□500□2□4□□ANT3□800□2□9□, while real database are Iris□150□4□3□and Soybean(307,35,19).

We have used 4 evaluation measures to evaluate the resulting partition obtained by the three clustering algorithms. They are the number of identified clusters(#Clusters)□Inner Cluster Variance(Variance)□Classification Error Rate (Cl.Err) [8] and the overall running time of the algorithm(Runtime).

The results demonstrate that, if clear cluster structures exist within the data, the ant clustering algorithm including: CSI and AMC, is quite reliable at identifying the correct number of clusters. In contrast with the *k*-means, the AMC algorithm shows its strength in its ability to automatically determine the number of clusters within the data.

Compare the runtimes of the three algorithms, we can see AMC is the fastest algorithms and its time consumer changes little with the scale of data set. So it is a fast clustering algorithm with prefect scalability. The CSI algorithm is the slowest one of the three algorithms, but compared with the k-means, the increasing gradient of its time consumption decreases with the growth of data set.

5. Conclusion

In this paper, we have proposed a new ant-based clustering algorithm, which is derived from the AntClass, LF clustering algorithm and CSI. Firstly, the AM model has been proposed and a new clustering methods has been presented based on the AM model. Secondly, the device of memory bank is proposed, which can bring forth heuristic knowledge guiding ant moving in the bi-dimensional grid space. So the classification error rate drops subsequently. Thirdly, we proposed a density-based method permits each ant to “look ahead”, which reduces the times of region-inquiry. Consequently the clustering time gets saved. We made some experiments on real data sets and synthetic data sets. The experiments’ results are compared with those obtained using other classical clustering algorithm. The results demonstrated that AMC is a viable and effective clustering algorithm. Future work focuses in:

(1) How to give ant more powerful heuristic rule, which can guide the ant motion, therefore speed up the clustering rate.

(2) Combines AMC with the other clustering algorithm such as k-means and DBSCAN to further improve the clustering quality.

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Tools for Designing Collaborative Working Environments in Manufacturing Industry

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Abstract. The objective of the work presented is to enable different equipment manufacturers, especially SMEs, to provide new services to extend their products. Although a number of ICT solutions for product extension are available, they do not allow for an efficient collaboration within extended enterprise, taking into account different, dynamically changing collaboration patterns and different technical backgrounds of the actors to be involved. The research work presented is aimed at pushing the use of advanced service oriented architectures for Collaborative Working Environments (CWE) in industrial practice. The new CWE solution will include so-called core collaborative services, addressing application independent functionality to support collaboration and covering the common collaboration actions. The objective is to develop means/tools to efficiently engineer application services for product extensions. The tools which will either automatically update application services and/or allow users, non-IT experts, to generate/update application services by themselves, are investigated. The applications in specific industrial environments are presented.

Keywords. Collaborative working environments, product extension, extended enterprise, service design tools, core collaborative services, knowledge sharing.

1 Introduction

The main business objective of the work presented in this paper is to provide a comprehensive solution to extend products of manufacturing companies acting at the global market. The objective is to enable different equipment manufacturers, especially SMEs, to provide new services and new business models, e.g. selling services (instead of selling classical equipment as e.g. control systems), by renting the equipment and guaranteeing its optimal use, which in turn will ask for innovative monitoring of product usage conditions and functions. So companies

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will not sell (only) the classical products, but also the knowledge on how to optimally select and use the products. Such an approach, i.e. provision of effective customer support for the equipment operating world wide, is of a vital importance for survival on the global market. An effective provision of such application services requires means for efficient collaboration of different actors within a supply chain on one side and customers on the other side, within an extended enterprise (EE) context. Although a number of ICT solutions for product extension are available, they do not allow for an efficient collaboration within EE, taking into account different, dynamically changing collaboration patterns and different technical backgrounds of the actors to be involved.

The research work presented is aimed at pushing the use of advanced service oriented architectures for Collaborative Working Environments (CWE) in real industrial practice. Such a CWE solution has to enable cost-effective product extension independently of geographical locations of customers and manufacturers.

The paper is structured as follows. In Section 2 a brief overview of the State-of-the-art of CWE in manufacturing industry is provided. Section 3 explains the concept of the proposed CWE platform. Section 4 is dedicated to the tools for design of CWE in manufacturing industry. Section 5 briefly presents applications of the results in specific industrial environments. Conclusions indicate the key innovations of the research work presented in this paper and outline future work.

2 State-of-the-art

The collaborative work in manufacturing industry requires solving several fundamental problems. Collaboration amongst teams in an enterprise often geographically dislocated, is currently burdened with a number of problems concerning distribution of work, synchronisation and persistence of workspaces, knowledge activation etc. The teams in modern and highly flexible manufacturing industry often require different collaboration patterns (e.g. a combination of synchronous and asynchronous collaboration) [6]. For example, a collaboration for product problem solving has to integrate effective information sharing and activity synchronization [4].

Based on the analysis of the requirements of users in manufacturing industry in the two European projects [8, 2], and on the analysis of state-of-the-art (SotA) the main gaps between the requirements and SotA are identified. This led to the definition of the key RTD challenges which have to be addressed in order to satisfy the requirements of industry regarding CWEs for product extensions.

The analysis of users´ requirements clearly indicate that different so-called collaborative application services (see the next Section) are needed which will satisfy the (basic) requirements to support (a) different collaboration patterns with special emphasis on temporal aspect: synchronous, asynchronous, multi-synchronous patterns, (b) distributed work in EE environment, which includes identification of appropriate expertise, team forming, checking availability of experts etc. with special challenges regarding collaboration among organized teams and wider community, (c) effective (on-line) provision of knowledge on product/equipment and on actors involved, (d) effective knowledge management

(KM), (e) dynamic changes in collaborative work conditions, and (f) decision making in CWE.

Many of the addressed problems are common for collaboration work in multiple different domains. However, there are several specific issues related to CWE in manufacturing industry which impose the needs for RTD activities specifically focused upon manufacturing industry. Such issues are:

- high difference in working environments of the collaborative teams (e.g. shop-floor, logistics area, office area for design teams, etc.)
- different technical backgrounds of teams collaborating on common problems (e.g. shop-floor workers with practical experience but (often) low ICT backgrounds, designers with technical expertise etc.)
- specific security requirements
- strong focusing on organized groups but evident needs to include in collaboration more ad-hoc groups.

3 Proposed CWE

The objective is to develop a generic and widely applicable, modular collaborative platform to support product extensions. The platform will provide various Collaborative Application Services (CAS) to support product extensions, e.g. support in solving problems related to product use (including support in diagnostics etc.), maintenance service, product/equipment reconfiguration etc. The targeted platform will be open for various services to support different products/equipment and involvement of different actors (product designers and service providers, maintenance providers, shop-floor operators, end-customers).

Under CAS are understood the services which involve collaboration of different actors, teams and artefacts within an EE, and which are focused on specific application areas [7]. These services use the information middleware which connects machines/equipment with the platform and provides information on products/processes/production units (equipment) needed for collaborative work within specific application area.

The analysis has shown that the required application services to support product extension have common ‘collaborative’ actions which may be supported by a common approach. Therefore, the new CWE solution will include so-called core collaborative services, addressing application independent functionality to support collaboration and covering these common collaboration actions (such as resource discovery, collaboration traceability, knowledge provision etc.). The core collaborative services (CCS) will be combined with application specific software solutions and semantic-based knowledge management tools (SBKM) allowing for effective collaborative work and knowledge sharing among different actors.

Since the application services will have to be dynamically updated, due to frequent changes in collaboration needs and conditions, and have to be integrated with other collaborative services, there is a clear need to provide a platform which will allow for effective generation/update of such services. The objective is to develop means/tools to efficiently engineer CAS supporting different collaboration patterns and users' backgrounds. The challenge is to provide tools for design of CAS which will either automatically update CAS (e.g. make changes in collaboration support based on tracing of the collaboration work) and/or allow users, non-IT experts, to generate/update application services by themselves.

4 Main Collaboration Design tools

The main design tools have to support development of CAS which can be easily integrated in different environments (i.e. at different information middleware, with different legacy systems) and which can be easily integrated with the existing application solutions (e.g. existing systems for equipment maintenance, diagnostics CAD/CAM etc.). Several groups of tools are investigated as indicated in Figure 1.

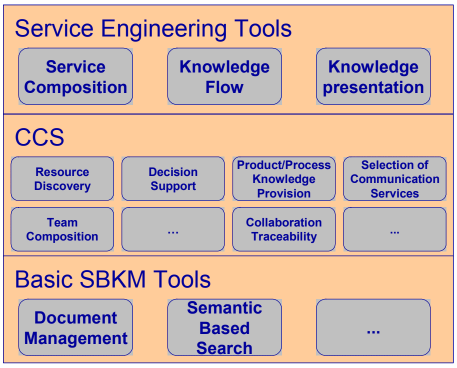

Figure 1. Design tools

4.1. Service engineering tools

Three tools are investigated and developed, addressing several RTD problems:

Service Creation and Edition of CAS: The tool allows users to create a new application service, or edit/modify an existing application service. The functionality is available to expert users, and might require programming skills and it certainly requires high-level access rights, as it implies access to sensitive information of the company (e.g. list of all users and respective rights). The tool will allow users to define issues such as: the purpose of CAS; text and structure for the help system to be used in CAS; users who are allowed to use CAS; collaboration patterns which are supported by CAS; CCS and additional functionality that are necessary to implement CAS, the history of all actions related to creating and editing of CAS.

Identification of Knowledge Flow for CAS: The tool will help the service developer in defining which information is needed for the service, a selection of SBKM tools and auxiliary functionality and their potential use in the services. It provides a list of information/knowledge needed for the CAS, together with sources from which this information can be collected.

This tool supports the knowledge flow identification for the application services, also helping the BPEL (Buisnes Process Exceution Laguage) process definition by providing BPEL partner links details[62]. The tool has the functionality for presentation of the existing knowledge objects in the system, filtered by the target user group's rights and the desired collaboration pattern, allowing the user to select which one is relevant for the composite application service and for presentation of the available SBKM tools/functionality and other relevant tools (again, filtered by user rights and collaboration pattern) so that the user can select the ones needed for the CAS

An oriented graph of the dependencies between entities which are manipulated by this tool helps to define the correct order of the operations. An oriented arrow from A to B means that A influences B, i.e. a fixed A reduces the possible B's to a subset of the original set.

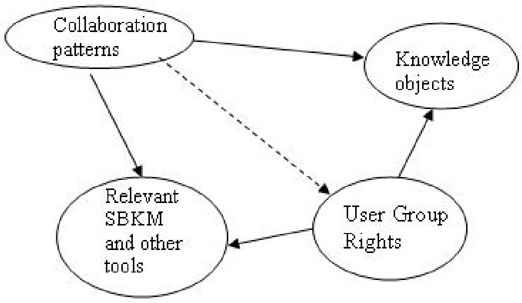

Figure 2. Concepts dependencies

The tool gets information from the Service Creation tool what the supported collaboration patterns will be for CAS, as well as the target user group. Knowing those is the starting point for the definition process. For instance, as can be seen in Figure 2, the expected collaboration patterns restrict the possible range of available Knowledge objects. The visibility of a knowledge object is defined as follows:

Visibility (Object) = v (collaboration pattern, user rights)

That means that whether a Knowledge object will be available in a service depends both on the desired collaboration pattern (for instance, some objects could be available only in asynchronous mode) and on the rights of the users in the group cleared for using the service.

The relevance of a SBKM tool is defined in an analogous way:

Relevance (Tool) = r(collaboration pattern, user rights)

e.g. Particular cases of tool relevances: for instance, communication tools like email are not highly relevant if the spatial collaboration pattern is local.

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[62] The CCS are available as atomic Web Services which can then be composed/orchestrated in order to obtain composite CASs. An orchestration of CCS could be done by BPEL tools. Thus, the BPEL partner links will point to CCS which will be used by the composite service.

Even if a tool would be helpful, if the users' collaboration is conducted after a pattern which does not allow for the use of said tool, its relative relevance is minimal in that case. The User rights themselves could be treated differently at different levels: (a) transparently, at OS level – influenced by collaboration pattern (for instance, permission to read/write in a synchronous collaboration mode). This influence is symbolized in Figure 2 by the dotted arrow linking collaboration patterns with user rights, (b) visibly, at ICP level: user rights defined upon the user's SME affiliation, expertise level , etc.

Definition of Knowledge Presentation and GUI for CAS: This module helps ascertain which information will be provided to different actors in the scope of the application service. In order to do this, different actors will see different GUIs which present only the information they need or have access to. This module has the functionality to define the information which will be presented in the GUI for the CAS; given a user or group of users and the available GUIs, the designer may define which GUI can be used by which user. The presentation of the available GUIs will be made taking into account an ontology of existing GUIs. A rough sketch of the ontology is defined in terms of classes: (1) GUI, (2) User Group, (3) Information/Knowledge Object, and slots (properties of classes): User rights, User device type, Collaboration pattern (some objects may not be visible with some collaboration patterns, or have restricted visibility), visibility, or viewing rights (an object is visible-to a user group which has the proper rights for that; a GUI formatted for a desktop computer monitor is not visible-to a user group which uses PDAs) . The user's device type could be merged as a special case into user rights.

4.2. Core Collaborative Services

The key layer includes CCS – generic set of services supporting collaboration among teams in an EE. The key issue is that the design tools and the CCS support different patterns for collaboration among the teams [5]. Table 1 provides an overview of the key CCS.

4.3. Semantic based Knowledge Management Tools

Different (existing) tools for KM are combined within CAS to support knowledge sharing among teams. The CCS for Product/process knowledge provision has a task to select the appropriate tool to provide knowledge (e.g. for searching on documents related to problems etc.). This CCS provides e.g. 'similar' problems to the one to be solved by an actor/group by applying Case Based Reasoning and Rule Based Reasoning tools [8]. The existing tools are used, but they are upgraded by adding collaborative aspects: for each actor the knowledge on his/her collaboration within different groups is used in defining searching criteria and/or weighting of different similarity criteria for Case Based Reasoning. The problem of ontology is addressed by applying new approach for distributed set-up and maintenance of ontology [3].

Table 4. CCS for work on innovation in manufacturing industry

CCS	**Input/request**	**Output**	**Main functionality**	**Specific requirements**
Resource discovery	Request for expertise	Appropriate and available expert(s)	Searching for expertise Check availability	Mobile users Defined groups Open group
Collaboration Traceability	Request for tracing of the group	Info. on the requested states of groups	Tracing of collaboration: - continuous - event driven, (event identification)	Specific requirements regarding security, companies specific rules
Product/pro-cess knowledge provision	Request for a specific knowledge for the actor/group	Knowledge provided to the actor /group	Selection from the set of the basic KM functionalities the most appropriate one	Documents Stored user knowledge Data bases
Decision support	Problem defined, ideas evaluated	Decision support	Supports weighting of criteria for decision, and decisions traceability	Hierarchy in decision making according to enterprise rules
Team composition	Request for optimal team	Optimal team	Proposes team based on ident. expertise	Enterprise rules
Selection of communicatio n services	Communicatio n needs	Selected commu-nication	Selects most appro-priate for the specific actor, pattern etc.	Voice, Text, Drawings, imagines, Videos, (e-mail Chats)

5 Application

One application addresses CAS for problem solving within complex assembly lines (for small motors at the automotive industry supplier), supporting collaboration among product (line) designers with: operators/foreman at the shop-floor, maintenance service and control system providers, in order to identify the problems/possible improvements and support design of new/reengineered lines. The currently used information middleware (based on the Siemens' ePS) is 'upgraded' with CCS.

Another application is the company that designs, manufactures and trades air conditioning equipment. The company needs effective solutions for maintenance and after-sales services since such CAS have a strong impact on the brand image. In one CAS oriented to the support of acclimatisation units, three different entities in distinct geographical locations interact simultaneously to solve a problem in the machine. The second CAS is oriented to product design and reconfiguration.

6 Conclusions

The main innovation of the work presented is the provision of a new CWE platform including a set of CCS, combined with existing technologies to provide application services for product extensions in manufacturing industry. The proposed approach is fully in line with the findings of the Expert Group on CWE [1]. The group has identified needs to develop collaboration services which can be layered in three blocks: generic services that define basic components (i.e. CCS); domain-specific services (e.g. for manufacturing industry) and context-specific services. Any layer of this architecture has to be supported by services and tools for collaboration design. Exactly these are the objectives of the work presented:

- to develop a set of CCS to allow building of CAS for product extensions

10. to develop a set of tools for design of CAS in manufacturing industry.

The solution will be general enough to be used for different products and scalable to support future products, and thus usable by a wide spectrum of companies and their customers. The future work will be focused upon automatic design/update of CAS by the developed design tools.

Acknowledgement

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The Collaborative Digital Process Methodology achieved the half lead-time of new car development

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Abstract. In Brazil, the industry of agricultural machines and implements represents a A Japanese automotive manufacturer finally achieved the less than one year lead-time for product development of its new automotive that was released in 2005.

NOTE, a new automotive released from Nissan Motor Co., Ltd. in January 2005, was thrown into the market after 10 and a half months of product development period, which was the first achievement all over the world. (1) That means "super-shortened process" reduced the lead-time of new automotive development to the half which had needed more than 20 months. The Japanese automotive industry has achieved the less than one year period of "super-shortened process", coming from "five-lot process" in 1980's through "shortened process" in 1990's as a result of its continuous efforts.(Fig.1) I have brought up the methodology called "Digital Collaboration Process Methodology" from the countermeasures which has contributed these 20 year process innovations.

Keywords. Computer Aided Design (CAD), Computer Aided Manufacturing (CAM), Computer Aided Engineering (CAE), Modeling, Concurrent Engineering, Computer Aided Production Engineering (CAPE), Digital Collaboration, Knowledge CAD/ Knowledge Engineering.

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1. Three Process Innovations

Through CAD/CAM unification" in 1980's and "Data Master Process" in last half of 1990's, "Digital Engineering Release Process" has been established recently. It has achieved the innovation "super-shortened process" which conducts only once prototype testing in less than one year. The development lead-time has shortened to 1/3 from 2.5 year development lead-time in 1980's to 10.5 months in 2000's. Simply saying, the three innovations have achieved in each 10 years. (Fig.1)

1.1 CAD/CAM unification

In 1970's, the automotive manufacturers in the world developed their own "in-house CAD", the first generation CAD program using wire frame and surface, and began utilizing it. Through practical use of "in-house CAD", they reached "CAD/CAM unification" in 1980's. As expressed as the keyword "Clay to Die", a conceptual design model created with clay was directly converted to 3D CAD data, and die processing was unified to NC manufacturing. It greatly contributed to quality improvement in automotive manufacturing.

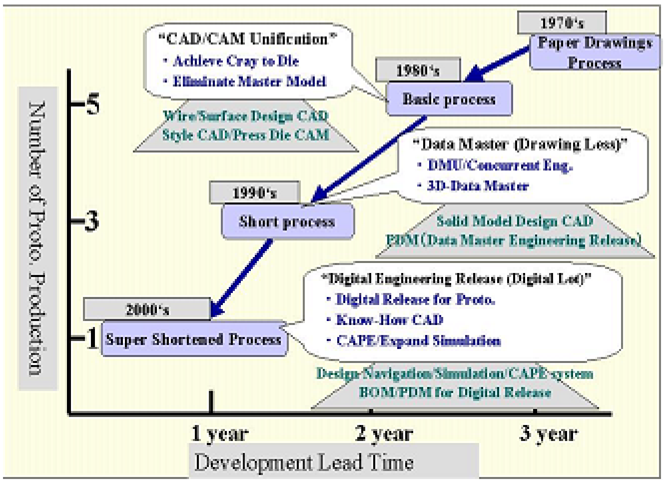

Fig.1. History of Development Process Innovation in Automotive Manufacture

In model based die manufacturing, a wood pattern making expert produces a press die by creating a 3D plaster model (master model) from curves expressed in conceptual design and drafting and by performing profiling the model.
An actual scaled clay model car is measured with 3D geometry measurement equipment. Based on the measured data, the master geometry of faces is converted to CAD data. This data is developed to "vehicle geometry master data" into which

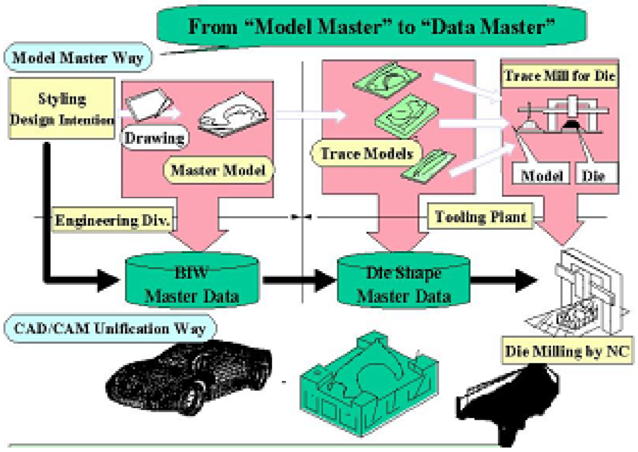

Fig.2. Die Production in CAD/CAM Unification

design information of the internal structure has been incorporated. Adding die-specific addendum and die face geometry to this 3D face geometry, "Die geometry master data" is created; in addition, NC data for die machining is produced with CAM software. In other words, "CAD/CAM unification method" is the procedure that a series of die creation steps is consistently connected by using CAD data united from conceptual design to die creation. (Fig.2)

1.2 Data Master Process

In 1990's, with the progress of computer technology, the first generation CAD "in-house CAD" began to be replaced with "second generation CAD", commercial solid modeling CAD system software which had achieved the practical use level. The automotive manufacturers began to employ and utilize this software. "Second generation CAD" reached for the efficiency represented by DMU (Digital Mock Up) and enabled the automotive manufacturers to realize "shortened process", a year and half period of development and three times of prototyping cycle. "Vehicle layout design" typified by engine room layout had been realized in the first generation CAD (wireframe-based). It was enabled to be verified by using solid models, which brought tremendous efficiency gains and improvement in quality of verification to the automotive manufacturers. (Fig.3).

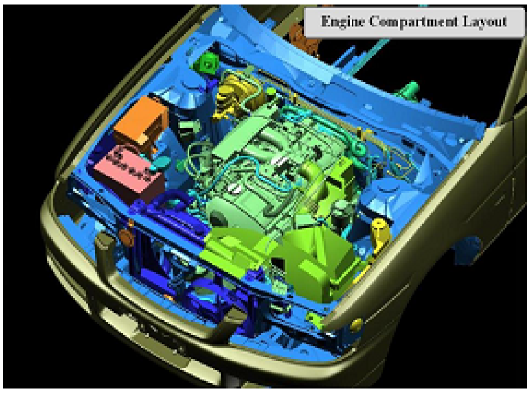

Fig.3. Digital Mock-up by Solid Models

This "DMU realization" has largely contributed not only to design process but also to digitizing and bringing forward the process of productivity verification by enabling "production engineering verification" which had not be realized with the drawing. In body structural analysis field, furthermore, "Digital Performance Evaluation" became possible by supplying CAD DMU data from design department, which had been difficult to evaluate timely because of a long lead-time to prepare the structural analysis model.

Not only design department itself but also both of the production engineering department and performance evaluation department have became able to use DMU data for their tasks on the faith of data. It means that both the departments creating data and using data perform their works using the scheme of "data master =data criteria". From this point, we call these basic design process using DMU as "Data Master Process" (Fig.4)

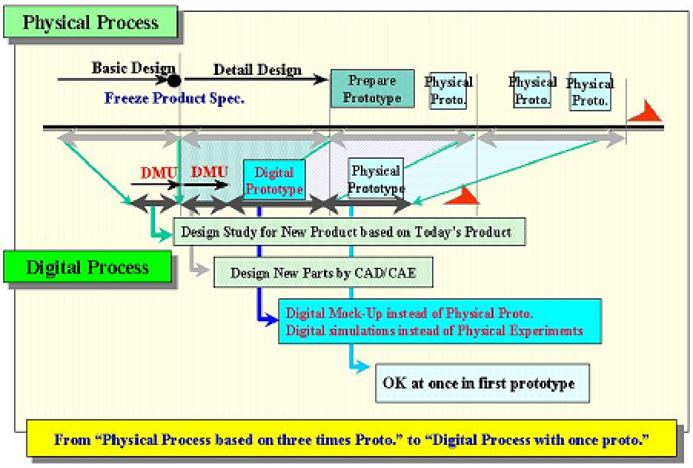

Fig.4. Achieve "Super Shorted Development Lead Time" less than one year

1.3 Digital Engineering Release Process

"Super-shortened Process" realized in the middle of 2000's was achieved by building the new measures on the foundation of "Data Master Process" realized from the late 1990's to the beginning of 2000's. There are four new shemes; "Improvement of DMU as Digital prototype quality", "Design support system incorporated with knowledge (Knowlegde CAD)", "Minimization of degree of dependence on physical tesing with an actucal prototype by expanding analysis simulation" and "Minimization of degree of dependence on an actual prototype by using complete digital process verification" (2).

Thorough "data master process" and accumulation of those schemes led to launch of mass production of a new car with "half of the conventional development period" and "one time prototyping".

2. Seven schemes for digitalization

I explain the major seven schemes, which contributed to achieve three process innovations described above. Table 1 shows the relationship between seven schemes and three innovations, and the contribution to those innovations. I have named these "Seven schemes for digitalization".

2.1. Realization of Styling CAD

A required factor to realize "Clay to die" is "plotting of prototype data" with a Styling CAD system. Styling CAD, which is completing smooth and aesthetic surfaces through the process of "surface creation" called as Fairing based on the coordinate values from measurement of an actual scaled clay model. The most contributing factors to succeed realization of CAD/CAM unification are completion of the Styling CAD system in early 1980's and establishment of its use in the actual operation. (Fig.5).

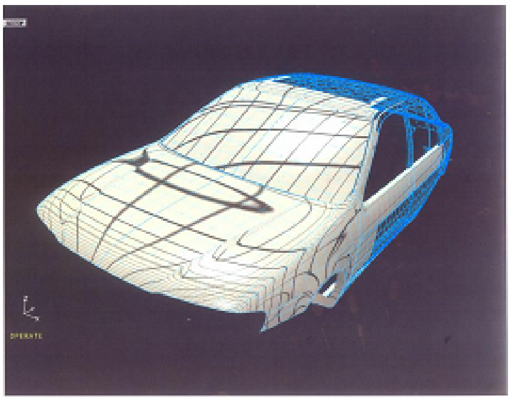

Fig.5. Styling CAD (Exterior High-Light Simulation)

2.2. Body structure master data method, "KOGEN method"

A large issue to succeed "CAD/CAM unification method" is "who will create a 3D model from the results of structural design". In "KOGEN method", a segregated CAD designer is responsible for creating a vehicle structural original image (3D-CAD geometry), modifying and completing it. Dividing the work with other designers enabled to maintain "CAD data quality", create data efficiently and "assure data" toward downstream. Currently, many of the automotive companies have employed this division-of-labor method. The "KOGEN method" is another key factor to support the CAD/CAM unification. (Fig.6)

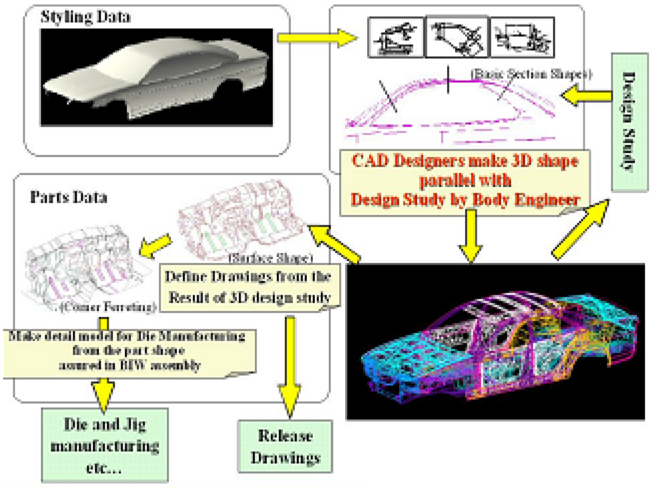

Fig. 6. Kogen Way

2.3. Basic design work with DMU (Digital Mock Up)

By defining all the components composing a vehicle with 3D solids and surfaces, the digital prototype of a new car which was shown like a real experiment car was created. The key factors for this were progress in the second generation CAD software and improvement in performance of workstation platform running such CAD software. This is indeed the innovation of automotive engineering supported with progress in Information Technology.

However, the automotive manufacturers encountered a lot of issues when trying to apply DMU (Digital Mock Up) on the stages of their new product development:

(1) DMU has not been completed until all the components are collected.

(2) To present variation of a product with DMU, product requirements and management of the related assembly components are needed.

(3) How they manage the timing of replacement of assembly component geometry which is intermittently modified with the new one for DMU.

To solve these issues, the following measures were taken:

(a) Establish the system to support creating data for reused components in order to ease designer's burden.
(b) As for components in provision (components on the approved drawing), the component suppliers in charge should be responsible for delivery in 3D data.
(c) Set DMUs under verification planning only necessary times, list required components for individual DMU, and regulate levels of details for creating CAD data of the component.
(d) By using created DMU, clarify items and simulation criteria for "analysis evaluation" and "production engineering verification", and get more precise results of design verification.
Complying with these "DMU operation rules" in an entire company increases the value of using "digital mock up car" and brings successful results. The key here is that the design department creating data assures "segregated analysis group" and "production engineering group" of liability of the product assembly, and engineers can use it on each engineering stage without their concern. Concurrent engineering with DMU cannot be completed unless liability of CAD data is assured.

2.4. Drawing-less process

Compared to the method of assuring creation and maintenance of 2D drawings, the method of creating and maintaining DMU and assuring relative departments or supplies of liability of 3D data forces the designers to take a lot of man-hour. Immediate increase of man-hour turns to a burden even if they well know that the entire product development will be carried out much more efficiently and it will result in less rework and efficiency. As an approach to moderate that burden, "Drawing-less" process had been applied.

This method removes 2D paper drawings and mainly uses 3D CAD data to arrange the production process. The traditional set of "design requirement", "component structural information" and "paper drawing" was replaced with "electrical design requirement", "component structural information", "3D CAD data" "data note" and "auxiliary drawing". Focused on "3D data incorporated with a minimum of dimension values and annotations", technical contents in 2D drawings can be covered by providing literal information on "data note of worksheet" including Parts No., Drawing No., Author, Material, Thickness and Modification, and by adding "2D auxiliary drawing such as sectional view" which cannot be represented in 3D. (Fig.7)

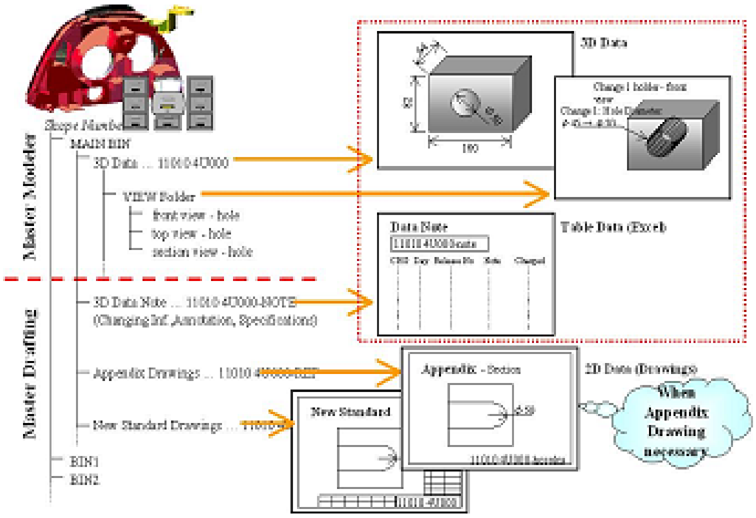

Fig. 7. Drawing Less Release

The largest issue of drawing-less process is insufficient capability of the receiving sites. How do the receiving sites in an automotive company such as manufacturing, quality assurance and purchase divisions perform their traditional tasks without using paper drawings? How does the automotive company deliver necessary information to hundreds of suppliers (parts manufacturers) that treat 70 percent of total vehicle components? Those suppliers would feel difficulties in purchasing and using the 3D CAD system. Nissan Motor overcame this problem by receiving the set of three items (3D CAD data, data note and auxiliary drawing) for drawing-less process and preparing 3D viewer software which can be used for measurement, verification of sections and creation of rough image and providing it to them at inexpensive price.

This approach enabled Nissan Motor to carry out a smooth arrangement for manufacturing process toward the globally extended manufacturing sites; in addition, realize "Real-time arrangement" that was the target of drawing-less process. The "drawing-less process" Nissan Motor introduced ahead of other companies will be a standard process for the Japanese automotive industry in near future.

2.5. Knowledge CAD

Documentation is created after standardizing engineering tasks such as "3D modeling" and "CAD manipulation" which are needed for "design verification" and "production engineering verification". Regarding each detailed task item which consists of the "engineering work flow", engineers "run the 3D CAD system", "do calculation on a worksheet" or "refer technical documents". They use "CAD template" to always output a correct result efficiently when "running the 3D CAD system". This "CAD template" provides the advancement that the functionality to modify dimensions is incorporated into the manipulation history of the CAD system, and 3D manipulation for a same structural work is re-executed for different dimension. Knowledge CAD effectively performs 3D verification on the phase of "Basic design", early in the new automotive development process. (2)

2.6. Use of analysis simulation

"Analysis simulation" called CAE is a dynamics simulation method represented by "Finite element method structural analysis" that divides a product model into a lot of fragments in the digital world and replaces them with matrix calculation to apply theoretical strength of materials to a complex shaped object model in order to calculate deformation and stress. "Analysis simulation" was employed for actual operations in 1970's and has been evolved according to the progress of super computers. There are two purposes for applying "Analysis simulation"; one is, by using computer aid, to help insight of dynamics phenomenon from the engineering view point which is difficult to measure and analyze a real product, the other one is to replace tests which uses a real product with evaluation of functionalities and performance of the product by using a virtual product model. Since then, "3D CAD product model", a base for "Analysis simulation" had been created by designers, and man-hour for creating an analysis model had been decreased, so that the use of "Analysis simulation" had been expanded rapidly (Fig.8).

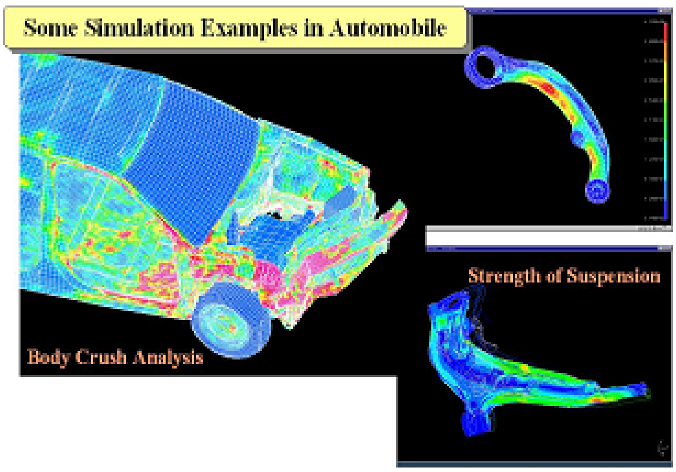

Fig. 8. Apply and Stablish CAE Simulation

For development of a new automotive, there are thousands of "functionality and performance evaluation items" which are required to calculate and verify on the phase of development in order to throw the new automotive to the market. Nissan Motor reported that they had shifted 45 percent of those items from test using a real product to virtual simulation (2). Main contributors to expansion of evaluation with Analysis simulation to such level are "preparation of 3D CAD model as a foundation" and "progress in functionalities of analysis software including pre-post processing such as analysis modeling" as well as "development of analysis simulation technology".

For example, as for "crash safety performance", one of the most important items of automotive performance evaluation, dependency on "Crash simulation" became extremely higher to maintain a certain level of performance. "Crash safety performance" depends on the basic structure of an automotive. If its performance does not achieve the certain level, engineers have to go back to modification of the basic structure. As a result, loss of time and man-hour caused by the rework would be enormous. The "crash analysis model" had consisted of approximately 10 thousands of elements at the launch of this evaluation in 1980's, while the model is, currently, divided into more than one million elements. This enabled to predict a calculation result with a gap of less than 10% on the amount of deformation after a crash test. Continual efforts on development of the crash analysis technology for 20 years brought success, which is only one time verification with prototype.

2.7. Digital production process verification

CAM, the computer technology for creating die and tools with NC controlled machining equipment, was introduced in 1970's and is currently a typical approach for die creation. Furthermore, there is an approach of more comprehensive verification of production engineering by using computer technology, called CAPE (Computer Aided Production Engineering). This system provides a verification method on production engineering aspects by simulating a series of worker's assembling activities with computer and evaluating the procedure and problems in advance. CAPE also has a long history as software or method; however, its usage has been propagated rapidly for recent several years for which upstream designers have turned to create a 3D product model and supply it to production engineers. To shorten the period of a new automotive development and reduce the rework cycle of prototyping and tests, it is necessary to be able to manufacture the product efficiently at a reasonable cost, in addition to "maintain functionalities and performance".

The key three simulations for the "productivity evaluation" are NC data teaching for welding robot, etc and "equipment movement simulation (robot simulation)" (Fig.9), "worker's assembling activities" and "forming simulation" such as die sequence.

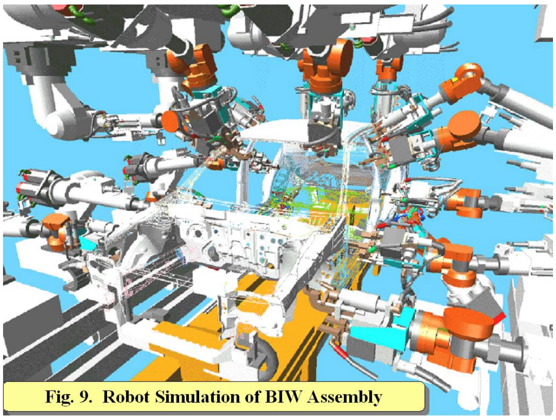

Fig.9. Robot Simulation of BIW Assembly

All of them have more than 10 year history as digitization technology application, and have achieved complete application of CAPE to maintain productivity with only one time mass prototyping. Conventional CAPE used to "check extracted portion" in the process including a potential problem has been improved to standardize necessary items to be checked based on error information from past manufacturing and to extend a limited number of portions to be check to the all. This leaded CAPE to the level that can be called as "Digital prototyping" and realized a successful level of productivity with one-time mass prototyping.
In the CAPE area, although necessary technology was ready to be used, the foundation of "preparation of product data" was incomplete, which had not lead to a large achievement. However, it had been rapidly improved by "reinforcing product data with complete DMU" and by "arranging the environment", and became an innovation.

Table 1: "Seven coutermeasues for digitalization" and contributions for "Three Process Innovations"

Countermeasues \ Process Innovations	CAD/CAM unification	Data Master Process	Digital Engineering Release Proces
(1) Realization of Styling CAD	◎	○	
(2) Body structue master data method, "KOGEN method"	◎	◎	
(3) Basic design work by DMU (Digital Mock Up)		◎	◎
(4) Drawing-less process		◎	◎
(5) Knowledge CAD			◎
(6) Use of analysis simulation		○	◎
(7) Digital production process verification		○	◎

Table 2: "Seven couterneasues for digitalization" and its Details

Countermeasures and effect	Detail countermeasures
(1) Realization of Styling CAD	(a) Establish Styling CAD system
Assure initial 3D data of styling parts	(b) Train Styling CAD modeler
	(c) 3D shape measurment machine for full size cray model and deployment
(2) Body structue master data method, "KOGEN	(a) Establish the work division of Engineer and CAD designer
Assure "Growth of 3D Data" of auto body	(b) Train CAD designer
combined by Styling and Structure	(c) Create the detail parts shape and assure for Tooling Division
	(d) Release simplified drawing from Body master data
(3) Basic design work by DMU	(a) Establish DMDR
Concurrent engineering with collabolation of	(b) Keep DMU experts team and data creation organization
desgner, analysit and production engineer	(c) Make the rule of DMU-BOM and apply placticaly
	(d) DB system which create and maintain DMU BOM structure and parts 3D data
(4) Drawing-less process	(a) Make rules for three items, 3D-data, asistant drawings, data notes
Speedup of technical information flow from	(b) Establish the system to connect several division and several companies
design division to dawnstream devision	(c) Establish the deliverly rules of Proposal drawing data with suplyers
	(d) Develop and promotion of simple CAD system which is able to receive Drawing-less data
(5) Knowledge CAD	(a) Standerization of design procedure and its digital description
Speedup of design study and keep design	(b) Establish "Design guidance system" and penatration
quality	(c) Develop 3D-CAD Template and penetration for actual work
(6) Use of analysis simulation	(a) Develope technology to evaluate the performance in experiments experience.
DMU performance evaluation instead of	(b) Improve the accuracy of Body structural analysis which require longest lead-time.
physical experiments	(c) Shorten the lead-time to priare the final DMU.
	(d) Establish the dedicated body structuring Man-power,
(7) Digital engineering process verification	(a) Introduction CAPE systems and promote
DMU productivity evaluation instead of	(b) Training of Dedicated CAD designers process in German.
physical models	(c) Standerization items should be defined, and sutisfy for 1day stay/

3. The Collaborative Digital Process Methodology

A new product development is defined as that a manufacture "decides consisting components (by designing/choosing them)", "makes a layout for building up the product", "check if the functionalities and performance meet the requirements of the product" and "verifies if the product can be manufactured at a reasonable cost". Currently, most of the engineering needed for product development can be verified in the digital environment such as "layout by DMU", "functionalities and performance by CAE" and "productivity by CAPE".

"Seven schemes for digitalization", described before, have the relation of mutual dependence and mutual contribution. I have named the scenario, which have achieved the "Three Process Innovations" by collaboration of seven schemes, "The Collaborative Digital Process Methodology". It will support the process innovation not only in automotive industries but also in other manufacturers.

"The Collaborative Digital Process Methodology" is constructed by "Growth and Utilization of Data" and "Concurrent Engineering with Event-DR". We can recognize that "Growth and Utilization of Data" is technical methodology and "Concurrent Engineering with DR-events" is organizational methodology.

3.1. Growth and Utilization of Data

"Growth and Utilization of Data" is the approach of defining 3D shapes roughly and using them for layout or analysis roughly on the basic planning phase, and in connection with design progress, developing the 3D shapes to be detailed in order to be supplied for required engineering verification step by step. The old process creating a 3D geometry model from the results of designs created in 2D and conducting verification of analysis and production engineering using the 3D model does not help intentional design, just like making the engineers count the age of dead children. Developing design, engineers create a 3D shape based on undecided design information, verify it with CAE and CAPE, and then decide the design. That is "growth and utilization of a 3D model" (Fig.10).

This Methodology enables to eliminate the loss of big man-power to re-create the model data in early stage of process because of design change. Users can get the biggest advantage in 3D design work by this methodology and establish the most efficient process.

"Growth and Utilization of Data" are supported by "Seven schemes for digitalization" in the following points.

(1) Realization of Styling CAD

This is a neccesary tool to create initial 3D data of styling parts. It is impossible to establish automotive 3D process without this tool.

(2) Body structure master data method, "KOGEN method"

This is the main and only one scheme to assure "Growth of 3D Data" of automotive body.

(3) Basic design work with DMU

This work is achived by the assurance of 3D data of compornent parts by "Growth of 3D Data"

(4) Drawing-less process

Downstream divisions can use "Drawing-less data" instead of drawings at ease when the design division assures "3D data" and maintains "3D data".

(5) Knowledge CAD

"Knowledge CAD" tools always assure up-to-date "3D data of component parts" and "DMU data" needed for design verification of individual portion.

(6) Use of analysis simulation

The assued 3D DMU data is neccesary to build structural analysis model. "Digital experiment model" is built from "Digital Prototype model".

(7) Digital engineering process verification

Digital engineering process verification enabled digital verification of production engineering such as in-advance verification of manufacturability.

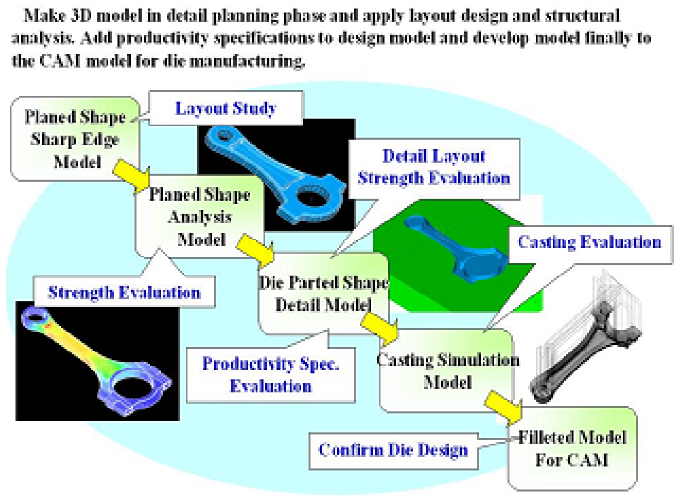

Fig. 10. Growth of 3D Model and its application

3.2. Concurrent Engineering with DR (Design Review)-events

"Concurrent Engineering with DR-events" is the approach of communicating geometry information decided in the design phase to the analysis and production engineering divisions at real time, and performing engineering verification by the specialist timely. The collaboration by several organizations is the key point to reflect production engineering to product design in the basic design phase.

The design work is defined that "a designer decides design specifications temporarily", "a performance reviewer evaluates whether or not the functionality and performance meets the specifications", and "a production engineer verifies the productivity using the specifications". The design work is also defined as the collaborative task that the expert in each field shares same 3D data and modifies the best specifications for a certain level of satisfaction (Fig. 11).

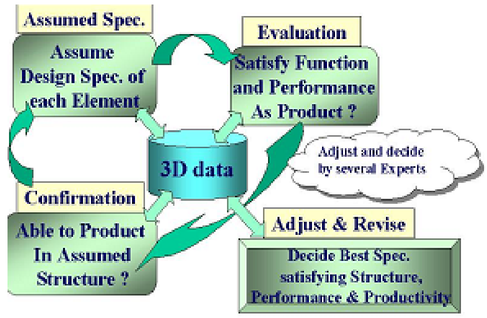

Fig. 11. Design work with collaboration

Practically, as shown in Fig. 12, "Product designer", "Parts designer", "Analysis engineer" and "Production engineer" make collaborative work and progress the product development according to the processes "Concept design"--> "Detail design"--> "Design release for prototype".

"Concurrent Engineering with DR-events" is supported by "Seven schemes for digitalization" in the following points.

(1) Realization of Styling CAD

Styling CAD enabled to release the styling data timely to the design division and die division. It has achieved early feed back to design and early start for die production.

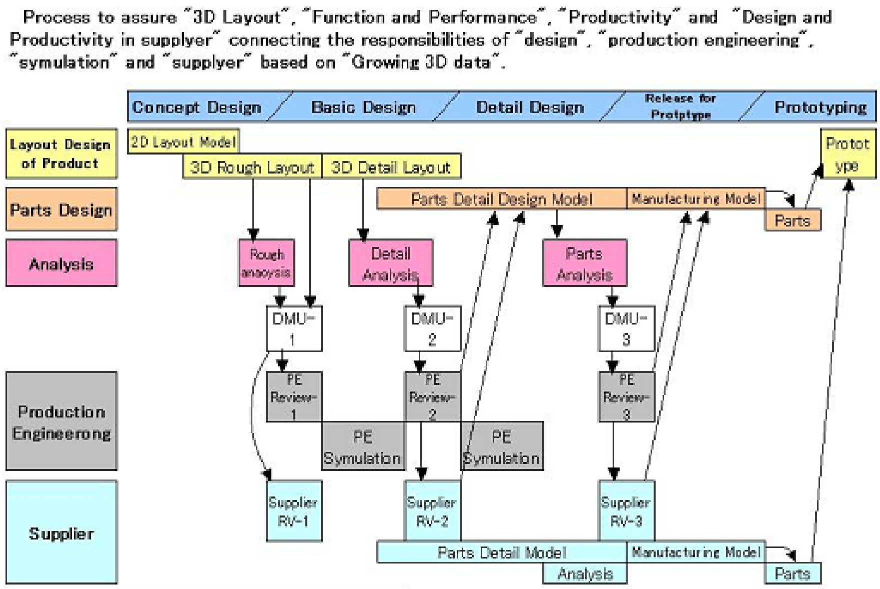

Fig. 12. Digital Collabolation Process

This contributed the biggest role to establish the concurrent engineering.
(2) Body structure master data method, "KOGEN method"
(3) Basic design work with DMU
Basic design work with DMU is the concurrent engineering itself performed with collaboration by designers, analysts and production engineers.
(4) Drawing-less process
This achieved the speedup of technical information flow from the design division to downstream divisions.
(5) Knowledge CAD.

Table 3: "The Collaborative Digital Process Methodolody" and "Seven countermeasues for digitalization"

Process Innovations / Countermeasues	Growth and Utilization of Data	Conccurent Engineering with DR(Design Review)-events
(1) Realization of Styling CAD	◎	
	Create Initial 3D data of sdtyling parts	"Early design feed back" and "early start to manufacture die"
(2) Body structue master data method, "KOGEN method"	◎	○
	Assure "Grawth of 3D data" of Body	Biggest contribution to realize "concurent Engineering"
(3) Basic design work by DMU (Digital Mock Up)	○	◎
	Assure component 3D data and "Grawth of 3D data" of Body	Realyze concurent engineering by collabolation with several division.
(4) Drawing-less process	○	
	Assure 3D data	Share technical data by several division
(5) Knowledge CAD		◎
	Assure "Parts data", "DMU data" in recent	"Early styling feed back" and "early manufacturing feed back"
(6) Use of analysis simulation	○	◎
	Achieve Digital experiment car	Collabolation of "Design spec." and "Evaluation by Productibity"
(7) Digital production process verification	○	◎
	Achieve Digital puroduction car	Collabolative Process for "Design Specs." and "Productivity confirmation"

With speedup of design study, it contributed the early feed back to styling change and early consideration of engineering requirements.
(6) Use of analysis simulation
By establishing "Early analysis evaluation" through DMU, it enables the speedy feed back cycle between "design specifications" and "functionality and performance evaluation".
(7) Digital engineering process verification
The collaboration cycle between design and production engineering has become speedy because all of the parts were processed in 3D data and the BOM system assured related data including specifications with the design division. It achieved the efficient study by production engineers and tremendously improved accuracy of verification.

3.3. Procedure to make "The Collaborative Digital Process"

To make "Process innovation action plan" for the targeted product development work, characteristic of the product, development organization and today's progress of digitalization should be considered. It is not true that "Seven schemes for digitalization" is always adaptable for any products or any organizations. We will study and analyze today's works at first, decide what work should be focused on, and select what schemes should be applied from "Seven schemes for digitalization" and 25 detail schemes. Through these processes, we are going to make the most suitable action plan and receive an approval from the person in charge to get start the action.

Fig. 13 shows the practical process, beginning with "Study current situation", through "make schemes" to make up "action plan" finally.

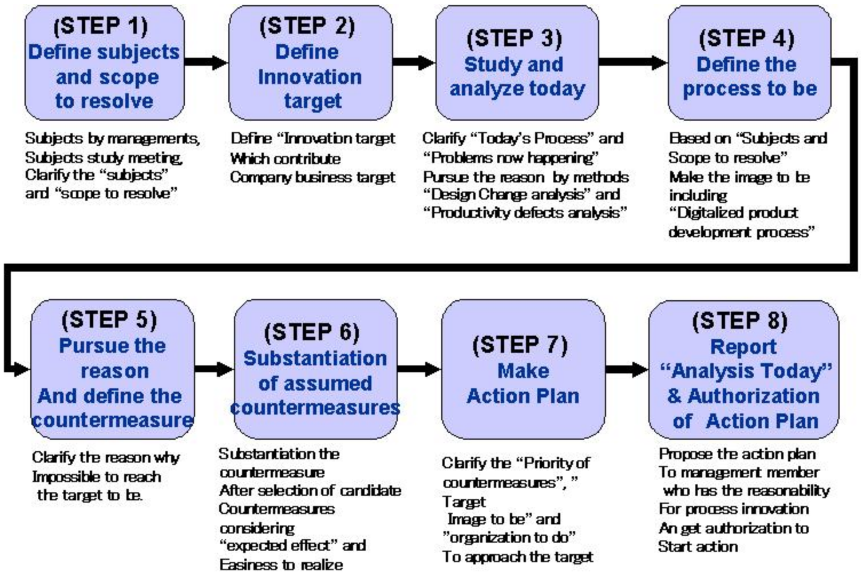

Fig.13 Procedure to make "The Collaborative Digital Process"

4. Conclusion

Today's "super-shortened process" is the result that the automaker has extruded the maximum synergy effect combining the "Seven schemes for digitalization" organically. I have established "The Collaborative Digital Process Methodology" based on my experiences to achieve these process innovations in the automaker.

Japanese automotive manufacturers have had advancement in product design and product manufacturing technologies. Japanese manufacturers have a big challenge that the automotive manufacturers have to use digitization technology efficiently and appropriately and continue having the ability to release their attractive products to the market in a short period of time. It can be said that 30-year effect for improvement in the Japanese way leads to their ability to develop the best products in the world. That is derived from their cleverness on using digital technology with scrap-and-build policy and from their effort "Continuation is power".

I would like to make effort to achieve the digital process innovation by this "The Collaborative Digital Process Methodology" for all of the manufacturing industries, using "Seven schemes for digitalization" and 25 detail schemes.

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Stakeholder Value Sustainability

Improvement of the Efficiency Model in Health Care through the use of Stakeholders' Analysis Techniques

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Abstract. The pursuit of health efficiency has become the aim of many stakeholders in their respective sector, because of the increasing demand for health care services and the rising expenses in the sector. However, the efficiency analysis is complex in systems, like the health system, where exist conceptual challenges, multiple objectives and great scope for error. One of the difficulties is the selection of prominent variables of the efficiency model, which represent the requirements of stakeholders. The Stakeholders' Analysis is a technique used to evaluate different clusters of insterest in complex systems. Yet, its application for efficiency analysis in the health sector is still rare. This paper aims at using the stakeholders' analysis as a support for the efficient health model and verify its advantages and restrictions.

Keywords. Health Sector, Complex System, Efficiency Model, Stakeholders Analysis

1 Introduction

During the last decades, an astonishing increase of pursuit for health care in all countries has been stated, independently of the economic classification in the world scope. The increase of demand excels actions of important social actors: the consumers, anxious for a long and healthy life and the suppliers, who, come across new medicines and technological advances in the health area. These changes are favorable, since they increase the life expectancy and well-being of the people. However, from another point of view, the countries have a raised expenditures with health, consuming a sizeable proportion of their gross domestic product. Because of this characteristic of the health sector, policy makers, administrators and clinicians are not only worried about supplying quality services, but also about efficient ways to deliver health services. According to [10], efficiency improvements in the health sector, even in small amounts, can yield considerable savings of resources or expansion of services for the community.

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So, health is seen as a production model, just like it normally occurs in industrial processes [1]. The main idea, of this model, is the process of converting health inputs (medical cares, medicines, food habits, education, etc) into health improvements (outputs). The health production model aids to identify possible variables, which will be used to measure efficiency and to find benchmarks. Notwithstanding, this model doesn't consider the actor involved in the process. So, how can we measure the efficiency in the health sector, considering inputs and outputs that represent the requirements of stakeholders?

The technique, usually used in processes of goods and services production, is the Stakeholders' Analysis. Mentioning the enterprise area, [5] affirm that on the strategic level, the performance optimization of any production can be achieved by identifying stakeholders of the operation. In complex sectors, stakeholders' analysis is used with the intention to promote improvements in the sector. [12] use context analysis and stakeholders' identification to improve the sectors (health and education) in the rural areas of Nicaragua.

[13] describes three main reasons for applying stakeholders' analysis in the health care field. These intentions are resumed as follows: understanding and influencing policy; facilitating the implementation of organizational goals or objectives; and finally determining optimal ways of relating with key stakeholders.

This paper intends to discuss the advantages and restrictions of the application of Stakeholders' Analysis to identify the variable in efficiency models in the health sector. In section 2, we discuss the conceptual aspects that involve the evaluation of performance in the health sector and the difficulties in defining the variable necessary to measure efficiency in this sector. Section 3 presents the concepts about Stakeholders' Analysis. Section 4 presents the methodology proposal in this paper, followed by a case study. Finally, section 5 presents the final commentaries about the methodology proposal.

2 Defining the Variable of the Efficiency Model in Health Care

To develop a satisfactory empirical model of efficiency in the health sector, it is necessary to consider three issues [4]: What is the appropriate unit of analysis (Decision-Making Unit - DMU)? What are the outputs of health care? What inputs are used in the production of these outputs and how should these be valued?

The DMUs of the health sector usually composes the basic objective of the analysis and they don't present great difficulties in being definite. For example, a macro approach, used by the World Health Organization (WHO), is the international comparison of health care systems. There the unities of analysis are the members of the WHO. In a micro approach, as like measuring hospital efficiency, the DMUs could be the hospitals in a country or region [10].

Notwithstanding, defining inputs and outputs isn't as easy as defining DMUs. It is always difficult to give clear inputs and outputs measurement of the health system because the whole health system is hard to measure in terms of quantity [7]. Also these variables are not usually chosen considering the stakeholders of the system. Further, different stakeholders need different sets of performance indicators, so that all of them are taken into consideration: suppliers and customers

[2]. The distinct stakeholders' points of view become the variable of model dynamic. The figure 1 shows an example. The variable "number of hospital beds" can be an output or input, in a hospital efficiency context. From the point of view of the administrator, this variable represents a system resource (input). For the beneficiary, it is an output, which he wants available whenever he needs.

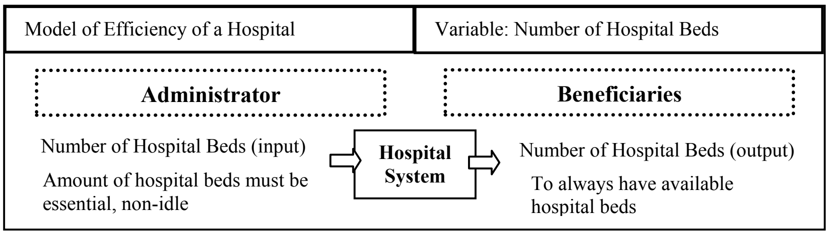

Figure 1. Variable, hospital beds, under different point of view

Another difficulty is the trust in the results of the efficiency model. As, most of the time, the choice of these variable is subjective. So, the goal of the analysis might be compromised, as some of the stakeholders could be biased. [4] stress that to attain the objective of the efficiency analysis and identification of benchmarks, in the health sector the correct identification of the inputs and outputs of the model is necessary. The methodology for performance evaluation depends on the clarity of the objectives and goals of the health systems that it desires to evaluate [6].

3 Stakeholders' Analysis

Stakeholders' Analysis is a methodology that promotes ways to evaluate and to understand people, groups of people and institutions involved in the system, through the identification of stakeholder requirements. Stakeholder requirements express what stakeholders of a system require of the product, processes and the organization of that system; these requirements may be expressed as needs, wants, expectations, desires, priorities, objectives, or capabilities [8].

[14] defines Stakeholders' Analysis as being a systematic process of capturing and analyzing qualitative information, used for identifying interests of third parties when wanting to develop and/or implement a policy or a program. For [15] Stakeholders' Analysis is a methodology to identify key stakeholders of a project, searching for their interests, and verifying how these interests can affect the risk and the viability of the project. In the health sector, [11] concludes that Stakeholders' Analysis is an important task to guarantee the success of the reform in the sector. Therefore this question must be answered: What have been the roles of stakeholders, and their effect on the process of health sector reforms in developing countries?

To apply Stakeholders' Analysis doesn't exist only one way to specify the stakeholders' requirements. However, is useful to know the goals of the project before start the analysis. The first step in approaching stakeholder analysis is determining the purpose of your inquiry; which in turn determines the time focus of interest and issues to consider in conducting the analysis [13].

4 Methodology and Application

Figure 2 presents the performance measurement and management cycle, which enables from the conceptualization and definition of the variables to measure efficiency of systems that compose the health sector. The outcomes can be used to assist the process of improvement in this sector. The methodology of Stakeholders' Analysis has as objective to find the best variables of the efficiency model.

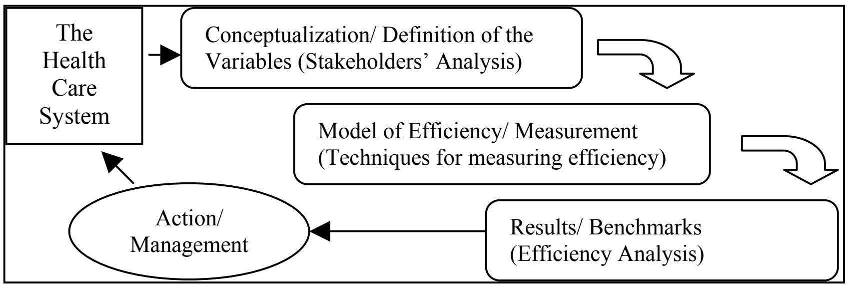

Figure 2. Stakeholders'analysis, performance measurement and management cycle

Source. Adapted from [6]

The methodology is composed for three phases (table 1), illustrated for a case study. This case pursues to identify the variables of the efficiency model, for a comparative analysis among the diverse Health Care Systems of the country members of the WHO. The definite variable (from this methodology) will be compared with the variable used in other studies as [7] and [9].

Table 1. Methodology of Stakeholders'Analisys for Efficiency Models

Phase	Methodology of Stakeholders' Analysis for Efficiency Models
1	1. Context Analysis of the health model to be evaluated 1.1 Objective 1.2 Context Analysis and DMUs' specification
2	2. Stakeholders' Analysis of health model 2.1 Identifying, describing and clustering of the stakeholders (inside the Context) 2.2. Capturing the stakeholders expectations and responsibilities in the sector, and how this information can influence the objective of the health system.
3	3. Variables Analysis: The variables are identified from the last phase

The first phase is characterized by the identification and context analysis of the system. Describing the objective is the first activity to be done. After, it is possible to specify the DMUs, which will be used in the efficiency model.

According to the phase I of methodology, the fundamental objective of our study is an international comparison of health systems. Therefore, each DMU will be represented by the Health Care System of these countries. For this reason, we need to define what will be considered a Health Care System. According to [16] "The Health Care System" is the total sum of all the organizations, institutions and resources whose primary purpose is to improve health.

In the second phase the identification and the clustering of stakeholders is done (figure 3). Further, it captures the requirements of stakeholders in the sector, which is the most important stage of the methodology. It is important to observe that the stakeholders are part of the health system. This determines the approach used by the methodology of the stakeholders' analysis, and it is based on two issues: What stakeholders receive from the health system (expectations): what stakeholders supply to the system (responsibilities). To identify the stakeholders of the health system, we have used a guidance list provided by [3], which have helped us to execute a brainstorming. After the brainstorming we have interviewed health sector expertise.

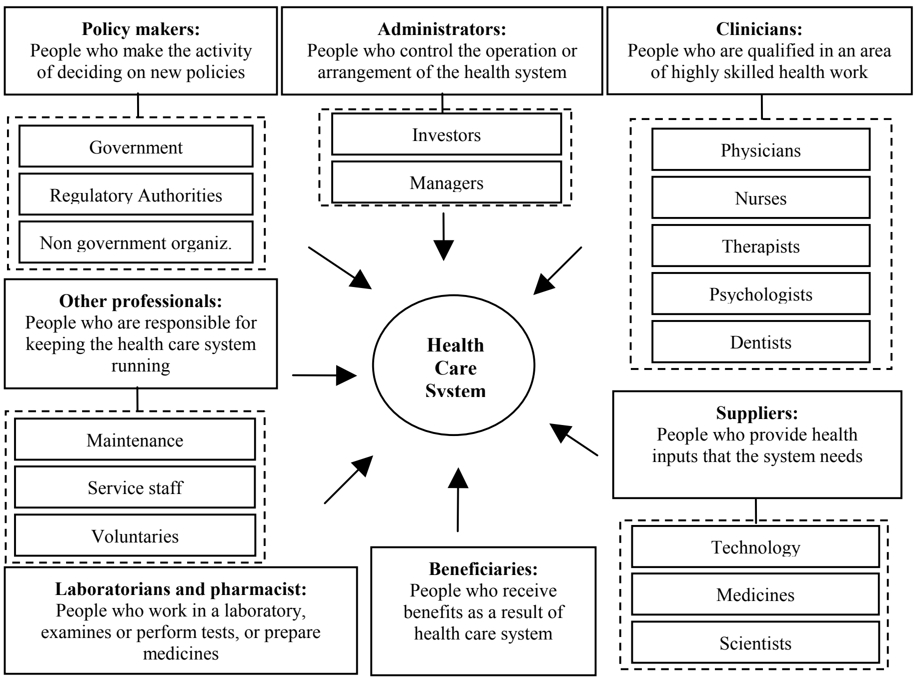

Figure 3. Stakeholders' Diagram

To apply the phase three, we choose two clusters of stakeholders, the policy makers and the beneficiaries (figure 4). The variables are found answering the two previous issues. The inputs possibly come from the responsibilities of stakeholders and the outputs come from the expectations.

	Responsibilities	**Indicator (possible input)**	**Expectations**	**Indicator (possible output)**
Policy Makers	1. Promoting conditions for protection and recovery of the health of the population	• Basic infrastructure: number of professionals, hospitals, medicines • % covering of sanitations services and garbage collection • % population in urban and rural area	1. Supplying health for all the population with quality and fairness	• Infant Mortality • Life expectancy • % of population covered by health programs
	2. Promoting laws and programs aiming at improvements in the health	• Number of laws and national programs (preventions, immunization, vaccination)		
	3. Financial accounting of the health system	• Total expenditure on health (as % of GDP, per capita, government, private) • Number of beneficiaries of private and public plans		
Beneficiaries	1. Payment of taxes	• The beneficiaries` contribution to health expenses	1. To have a long and healthy life	• Life expectancy
	2. Respect for the law	• Expenses with taxes	2. Basic infrastructure	• Numbers of clinicians, laboratorians, pharmacists and hospital beds
	3. Awareness of the health programs	• Number of laws and national programs (preventions, immunization, vaccination)	3. Indicators of quality	

Figure 4. Phase 2 and 3 of methodology

Table 2 presents a comparison among the variables used in two other studies about efficiency analysis with the variables found through our methodology. As can observe, there are several approaches that can be used for efficiency analysis, for example historical, monetary or quantitative approaches. However, the stakeholders approach identifies different variable that are based on the requirements of stakeholders. Through inputs as: "% covering Sanitation" and "Average years of schooling", the methodology retracts the complexity of evaluating the health sector.

5 Conclusion and Final Commentaries

With the methodoology proposal it is possible to obtain a larger understanding of the size of the problem that will be studied. Specifying the objective and the context of the analysis, we can justify why we use these variable in the efficiency model. Thus, the subjectivity of the analysis is avoided and certain are aided DMUs. Further, we can observe the dynamic of variables, because of the stakeholders in the system; the variables can be used as an input or output, according to the stakeholders requirements. The Stakeholders' Analysis provides security to define when one variable is input or output based on the point of view of the stakeholder in the health system.

Because of the data limitations, the study case encountered dificulties, which are normal in the health sector. Another complex matter was the time spent to identify the stakeholders requirements, which can increase the cost of the project.

Notwithstanding the methodology when used for specific goals, for example, can be applied to justify the necessity of an investment or assist a reform in the health sector, because it is based on the responsibilities and expectations of influential stakeholders.

Table 2. Comparative Analysis between different approaches in Health Systems

Papers	**Variables for Efficiency Model in Health Care Systems**		
	Approach	***Inputs***	***Outputs***
Our Methodology (Stockholder's Analysis)	Policy makers	• Number of health professionals • Number of hospital beds • % covering sanitation • % urban population • Average years of schooling • Health expenditure	• Life expectancy at birth • Low birthweight infant mortality • % of population covered by public health system
	Beneficiaries	• Taxes expenditure • Out-of-pocket expenditure	• Life expectancy • Number of health professionals • Number of hospital beds
[9] "Compare the efficiency of health systems in G-20 Countries"	Fairness Model	• Gini coefficient • Health expenditure as % of GDP	• Life expectancy at birth • Low birthweight infant mortality
	Historical Model	• Life expectancy at birth (1995) • Low birthweight infant mortality (1995)	• Life expectancy at birth (2005) • Low birthweight infant mortality (2005)

[7] "Compare the efficiency of health systems in Canada and the U.S. at sub-national levels"	Quantity Model	• Numbers of (per 1000):
		  • Physicians
		  • Nurses
		  • Hospitals
		• Real expenditure on pharmaceuticals per 1000 population
			• Life expectancy at birth
			• Low birthweight infant mortality
			• Age-standardized self-assessed health status
			• PYLL (Years of Potential Life Lost) from:
			  • malignant neoplasms
			  • cerebrovascular disease

	Monetary Model	• Expenditure on:
		  • physicians
		  • hospitals
		  • pharmaceuticals
		  • others	

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Enterprise Integration for Value Creation in an Organization

Aravind Betha[64]

Abstract. In day to day's competitive and dynamic business environment. The complexity of the technology is increasing in the applications in the industries. A new system is required to maintain the competitive advantage of the industries. Increasingly successful business leaders recognize that the integration of management and organization and facilities is the key to inspiring organizational performance and value creation.

Three of the primary resources namely people, place and tools are to integrate as a coherent whole and aligned to support a robust strategy. The new frontier of Knowledge Worker effectiveness lies in integrating the design and implementation of these three keys.

The Industries have begun to integrate their operations along the value chain of the products they design, produce or sustain. The creation of the value is one of the important tasks in Integration. The object of meeting the technical performance and the costs and scheduled goals effectively and efficiently is a serious challenge. Hence, the process of integration to the enterprises can achieve the target. The nature of enterprises provides a solution for obtaining these challenges. Enterprise Integration is the process of linking these applications and creating a linkage between the different sources is an important aspect.

Information is the consideration as the most important factor for implementation of integration in the enterprise. The second step takes place in close interaction between the customer and the supplier. The customer is to integrate into the value creation of the supplier. Value is the mutual creation among the factors on different levels. Customer integration is to define as a form of industrial value creation where the consumers take part in activities and processes, which is the domain of the companies.

The current practice of Enterprise Architecting has been a significant contribution to creating and sustaining modern enterprises. However, the current field is not a sufficient approach to the enterprises of this new century. A broader and more holistic approach is to achieve by drawing on the emerging systems and the architecting field.

The objective of this paper is to set a framework for value generation in the enterprise based on a strong integration of the customer. The main part of the paper will explore customer integration.

Keywords: Enterprise**,** Integration, Architecture, Value Creation, Lean, Stake Holders.

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1. Introduction

Companies have to adopt strategies, which embrace both cost efficiency and a closer reaction to customers' needs. The consumer is a concern as the partner in value creation. The customer is to integrate in the value creation of the supplier. Customer-related value added is to produce at the information level. The customer is to integrate in the value creation of the supplier. Industrial value production is most often conceptual in terms of the value chain. In this concept, value creation is sequential. Value is to add from one-step to the other. The customer is not a part of the value chain. Value is the consideration only in the transaction between the customer and producer. The large-scale projects often have high complexity. They have significant technical risks, and a large number of diverse stakeholders. This environment is challenging for the effective and efficient execution. The objective of this discussion is to set a framework for value generation in the enterprise based on a strong integration of the customer.

2 Enterprise

Black's Law Dictionary defines an enterprise as "an organization united by a common purpose," focusing on a common purpose as the defining element of an enterprise. The term "Enterprise" refers to the Inter-organizational network. The coalition of different department as a whole is an enterprise. The interconnectivity existing between the different departments is well defined. It contributes to the development and the delivery of a system [1].The Enterprise consists of distributed responsibility and leadership. They have stakeholders with both common and diverse interests. This common purpose as *creating value, s*ays that an enterprise "is an integrated entity that efficiently creates value for its multiple stakeholders". A single business unit of a larger firm is an enterprise, as it is the unity in a common purpose of creating value [1].

3 Integration

The term Integration refers to the bringing together of two entities in such a way that unites and coordinates not only their computing resources, but also their strategies, processes, and organization. This is so that the integrated enterprise behaves as a coherent entity. Integration plays an important role for enterprise networks. Enterprise Integration deals with the face of the accelerating rates of technological change [1].

Integration plays an important role for enterprise networks. The enterprise integration can quickly multiply in several directions in the face of growing technological as well as organizational complexity. Enterprise Integration deals with the face of the accelerating rates of technological change [1].

4 The Five Lean Fundamentals

Specify Value: This is the first stage in the implication of lean integration. The basic task is to generate value for the product. The customer generally does the value specification. The process involved is the “pull” system [2].

Identify the Value Stream: The products require the system of streaming the process. This streaming of information or the process cycle is a principle of lean. The mapping of the end-to-end linked resources is applied. The inputs and outputs are to identify to eliminate waste [2].

Flow continuously: The process involves flow. The streaming should be continuous. Thus by the elimination of waste in the process the value creating steps flow [2].

Pull system: The Customer determines the value of a product. This system is the pull system. The customers pull cascades to the lowest level supplier enabling just in time production [2].

Pursue Perfection: A process is perfect through the gradual improvement. This is the application to any product. In order to achieve the perfection a continuous modifications is required. [2].

4.1 The Levels of Integration

The first level is *free market coordination.* The implicit coordination exists between enterprises in a free market. The second level is *cooperation*. When two enterprises cooperate, they directly communicate and identify divisions of labor and desired directions and outcomes. The third level is the *collaboration*. Collaboration enterprises begin to exchange sensitive information such as performance metrics, the long-term strategy, and the process data [1,4].

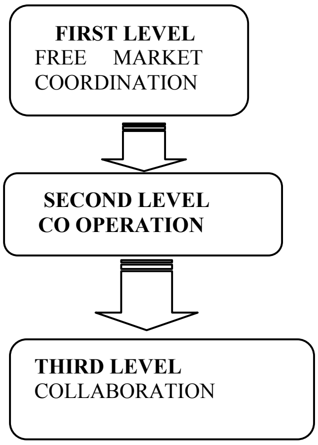

Figure 1: The Levels of Integration.

4.2 Barriers to Integration

Integration challenges have proven to be fraught with many barriers. The barriers to integration have simply held back large gains and integration has proven to be ineffective. [1]. Our aim is to examine the most common barriers to integration across enterprises and to identify best practices and strategies for integration that mitigate the observed barriers.

5 Value Creation

Value Creation is an important factor in enterprise integration. Every component has a value. The aim is to create the right products. This is the requirement with the efficient lifecycle and enterprise integration. The customer is a part of integration in the value creation of the supplier. Every transaction implies information and coordination about the customer specific product design .This type of value creation breaks with the traditional view of value creation in a firm [5].
The value is the mutual creation created among the factors on the different levels. Customer integration is a form of industrial value creation where "the consumers take part in activities and processes which used to be seen as the domain of the companies" The result is a system of co-production, i.e. a company-customer interaction and adaptation for attaining benefit [5].

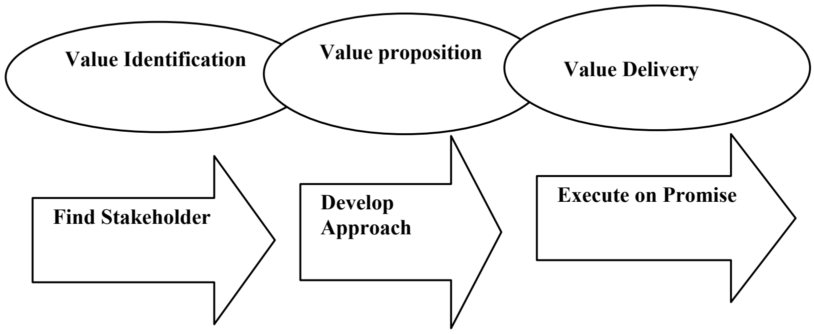

Figure 2: The value creation in a network [4].

Elements of Value Identification

The basic requirement to identify the value of an enterprise is to define the user needs as per the requirement in an enterprise. In order to execute this principle, first there is a need to find the stakeholder in the enterprise. The next stage is the value proposition stage. In this stage, the process of development undergoes as per the required approach. The right product is to identify with the required capabilities .The last stage is the program implementation [5]. A process is perfect through the gradual improvement. In order to achieve the perfection a continuous modifications is required. The customer determines the value of a product. This system is the pull system.

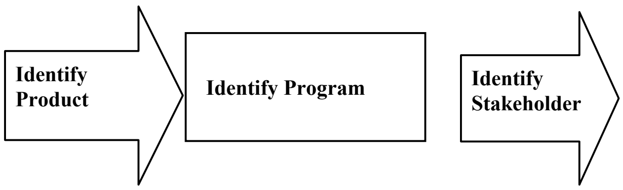

Figure 3: Elements of Value Identification [4].

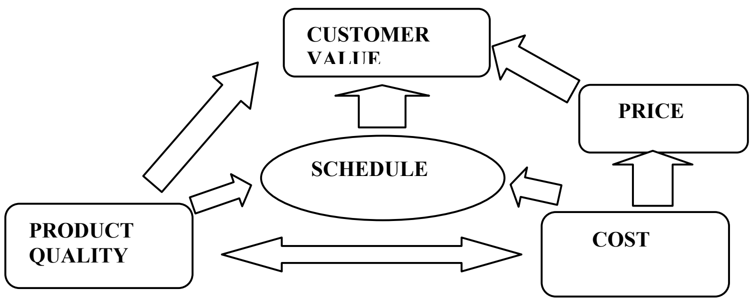

Figure 4: The customer creates the product value creation [4].

5.2 Enterprise Network Life cycle

The four stages make up the basic life cycle of all limited duration enterprise networks. [1].The first major stage is *creation*. This is also the most critical stage to the overall success of the network. The key activities in this initial stage include the definition of many crucial aspects of business, technology, and organizational strategy. The second major stage is *operation.* Processes in this stage include secure data exchange and information sharing, order management, dynamic planning and scheduling, and task management and coordination. A third stage in the life cycle of enterprise networks is *evolution.* Evolution stage handles the exceptions to routine operation, such as a change in the environment, a change of network membership, or other events that would necessitate a change in course and restructuring of the network. The final life-cycle stage is *dissolution,* when an enterprise network has reached the end of its useful life; either by completing its goals or through the determination of a network collaborates, and must dissolve.

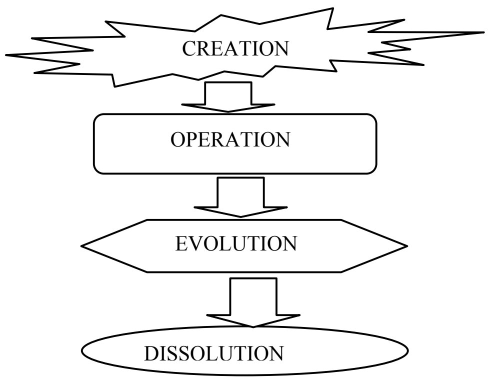

Figure 5: The Enterprise Network Lifecycle.

6. Stake Holders

A stakeholder is ‘any group or individual who can affect or is affected by the achievements of the organization’s objective’. [8].Shareholders provides capital and expects a positive return on their investment. This is the center of value creation. [9].

6.1. Organization

Organizations are generically a large number of people unified by common goals. Programs generally involve teams from many different organizations. They involve large subunits of organizations acting as coordination between the different departments. [4,10].

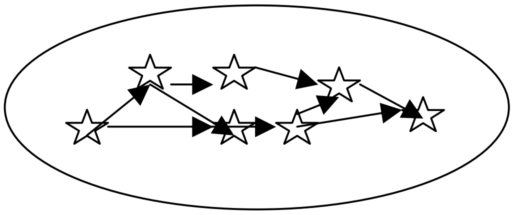

Figure 6: Organizational Network

6.2 Inter Organizational Network:

Enterprises have a specific purpose, distributed leadership, and stakeholders with common and diverse interests. The teams are a base on interpersonal relationships and face-to-face interactions, whereas the programs are base on both inter personal relationships and inter organizational relationships. [4,10].

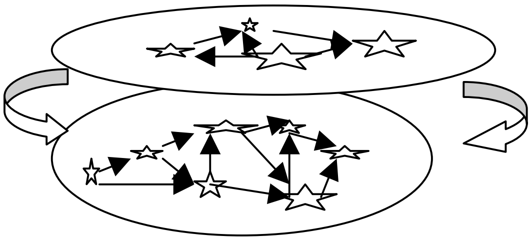

Figure 7: Inter Organizational Network

7. Conclusion

Integration of enterprises is the key element for the success of business structure in the future. The basic goal is to identify opportunities for integration and to establish strategies to overcome barriers to integration for the enterprise. Integrating the network should represent a perfect architecture. The strategy has been successful in large part. [10].

The identification of the Value Creation is an important factor in enterprise integration. The aim is to create the right products with the required value. This is the requirement with the efficient lifecycle and enterprise integration. The customer is a part of integration in the value creation of the supplier [11].

The key element of integration is to achieve through the seamless flow of information. This is through the utilization of latest available technology. The other element is the requirement of a perfect leadership and understanding between the different departments of an organization. The latest implementation is to achieve by eliminating the boundaries and barriers between the different departments and making it as a whole [11].

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Factors Influencing New Products Success in Small Brazilian Medical and Hospital Equipment Firms

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Abstract. *A research line in new product development (NPD) management is identifying success factors, that is, best practices that contribute towards reducing the unsuccessful in launching new products. The objective of this paper is identify and analyze these factors that influence project development success of new products in the Brazilian High Technology Small Firms (HTSF) of the medical-hospital equipments sector. The data were obtained by a survey in 30 HTSFs, located in the State of São Paulo, Brazil. The application resulted in a sample of 49 new product projects: 30 were considered as successful and 19 were considered unsuccessful. Initially, the association of the 64 variables investigated was measured with the result of the project product (successful and unsuccessful) by means of the respective coefficients of contingency. It was also sought to reduce the individual variables by using the Analysis of Main Components. Considering the characteristics of market-target the pre-development activities stand out. The successful projects are those in which user requirements are well served and correctly interpreted concerning specifications. Moreover, market assessment was properly carried out and the clients wanted the new product. Therefore, these companies should carefully manage such factors in the development of new products.*

Keywords. New product development management, high technology small firms, success factors, small brazilian medical-hospital firms.

1. Introduction

In new product development (NPD) management many strategies, methodologies and tools are employed aiming at improving efficiency, quality, speed and innovation indicators. In this case, the most innovative companies seek to adopt strategies and structures that can combine operational efficiency and high innovation capacity in NPD in order to continually develop new products.

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A traditional research line in the area of NPD management is the discovery of success factors, that is, best practices (tactics, methods, tools and techniques) that when well executed contribute to increase the probabilities for success in new product development [5, 6, 9,10, 12 13, 16, 18]. Many of these factors are related to Concurrent Engineering principles.

Concurrent Engineering comprises two basic principles: early involvement of all enterprise functions that contribute to a successful product and parallelism in the NPD activities. This requires changes in the organizational structure, culture and new approaches to management and control, with a focus on human resource management [14].

The grounds for executing the present work lie in the extension of knowledge concerning NPD management in specific settings. In this case, it is the Brazilian High Technology Small Firms (HTSF) in the medical-hospital equipment sector. The HTSFs have aroused the attention of the academic community, governments and economic representatives on account of their role in regional development. Such companies stand out because of their technological density in creating products, which makes NPD very important for these companies' sustainability.

The HTSFs are companies that develop innovative products based on technologies found in less mature stages of development, which, on the one hand, involves much uncertainty concerning the path that these technologies will develop, but which, on the other hand, possess much potential to expand in the market. However, in the Brazilian reality, the HTSFs occupy a lower position in the innovation process by, usually, develop their technology and market by means of imitation and by occupying small market niches [7, 15].

The objective of this paper is identify and analyze the factors that influence project development success of new products in the Brazilian High Technology Small Firms (HTSF) of the medical-hospital equipments sector. The paper focused on the manufacturers of medical-hospital equipment because this sector stands out for its technological dynamics verified in Brazilian research concerning innovation.

2. Success Factors of New Produc Development

The vast literature in the NPD area produced a collection of factors associated to the success of new products. Classical studies [8, 18, 19] served as reference to carry out the present work. A new product's success depends on the configuration and dynamics of controllable variables (inherent to the company) and non-controlled variables (the company's insertion ambience). In this article, the following factors were investigated: innovation degree, market-target characteristics, product characteristics, technology sources, company skills, project leader competency, integration, NPD organization, the development proficiency activities and proficiency of other activities related to new product development. These factors are briefly discussed to follow.

Market guidelines have been indicated as a critical success factor of NPD [4,18]. This factor approaches aspects such as the capacity of a company to assess market potential for the new product, to understand the needs of the market-target and to interpret such information into NPD language.

Various authors [3, 17, 19] identify many product characteristics that propel them to success: low cost, high quality, superior performance and unique attributes. Also acknowledged is the need to integrate the strategy of product development to other business strategies. Technology sources can also contribute for the success or failure of a new project, since they demand acquisition, adaptation and management capacities from the technology-based companies [17].

Competency levels of the areas involved in NPD have been correlated to the success and failure of new products [3]. In this research, technical competency was defined as the competency and capacity to accurately execute activities, interfering directly in the quality of the tasks that make up product development.

The main organizational aspects of NPD mentioned in the literature include the organization methods of project development, the degree of integration among the functional areas, the structure of NDP and characteristics of key-individuals involved in executing the project [11]. However, the foremost factors that affect NPD performance are: project team, project leader, manager's role and the involvement of suppliers and clients during project execution of new products [2]. In regards to execution of NPD activities, it is recommend that attention be given to pre-development, especially, while conducting technical and market studies and feasibility analysis [5]. Similarly, the quality in the activities of generation and analysis of ideas, technical development and market presentation are very important [9].

3. Research Method

The Brazilian industry of medical-hospital equipment is composed of 374 companies [1]. Based on criteria such as size (small companies with less than 100 employees and mid-sized companies with more than 100 and less than 500 employees), operation segment (equipment manufacturers), geographical localization (the State of São Paulo) and their own active NPD, totalizing 52 companies (in the State of São Paulo) that fit in the desired profile. From this number, 30 companies agreed to participate in the research.

For data collection, a questionnaire composed of 64 closed-ended questions was applied. It was requested that the companies choose two development projects that resulted in new products, where one was considered a success and the other one considered unsuccessful. All the answers were supposed to be grounded on the history, facts and situations experienced at the time of the project execution. The application of such procedures resulted in a sample made up of 30 companies and 49 new product projects, out of which 30 were considered as successful and 19 unsuccessful.

In the data treatment stage, various statistical techniques were applied. For the responses related to projects of new products, first, the association of the variables investigated was measured against the results of the product project (success and non-success) by means of the respective contingency coefficients. Thus, it was sought to determine which variables, considered isolatedly, elucidated the new product's success or unsuccess. Also, the individual variables were reduced and summarized by using techniques of factorial analysis, more specifically the

Analysis of Main Components. From the statistical procedures, the interpretation of the results enabled to find a set of factors (practices) that affect the success of product development in these HTSFs.

4. Analisys of Results

Each main component illustrated in Table 1 corresponds to a set of isolated variables (Table 2), which were reduced by applying the multivariate analysis technique, to facilitate data interpretation. The results in the Table 1 show the association coefficients and their respective significance levels (p-value) among ten main components (critical factors) and the result of the new product (success or not) for the companies. Table 2 shows the isolated variables considered significant for the companies investigated.

Table 1: Association: Main Components and the Result of the New Product

Main Components	**Eigenvalue**	**% Variance Explained**	**Association Coefficient**
Characteristics of Market Target	2,21	44,2	**0,630***
NPD Proficiency [1]	2,94	48,3	**0,576***
Integration	2,70	27,0	**0,534***
Proficiency –other activities	2,89	48,3	**0,484***
Degree of innovation	1,86	46,0	**0,436****
Project Leader Competency	4,14	51,9	**0,408****
Product characteristics	1,91	47,9	**0,327** $^{\alpha}$
Company competency	2,46	49,0	**0,278****
Organization	1,52	50,8	**0,208** $^{\alpha}$
Technology sources	2,25	32,0	**0,730** $^{\alpha}$

*Significant at $p \leq 0{,}001$ **Significant at $p \leq 0{,}05$ $^{\alpha}$ Not significant at $p \geq 0{,}1$

[1] Proficiency refers to thoroughness, completeness and competency in carrying out these activities

It was observed in Table 1 that there were three main components associated to the success of the new product: **characteristics of market target, proficiency of NPD activities and integration of areas involved in NPD**. The successful projects are those in which market assessment was well carried out and which had user requirements well interpreted concerning new product specifications

The first management implication of the research is to guide NPD to the market, that is, strategically align it to the needs of the client and the market. The consequence is that the companies need to develop competencies to constantly understand and assess consumer needs. From the data in Tables 1 and 2 it can be observed that placing a new product, based on superior performance compared to the competitors and the capacity to recognize and elucidate consumer needs, is important for these companies. Since marketing responsibility, in the companies studied, is basically done by personnel from the commercial areas, who maintain a close relationship with those responsible for product development, there is transference of knowledge concerning market needs, thus enabling those responsible for NPD to generate new technical solutions for such needs.

The results corroborated in the Characteristics of Market Target reinforce the need for greater efficiency in NPD activities, especially in the activities related to pre-development (generating ideas, sorting ideas, concept formulation and feasibility analysis), since they were indicated as critical for success.

Table 2: Association: Isolated Variables and New Product Result

Variables	**Contingency Coefficient ***	**p-value**
Innovation degree of product		
Use of platform product.	0.464	0.009
Characteristics of market target		
Market potential carried out well	0.426	0.034
Consumer desire for product.	0.526	0.001
Interpretation of needs.	0.567	0.000
Product Characteristics		
Superior technical performance than competitors.	0.483	0.006
Company Competency		
Technical competency of Manufacture area.	0.424	0.030
Project Leader Competency		
Interpersonal skills necessary for the project	0.394	0.029
Management skills necessary for the project	0.487	0.004
Team participation in project decisions.	0.423	0.014
Organizational characteristics - Integration		
Administrative management involvement and support	0.414	0.039
Participation – generating and selecting ideas.	0.463	0.010
Participation – feasibility analysis.	0.442	0.018
Proficiency of NPD activities		
Generating and selecting ideas.	0.513	0.001
Feasibility analysis (technical and economical).	0.437	0.021
Technical development (product project).	0.458	0.005
Product/market tests.	0.404	0.049
Preparation of documents – homologate product.	0.486	0.042
Proficiency - other activities		
Determine goals product objectives.	0.414	0.038
Provide project documentation.	0.474	0.008
Comply to legal norms necessary for product.	0.388	0.043

*Table 2 shows the individual variables considered significant for the companies investigated, which coefficients were over 0.38 (positive association of the practice with the result of the new product) and significant level below 5% ($p<0,05$).

The need for integration consists of the second management implication of the research. The Integration in table 1 indicates a strong association with the result of the product. Throughout the analysis of practices related to integration (Table 2) adopted during the course of the new product projects, it was found that the involvement of functional areas is fundamental during the pre-development phase.

In recent years, the substitution of a sequential model to execute NPD activities for greater parallelism has been emphasized in the initial stages of the development cycle. The formation of multifunctional structures has been adopted by companies as an alternative to surpass barriers created by functional specialization. The values assessed do not indicate significant differences between the organization manner of the project team and the result of the product (table 1).

In spite of it being a common problem faced by many companies, the HTSFs investigated did not report difficulties concerning integration in their functional areas. According to the interviewees, integration occurs naturally and normally, since proximity among the individuals, as a result of the small number of employees, emphasizes the level of contact and facilitates communication and information exchange.

A strong influence of the Commercial area in relation to product development was noticed. Owing to closer contact with the client, the commercial area becomes more responsible for eventual needs, for suggesting new product ideas and even partially or fully approving a developing project.

The third management implication refers to the proficiency of NPD activities. Similarly to the analysis of individual variables (Table 2), when examining the results of the association level of the main components (Table 1), it can also be verified that pre-development and project activities are factors that should be carefully managed in NPD activities by such companies.

It is believed that correct guidance of development activities is capable of facilitating the deployment of desired characteristics by the consumer and the company's strategic view during the entire development cycle.

Finally, the project leader plays an essential role during the developing process of a new product, since he is directly responsible for the organization and direction of the development team. Besides leading the team, the leader must know how to negotiate with the administrative board in order to obtain the necessary resources for the project. In order to perform this role, the leader must have managing and relationships skills that will enable him to construct an environment of trust, coordination and control. The results in Tables 1 and 2 reinforce the importance of a leader that possesses technical and managerial competencies related to the activities of developing projects of a new product.

It was observed that three main components (skill levels of the company, technology sources and types of organizational structures applied to development projects) contributed very little or not at all for the success or failure of products developed by those companies. In regards to competency levels, two hypotheses can be raised as explanations of the results. The first one is a more complacent judgment by the responders, when they do not directly hold the functional areas accountable, due to ensuing problems and mistakes that took place during the unsuccessful projects. Another hypothesis suggests that the successful projects, as well as the unsuccessful ones, relied on appropriate endeavour and effort from the personnel of the departments involved. In this case, the failure can be explained by other reasons than lack of technical capacity.

5. Final Considerations

This paper analyzed practices adopted during the execution of development projects and their impact on the results of the new product, in a specific type of company. The limitation in this exploratory study is the fact that it was carried out with a small sample of Brazilian companies pertaining to only one sector of the technology-based companies.

The four management implication highlighted in this paper reinforce concurrent engineering principles, which enable the companies to continuously innovate. Concurrent engineering is defined as a systematic approach to paralell development of all product life-cycle activities, from inicial conception through desing, planning, production and disposal. It encourages right-first-time methods through cross-functional team working and consensus.

The increase involvement of the functional areas with NPD (integration) was observed, mainly in the pre-development activities. When the solutions appear in initial stages of the development, it become more evident the shortening of the time expended in some procedures, what it contributes to attenuate or even to eliminate errors in more advanced stages of development, favoring the anticipation in the launching of products in the market. For small firms, correct involvement of the functional areas in this stage can guarantee the rational use of resources employed in product development.

Notwithstanding, some results are not compatible with success factors in the literature about critical factors of success in NPD. Seeing that they are high technology firms, it was expected that the acquisition process and technological transference would be critical for such companies. However, this hypothesis was not verified with the results of the research. Another issue is related to the type of organizational arrangement in the development of a project and the success of a new product. It is perceived that cross-functional teams represent an important form of integration. However, the functional approach seems to be more common in the companies investigated. Nevertheless, the most natural behavior found in the small and mid-sized companies ends up compensating potential deficiencies of such organizational arrangement.

Especially in environments where the technological level is high, the improvement of the process of communication among the individuals and sectors, becomes a determinative factor for the success of the work. It was observed, therefore, the support of “project leader” for the success of the new product.

Market guidance, concern with efficiency and activity effectiveness of NPD, integration of know-how and leadership are key elements in any model of product development. NPD must combine technical elements that need to be planned and natural behaviors that bring diversity to the organizations. One can add to these elements a vision that adapts to contingencies as a way to promote new process configurations, structure and resources.

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Systematic for Increase of the Operational Efficiency from the Allocation of Resources in Intangible Assets

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Abstract. The present article presents a model for the operational efficiency management from the identification and allocation of resources in organizational intangible assets. For that, the identification of the intangible assets that are linked to priorities strategic products are used, considering these last ones as the ones which determine the organization's economic sustainability. Concomitantly, organizational objectives are established that are compatible to the development of performance indicators, linked to intern intangible assets from the organization, classifying them according their contributions for the reach of the goals of the manufacture's section. Besides that, it is aimed at establishing criteria for the application of resources in the elements which form the intangible assets that are considered crucial to the maintenance of the production capacity.

Keywords. Intangible assets, manufacture, operational efficiency and performance indicators.

1 Introduction

It can be observed that the need for better levels of the organizational assets used in the intern context still constitutes an imperative one, once they can raise the performance of the manufacture, adjusting it to the reach of the strategic goals. It is assumed that the compatibility of these goals can be reached by the demonstration of better levels of acceptance of the products offered for consumer market. Furthermore, by the consideration of the profit margins decurrent of the improvement in the execution efficiency of production activities in an operational level. It is aimed at the identification of organizational intangible assets in order to

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reach better levels of operational efficiency and an establishment of evolution indicators of the performance for production processes.

Therefore, present states of the art concerning intangible assets with the justification these same assets have for organization performance, the systematization of a model that promotes the correct application of resources in intern intangible assets considered critical (from the management of operational efficiency levels in the manufacture activities), the application context and future results this job, considering that the intangible assets can characterize competitive differences for products that allow for the reach of the organizational strategic goals.

2 State of the Art

Individual and collective can be augmented by intangible assets, the definition of this is neither concise nor uniform. In order to define the internal intangible assets effect, we shall initially use the taxonomy advanced in [6] which defines internal intangibles as organizational resources that the company utilizes. Their correct application generates results in the form of products (tangible and/or intangible) derived from a specific organizational structure (internal concepts targeting to increased value), applied to the production of goods and services that aim to generating perceived benefits.

The identification of intangible assets for the growth of organizational performance is born out of the need to provide supply differentiation. This supply embodies the perspective of superior value attributed to products and services, derived necessarily from the organizational capacity to contemplate distinct market demands. Thus, it becomes necessary to analyse the way that internal intangible assets energize organizational performance with a focus on the efficiency of production operations. This way it demonstrate the relevance of these assets in maintaining better levels of economic performance of organizational activities.

At the same time, research suggests that there is a need for management methods that are adjusted to goods production (tangible and/or intangible assets) with the goal of providing constant revision of the means to instigate operational efficiency, by identifying potential intangible assets.

2.1 Intangible Assets as Criteria for Organizational Performance

During the development of a business proposal, the valuation of the assets to be used in order to reach the goal of economic ally profitable production obeys a logic of "subjective" rationality, according to criteria defined by the owner of the assets.

However, the sum of individual values in the assets used for pursuing the enterprise mission hardly represents the total value of the organization. Thus, the failure to determine a total value of the organizational assets leads to the appearance of the goodwill that for [13] represents an obstacle to the managers information, and is called "a repository of unexplained values".

Using the observations in [5], the best measure of the performance would be its subjective value in the eyes of the managers. By the observations in [14], from the perspective of management, the value of the company would be called “intrinsic value of the company”. The subjective concept of goodwill stressing that the interests of the proprietors should not oppose other interests, seeing that all the other interests (stockholders, shareholders and stakeholders) would be residual and would depend on the in achievement. From the perspective of economic management, such an assertion does not lack validity. However, it makes it necessary to consider non-economic interests that also affect the organizational performance [13].

2.2 Composition of the enterprise assets

The intangible asset, when understood systematically, consists of relationships between different forms of assets - tangible and intangible. Thus, the company must be analysed in its entirety, where, as in a system, its parts can contribute to the pursuit of the established goals *a priori* [10].

Additionally, its worth to mention that the composition of the assets and the metrics used for the performance measure does not always accommodate strictly economic and financial aspects. Factors such as maintenance of the competitiveness levels trough innovation and also new and better ways for product conception, which allows the development of complementary abilities, also show the need to accountability and parallel management [12].

By finding common characteristics between the typologies of intangible assets, it is possible to set parameters in order to formulate rules for the recognition of these assets [7]. The considerations of [9] are perfectly adjustable to the goals of identifying this study, as a way of intangible assets that belongs to the organization. However, it is necessary to demonstrate how the intangible assets can work as elements that let the operational efficiency emerge. Next, the stages and steps needed for the proposed model conduction are described.

3 Model Stages Description

The Stage 1 (Preparatory Stage) aims at describing the way of analyzing the portfolio of the company’s products to identify which product groups lead to a bigger contribution to the business. In Stage 2 the intangible assets linked to the products considered strategic to the business are identified, which therefore, must be primed. In Stage 3 are goals established and sorted by hierarchy of the manufacture, taking in consideration the levels of operational efficiency for the primed strategic products. Stage 4 proposes performance indicators for the primed strategic goals. Stage 5 finally establishes criteria for allocation of resources in intangible assets which are considered critical.

It observed that the model considers the occurrence of feedbacks between steps/stages/steps that propiciates a better visibility of its goals in the model scope.

3.1 Stage 1 (Preparation Stage) – Analyzing the portfolio of products

This Preparation Stage has the goal to analyze the current portfolio of the company's products. In this case, the positioning map adopted by Siemens [4] will be used, looking for positioning the products in homogeneous groups demonstrating their representation, using the analysis of market tendencies determinant factors and the profit percentage desired for each group.

3.1.1 Step 1 – Define products attraction levels
This step aims at positioning homogeneous product groups that determine a positive correlation between the market tendencies and the desired profits percentage.

3.1.2 Step 2 – Prime strategic products
Having positioned each product that belongs to the analyzed portfolio, the strategic ones that demonstrate a positive correlation between the considered variables (market tendencies and profit percentage) will be considered. It is presupposed that the group (or groups) of products with these characteristics can support the economic sustainability of the business from average to long terms.

The products (group of products) considered more attractive and competitive will be named Primed Strategic Products (PSPs), which will be considered prior having in mind the calculation of its efficiency levels in Stage 2 (Step 5).

It is followed with the identification of the intern intangible assets related to the PSPs.

3.2 Stage 2 – Identifying IIAs from the PSPs

To determine what the intangible assets are, the concept of [10] will be used that defines them as: the generators in the organizational context, the originators of research and development that effectively can represent future industrial or intellectual property rights and the criteria according to the normalization of intangible assets defined by FAS 141 (Financial Accounting Standards) [7]. In a complementary way, for the framing of which intangible assets are considered intern to the company (IIAs), the proposal elaborated by [12] is used due to its concision of separability criteria of the organizational intangible assets.

3.2.1 Step 3 – Identifying intangible assets related to the PSPs
This step has the goal to identify which intangible assets are related to the PSPs. This way, the relations of intangible assets that can generate future profits for the company.

3.2.2 Step 4 – Determining organization IIAs
With this step intended to identify the intern intangible assets that reside in the company. Using the considerations in [10 and 12], it will be distinguished which intern intangible assets belong effectively to the organization.

The calculation of the value referring to the IIAs will be effectuated, having in mind the qualitative variables (human, processes, structural and environmental), that represent the squares that need to be considered in the value determination of the intangible assets according to the methodology [9].

3.2.3 Step 5 – Calculating levels of efficiency for the PSPs

Yet, considering the presupposed efficiency determination from the intangible assets consideration leads to the below equation 1.

$$\text{Efficiency} = \frac{\text{Tangible Exits}}{\text{Entrances (Tangible Assets + Intangible Assets)}} \quad (1)$$

The goal is to determine the participation of the IIAs in the manufacture of the PSPs, focusing the section efficiency of the manufacture unit. In this case, the levels of efficiency calculation for the PSPs.

Considering the achievement of very distinct section levels of efficiency, it is not possible to establish an average level of efficiency for the sections involved in the PSPs production. This step will serve as a base for the determination of the manufacture and sections goals (SGs) according to what is described in Stage 3.

3.3 Stage 3 – Establishing and sorting the manufacture and section goals by hierarchy

Considering the exposed in Step 4, this stage is establishing and sorting the goals of the manufacture by hierarchy that are directly linked to the maintenance and the improvement of the operational levels of efficiency in the effective use of the intern tangible and intangible assets related to the PSPs, according to what is described in Step 5.

3.3.1 Step 6 – Determining the goals of the manufacture for the production of the PSPs

This step determines and sorts the goals of the manufacture by hierarchy in order to reach the operational levels of efficiency close to 1 (one) for the PSPs with related IIAs.

The order of the hierarchy of the manufacture goals (MGs) will obey the higher punctuation obtained in a decreasing scale. Obtaining equal punctuations, the hierarchy will be established by the relation of the goal with the manufacture section in which the PSP obtained the smallest level of efficiency.

3.3.2 Step 7 – Establishing manufacture section goals

Through an agreement between the section's managers of the units that compose the manufacture related to the execution importance of each MG established in Step 6. This way, reaching the manufacture goals will be accomplished by section actions, from now on determined SGs.

3.4 Stage 4 – Proposing performance indicators of the manufacture (PIs) related to the IIAs for the manufacture sections

This stage aims at proposing PIs that are related to the IIAs. For that, it must be considered the occurrence of different indicators for each kind of PSP and also having in mind the different form of utilization of the same IIA by the involved sections.

3.4.1 Step 8 – Proposing indicators related to the IIAs for the manufacture sections
To define the relations of PIs with the section goals in the production of the PSPs, considerations obtained from [15] will be used for the determination of the performance indicators of the manufacture with adaptations. Therefore, haven adopt as a reference the following question: "The performance indicators of manufacture have any relation with the IIAs?"

3.4.2 Step 9 – Establishing importance levels for Performance Indicators for the Intern Intangible Assets (PIIIAs)
The procedure is adopted from the importance level identification of each PIIIA, based on the "Source of Relations between the Manufacture Goals and the Performance Indicators Related to the Flexibility" [15]. Parallel to that, determining the level of importance of the indicator to be adopted by the section, using the information contained in Step 7.

3.4.3 Step 10 – Calculating levels of criticality and contribution margins of the IIAs
With the goal of using the IIAs as effective instruments of the growth of the manufacture operational efficiency, it is necessary to effectuate the calculations of its contribution margins and levels of criticality for the reach of the SGs.

3.5 Stage 5 – Establishing resources application criteria in critical IIAs

With this stage the allocation of resources in IIAs considered critical to the raise of the efficiency levels in the manufacture context, in a way that these IIAs proportionate the more rational utilization of other tangible assets categories. For this, a priorization order must be established for the use of the IIAs with the necessities pointed by the manufacture managers.

3.5.1 Step 11 – Defining elements that forms critical IIAs
The goal of this step is to identify elements that supply the elements necessary for the creation and maintenance of the IIAs in the manufacture context. These elements are: human resources, processes, organizational structure and environmental factors [9].

3.5.2 Step 12 – Priorizing the allocation of resources for the elements that form the critical IIAs
With the calculations of the contribution margins of each element that compose the IIAs and that are considered critical to the manufacture (by section), it is aimed for

information that can help to establish priorities in the application of resources in the elements that form the IIAs.

4 Development Context

Nowadays, the priorization form of portfolio of products is a very complex skill, due to different knowledge about concepts of the value of choice for different segments of the market. Working with the perception that intangible assets can be used as competitiveness criteria, for the units of manufacture is necessary knowledge about intangible assets to consider better levels operational efficiency. This way, the described model can be applied in manufacture context. It is the intended to inquire the significance in the improvement of intangible assets in better levels of internal efficiency.

5 Theoretical and Pratical Results

This section demonstrates the importance of the relations between intangible assets and processes of production for new tangible and intangible assets. However, the intention is to diagnose the contribution of the intangible assets for development indicators of the enterprise, considering the presents theoretical and pratical instruments that support this task. The principal practice objective is knowledge for manufacture units managers of the effective contribution of the internal intangible assets are considered strategic for maintaining the economy of business.

6 Conclusions

This study developed a managing model of the operational efficiency from the allocation of resources in intangible assets in the manufacture of products context (commodities and services). Furthermore, criteria for the allocation of resources in intern intangible assets considered critical to the production activity were established, incorporating the organization's aim for knowledge of the market's preferences to be attended, as well as taking advantage of opportunities with consequent alterations in the general pattern conceptions, in the fall or raise of profits that result in significant oscillations in the consume power.

This way, through the consequent model's application is expected to obtain a superior development of activities connected to the manufacture segment through the destination of intangible assets resources.

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Geotraceability and life cycle assessment in environmental life cycle management: towards sustainability

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Abstract. Sustainability is an emerging concept in product chains and integrates environmental, social, and economic aspects during the product's life cycle. Recently, the demand for environmental quality has required information about the products'life cycle. Life Cycle Assessment (LCA) includes the inventory analysis, where the inputs, outputs and feedback mechanisms of matter and energy for each phase of the product life cycle are systematized, and the Life Cycle Impact Assessment, when the environmental impacts potentials are calculated. A powerful tool to describe the history, use, and location of a product is called geotraceability. This paper presents an environmental life cycle management for storing and retrieving product life cycle data within a food chain (tracing), as well as following the location of the product in real time (tracking), particularly for recall operations in case of a crisis. Information about inputs and outputs can be structured and integrated through LCA. Geographic information can be obtained from satellite imagery and positioning systems. The development and integration of these tools will add value to products and enhance food safety to consumers, as well as the environmental quality within the production area, fostering environmental sustainability to the product life cycle.

Keywords. Environmental Life Cycle Management, Geotraceability, Life Cycle Assessment, Sustainability

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1 Introduction

Sustainability presents many definitions but the basic principles and concepts remain constant: balancing the economy aspects, protection for the environment, and social responsibility, so they together lead to an improved quality of life for ourselves and future generations. "This concept of sustainability encompasses ideas, aspirations, and values that continue to inspire public and private organizations to become better stewards of the environment and promote positive economic growth and social objectives. The principles of sustainability can stimulate technological innovation, advance competitiveness and improve our quality of life" [1].

The environmental, social, and economic impacts of the products have to be analyzed according to their life cycles. Product life cycle thinking is important in the path towards sustainability by expanding the focus from the production process to the product life cycle (figure 1).

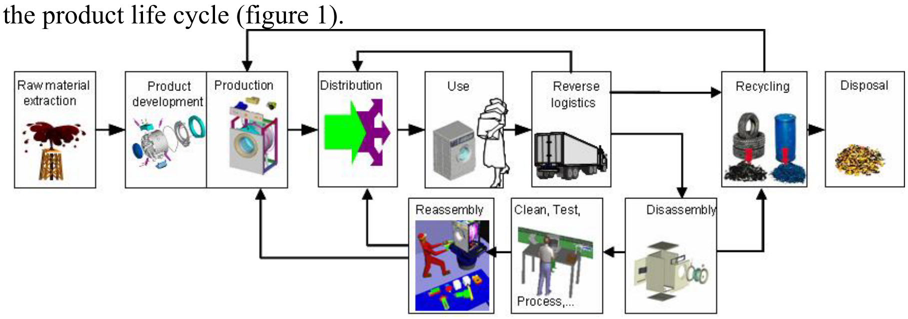

Figure 1. Product Life Cycle [2].

The importance of such topic is related to recent demands and regulations taking place in some countries, especially in the European Community, based on an Integrated Product Policy, including the:

- Directive on Waste Electrical and Electronic Equipment (WEEE - 2002/96/EC) and Directive on the Restriction of the Use of Certain Hazardous Substances in Electrical and Electronic Equipment (2002/95/EC);
- General food law 178/2002, "hygiene package" (Regulation 852-853-854/2004), and implications for non EU Countries of the new legislation on Food and Hygiene; geotraceability systems can comply with requirements along the whole food chain;
- European action plan for organic food and farming: the principle of a "trace and track" decisional operational system based on a multicriteria approach could be applied to organic farming and further away, for example, to landscape management or risk assessment;
- Environmental Technology Action Plan (ETAP), which encourages developing countries to use environmental technologies, for their potential to improve both the environment and economic competitiveness; a geotraceability system can promote new communication technologies to provide management tools allowing

impact mitigation on natural resources and fostering best land use practices.

This paper focuses on a cutting edge aspect related to environmental management taking in account the life cycle thinking. In fact, our goal is to integrate geotraceability and life cycle assessment as tools for an environmental life cycle management.

2 Environmental Management

Environmental management can be defined as the management of human activities so that natural resources are used adequately to meet human needs and the environment's continuing capacity to provide those resources is sustained [4].

This approach is illustrated in figure 2, which shows the phases required to achieve the environmental viability of an activity.

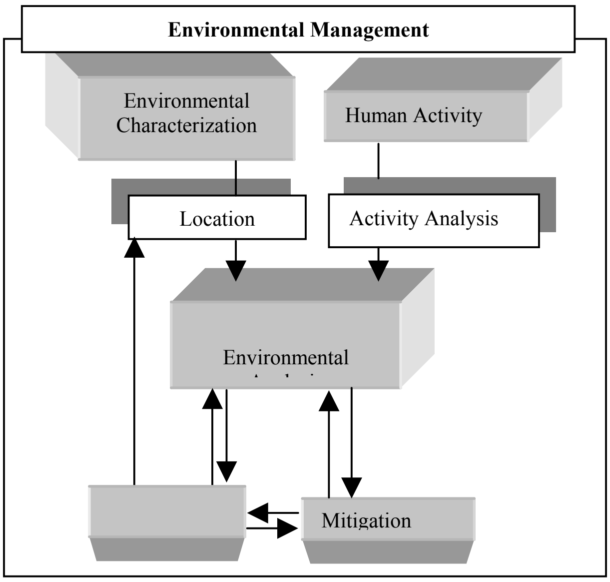

Figure 2. Environmental management diagram [3]

Knowledge about the environmental aspects of a production area, including physical, chemical, biological, social, economic, and cultural characteristics, is of primary importance to determine the potential of such area regarding the product's life cycle. Knowledge about the human activity is also crucial, as it will indicate potential impacts on matter cycles and energy fluxes. The environmental analysis evaluates the need of impact mitigation.

3 Geotraceability

Geotraceability is the ability of describing the history, the use, and the location of a product, allowing tracing and tracking from its production to its consumption. Thus, it is necessary to retrieve and store information about the characteristics and the history of the product (tracing), as well as to follow its real time location (tracking), in particular for recall operations in crisis situations, such as the avian influenza.

The importance of such tools is evident, as they integrate a spatial component to the product life cycle, adding value to market products, to certification and labeling in retail business, and to communication with consumers, with the potential. to subsidize future policies for the sector.

Geotraceability may be used to increase confidence in products being acquired by consumers through the knowledge of their trajectory, safety, and quality from production to consumption. The process is carried out through standard spatial indicators, in conformity with defined norms, to integrate information from various sources, quality, and scales of observation. Much has to be improved in terms of standardization, but efforts have been made in several countries. All these issues are associated with the availability of information and knowledge about the product chain.

Some food chains are particularly important due to the emerging sanitary risks attached to international commercial relations [6]. For obvious reasons, beef is among the most important products to be tracked and traced using a spatially explicit system.

In Brazil, various sectors are interested in such tools, as they may become crucial in the near future. Recently, a specific support action proposed by a partnership among Cemagref (France), University of Laval (Canada), Embrapa (Brazil), and Cirad (France) was funded by the European Commission. Its goal is to develop an operational management and geodecisional prototype to track and trace agricultural production, with a major focus on the beef chain (figure 3). The prototype will be implemented in Campo Grande, where Embrapa Beef Cattle is located.

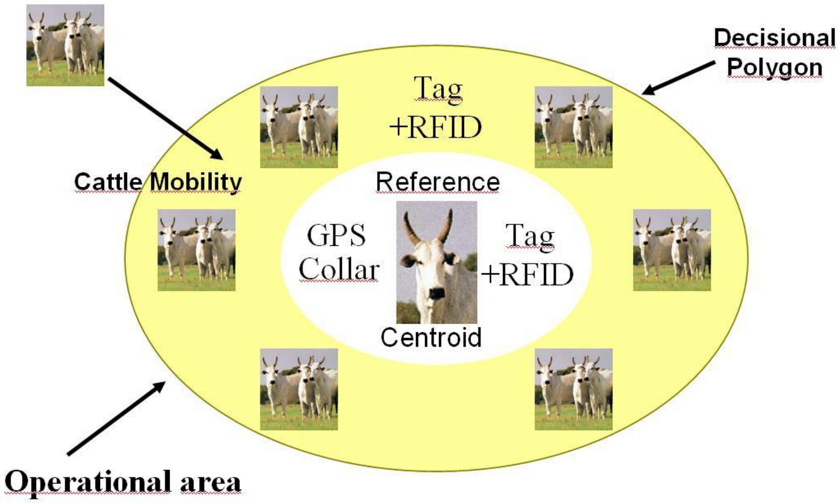

Figure 3. Framework for an operational management and geodecisional prototype to track and trace beef production .

4 Life Cycle Assessment

The first examples of environmental assessments of products were carried out for packaging in the 1960s. Twenty years later, the interest about environmental impacts grew and Life Cycle Assessments (LCA) were used in several European countries to compare different packaging processes. Recently, many complex products have been assessed through LCA and. companies have used it in product development, environmental management, marketing, and labeling. Consumer organizations have also used LCA in counseling consumers [7].

Life Cycle Assessment (LCA) is a tool for the systematic evaluation of environmental aspects related to a product or service system through all stages of its life cycle. LCA provides an adequate instrument for environmental decision support. Life cycle assessment has proven to be a valuable tool to document the environmental considerations that need to be part of decision-making towards sustainability. A reliable LCA performance is crucial to achieve a life-cycle economy [5].

The International Organization for Standardization (ISO) defines the methodological structure of LCA in four phases [5] (figure 4):

Goal and scope definition: the product(s) or service(s) to be assessed are defined, a functional basis for comparison is chosen and the required level of detail is defined.

Inventory of extractions and emissions, called Life Cycle Inventory (LCI): the energy carriers and raw materials used, the emissions to atmosphere, water and soil, and different types of land use are quantified for each process, then combined

in the process flow chart and related to the functional basis.
Life Cycle Impact assessment (LCIA): the effects of the resource use and emissions generated are grouped and quantified into a limited number of impact categories which may then be weighted for importance.
Interpretation: the results are reported in the most informative way possible and the need and opportunities to reduce the impact of the product(s) or service(s) on the environment are systematically evaluated.

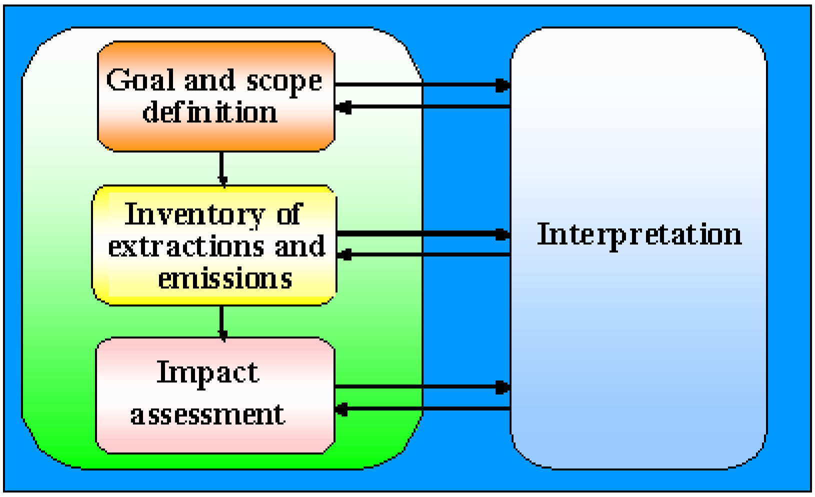

Figure 4. The phases of LCA [5]

The main expected results from the LCA are to identify and quantify the environmental loads involved; e.g. the energy and raw materials consumed, the emissions and wastes generated; to evaluate the potential environmental impacts of these loads and to assess the options available for reducing these environmental impacts [5].

5 Environmental Life Cycle Management

Environmental Life Cycle Management (ELCM) is the environmental management based on life cycle thinking.

The application of geotraceability and LCA can be practical tools for an ELCM. Based on figure 2, the environmental characterization, location, the environmental analysis which takes in account the caring capacity, and monitoring can be carried out through geotraceability. The human activity analysis can be carried out through LCA, as following: the Activity Analysis can be made by the LCA scope definition and LCI; the Environmental Analysis can be made by the LCIA, considering the caring capacity; and the Mitigation options can be made by the LCA interpretation (figure 5).

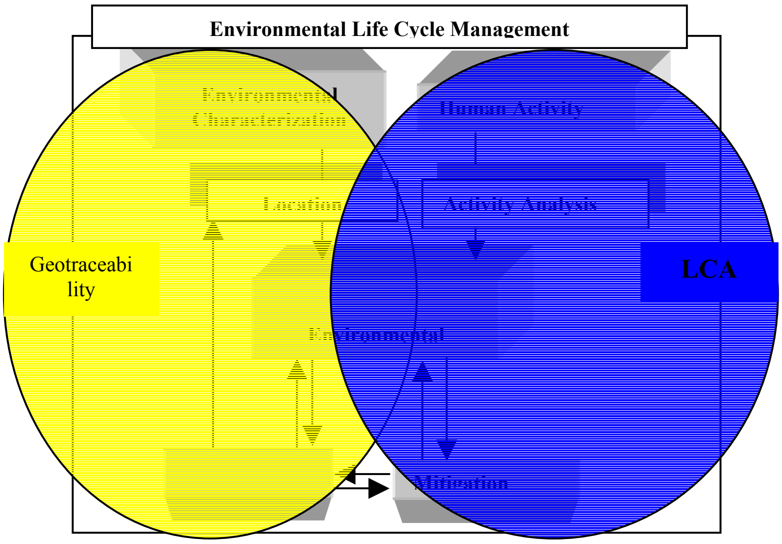

Figure 5. Geotraceability and LCA application in ELCM

6 Conclusion

Geotraceability and LCA are important tools with the potential to introduce, in a practical way, the life cycle thinking in environmental management (i.e., ELCM).

The adoption of geotraceability systems and LCA can enhance product safety and quality, providing industries, consumers, and all stakeholders with a level of information compatible with the demands of a global market and with the need of effective environmental management, taking in account the environmental characteristics and the product life cycle.

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Enterprise Architecture for Innovation

Experimentation of an Enterprise Architecture in aerospace electrical engineering process

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Abstract. This paper deals with an experimentation of Enterprise Architecture practices applied to a case study spacecraft electrical engineering domain. Viewpoints conforming to IEEE Std 1471 definition were built from popular architecture framework such as Zachman. Particular issue in the field of enterprise engineering was reviewed such as: metamodel for vertical integration, normative corpus for reasoning and modelisation language choice. A reference structure is presented as a starting point for metamodel creation. We have conducted an implementation with System Architect tool. According a waterfall approach, the user scenario maps step by step software components and functionalities into disciplines business needs and business strategy. IT and business users have provided early feedbacks for an operational use in engineering scope.

Keywords. Enterprise Architecture, Enterprise Modeling, Electrical Engineering Process.

1 Electrical Business problematic

EADS space transportation is one of the major actors in aerospace industry. The multinational unit develops products and capabilities in orbital systems, launcher, ballistic missiles, system design integration, propulsion and equipment. The total sales result in 2004 was 2.6 billions for 11.000 employees[1].

The electrical department is in charge of design and development of embedded electrical systems and ground electrical systems. This study focuses on the development of electrical cables and connectors components as part of the final launcher.

The electrical product development involves many actors from the design phase to manufacturing and integration phase. Theses phases make use of intensive collaboration between disciplines in concurrent engineering processes; in our context these processes are distributed on several locations.

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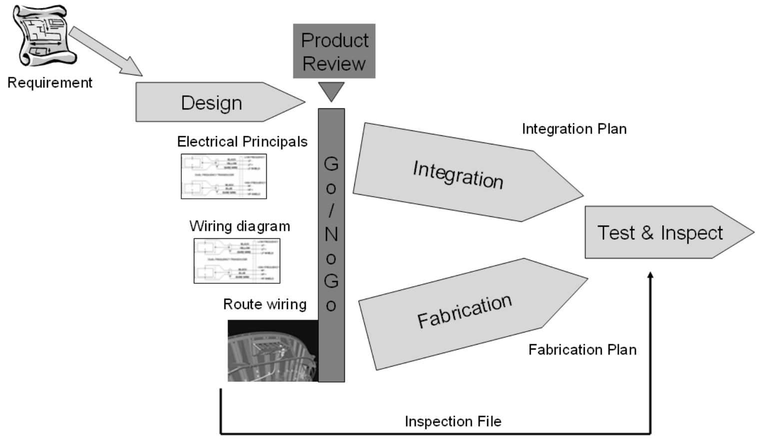

Figure 1. Electrical Business Process overview

The complete product development requirement is specified by the program management. At this level, product interfaces and functional requirements stage evolve with contractual acceptance of the client. The electrical department is in charge of enriching the technical solution with electrical business dossier for integration, fabrication and validation. A program commission states on design solution by evaluating technological risk, time and budget.

The problematic we address is an harmonization effort between multinational entities. The harmonization targets enterprise methods and tools such as CAD, exchange repository, data format, wiring diagram layout edition. Effort aims at a better integration of distributed business location by achieving common understanding of data, process and IT technology. The challenge is to plan roadmap to reach a common target from the actual background and legacy systems (As-is) to a future platform (to-be). The project involves multi stakeholder from business manager to IT engineer. Each concern should be represented and communicated efficiently to produce insightful vision. The problem to be solved is to identify technical and business criteria to identify high added value processes and information systems.

2 Enterprise Architecture

Current economic competitivity forces enterprise to lean their manufacturing and mangement operations to be more productive and efficient. Technological information potentially extends business capabilities by enabling collaborative practices on virtual product [2] and by enabling share space through Product Data Management solution [3]. Enterprise Architecture is a discipline that considers the enterprise as a system.

Architecture intends to capture components of a system, their organizations, and the relation to the environment. This definition is provided in the IEEE Std

1471-2000 [4] which gives a frame of reference and set of definitions targetting architectural description.

The standard defines the entity *model*. In our case model encompasses ER (entity relation) grammar such as UML Class Diagram [5,21], Process grammar like BPMN (Business Process Modeling Notation) [6], but also DfD (Data Flow Diagram) grammar such as Gane & Sarson diagram [7].

Stakeholder and associated *concerns* [8] are expressed into *viewpoints*. A *view* may consist of one or more *models* conforming to *viewpoint*. The standard does not provided recommendation for *viewpoints* choice [9]. External reference viewpoints are provided by many frameworks [10]. We review for the purpose of the study many architectures: Zachman Framework Architecture [11], Department of Defence Architecture System View [12], 4+1 views [13], TOGAF [14]. We focused on Zachman as a framework to think and organize viewpoints and DoD AF for ready to use system definition view.

3 Architecture exploitation mode

Information about relation and properties of elements to be managed is given by actors and available procedures documentations. Experience and know how can be extracted from different interviews. Elicitation method depends on the task [15]. Formalization range is defined in early phase of the architecture life cycle in accordance with stakeholder interest and needs.

Interest and concerns participate to build exploitation mode. Most interests are leaded by harmonization effort to build common policy in product management and to identify common IT building blocks that enables process and method. Business units' integration requires exchange capabilities at technological level and process level.

The architecture was designed to deliver model for communication and for supporting balanced decision. Elements associated to domain criteria such as time and cost provide key driver for discussion. The architecture aims at providing indicators to build and implement a target (to be) IT and process reference, and identify path from the (as is) architecture.

From the electrical perspective, the raised questions were which electrical process should be optimized, and what is the best support to communicate efficiently from business point of view to IT engineer. Further identified functions were to manage evaluation of method and tool change impact. Scenario provides a frame to elicit user query and possible solution that the architecture could provide in decision process.

4 Building electrical viewpoint

An informed decision is taken by balancing multiple criteria. In order to tackle different goals and concerns in the architecture, we designed a set of viewpoints to collect independent but interconnected models. From business to IT capabilities we defined: Business Context, Business Functional, Discipline Capabilities, Application Architecture and Infrastructure.

Viewpoint definition conforms to IEEE 1471. The viewpoint is structured by properties such as the name, eligible stakeholder, stakeholder concern addressed by the viewpoint, language and modeling techniques, the source of the viewpoint. In our case viewpoints inherits from Zachman's cells [16] and DoD AF system view [17]. Viewpoint is further described with analysis and evaluation method to be applied within the view, with any formal or informal completeness checks associated to the underlying method, and with any patterns or guidelines for model creation and reviewing.

Two viewpoints are represented here in table 1: discipline capabilities and IS architecture.

Table 1. Business and IT viewpoint definition

Name	Discipline Capabilities	Applications architecture
Eligible stakeholder	Electrical engineer in the design, production and integration field	IT analyst and engineer
List of concerns	How the people are working (business process) to fulfill enterprise function? Which are the associated applications ? What are the processed data? Who are involved in the business process? Where are entities involved in exchanged?	Which technologies are used? How applications are divided into module? What is the interface between applications? How exchanges are constrained? Applications support which operations?
Modelling techniques and associated definitions	BPMN (process, message flow , event, sequence flow, pool, lane) Entity Relation (element, relation), Organization chart (organizations units, decomposition relation, role) and matrix edition (elementary business process to data element, to application, to role, to technology)	Data Flow diagram from Gane&Sarson (Process, Data Flow, Physical Flow, Data Store, External), UML Class Diagram (Class, relation), Custom diagram based on Gane&Sarson and named System Architecture Map (Application, data flow)
Viewpoint's source	Zachman Business model	DoD AF system view SV1, SV4, SV5
Evaluation method	Conformance of business process to electrical operations, design and assess to-be process	Overview of applications deployment and exchange. Understand the current state and prepare a to-be architecture
Completeness checks	Elicit experiment rules to assess viewpoint consistency e.g.; consistency description of elementary business model with associated applications, technology, roles, data element. Theses checklists could specify synchronization of element from different grammar and reference to scenario description.	
Guidelines	Internal resources that describe and improve modelling comprehension	

Structured guideline advices good practises in model exploitation and model creation. It provides to learner but also to confirmed practitioner method to verify completeness and correctness in designing and reviewing architecture elements (i.e.: naming rules, existing equivalent element to be reused).

Viewpoint prescribes definition and modeling techniques. Small artifact, term and grammar enable to cut the complexity into a set of clusters [18]. More precise viewpoint can be added. Construction of architectural viewpoint allows people promoting specific concerns [19,20]. It offers opportunity to foster exchange between communities such as business manager, IT engineer, discipline actor [22].

Two views were implemented according previous viewpoint. Some extracted models are inserted below.

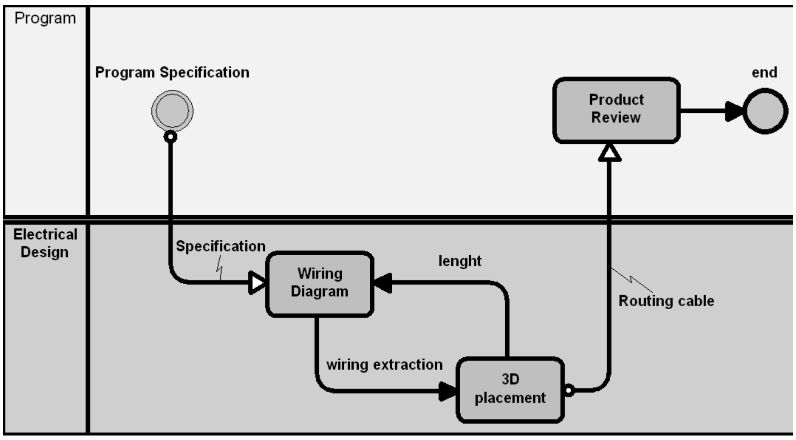

Figure 2. Electrical design Process in BPMN

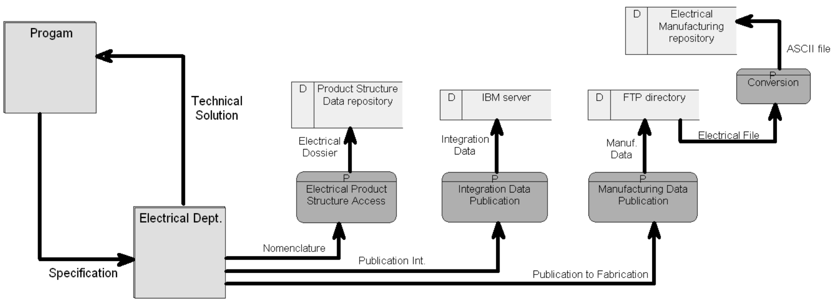

Figure 3. Electrical Design repository access

The first diagram is a big picture of electrical design process. The second diagram shows data repository accessed by electrical department after "program commission" approval of the design solution.

Electrical business process provides a description in BPMN. Association between process and actor is provided by horizontal pool in BPMN diagram. In addition to the graphical description, templates describe each element of the grammar with attributes, link to other elements and textual description. The description provides input for simulation and analysis purpose.

5 Reference construct and metamodel for interogation

Function of the information model is supported by element properties [23]. Graphical symbols and diagram depict a point of view by using dialects compliant with a grammar. The choice of a grammar is balanced between expressivity and complexity [24]. In order to allow problem solving across several viewpoint elements, an integration is required at different level. For that purpose we developed a construct reference for metamodel creation.

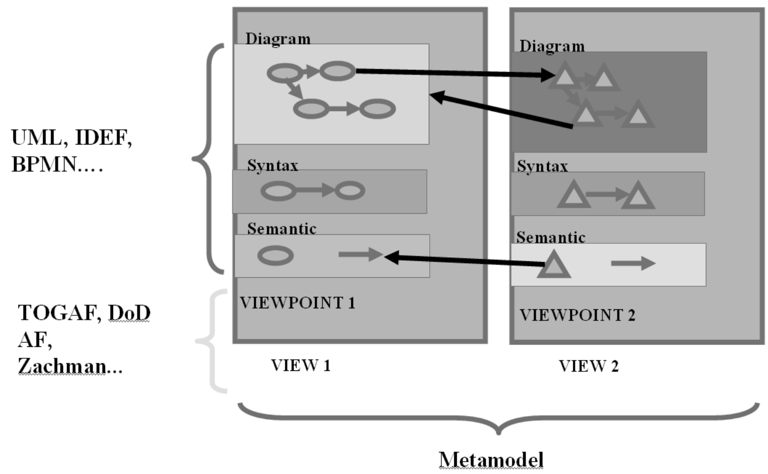

Figure 4. Reference construct for metamodel creation

Element is an artefact of the real world. It portrays enterprise asset [25]. Combination and cross usage of element extend the semantic coverage for problem solving.

Basic elements participate to diagram description, and are depicted according to a syntax. In addition to that, different types of links enhance element description. The first one is that two elements are synonym but expressed in different grammar. As an example, a lane in BPMN is equivalent to an organizational unit in organization chart. Second kind of link expresses a role relation between elements. Theses links are generally saved by inter domain matrix.

Matrix dependencies accurate navigation and reasoning from elements links and properties. Linking different view help to understand about what is really happening in an enterprise process.

The corpus manipulated from the architecture was restricted to six concepts: Process (P), Discipline Object (O), IS application (A), Function (F), people organizations (P&O), Requirement (R). All are used in viewpoint in a particular grammar. Metamodel was constructed by using the reference constructs in order to join concepts by retrieving link between diagram elements.

As an example, FxPxO contributes to discover and extract views and diagrams that define, for a particular function, which process contributes to that function and what is the discipline data involved.

In general manner, user query and performance analysis is a balancing process to find optimum for P x O x A x F x P&0 x R.

In addition to the concept declaration we add two time scales in the architecture. The first expressed the starting point of the business capabilities and is called as-is. The second time scale expressed a target architecture that provides clues for future deployment hypothesis.

6 Experimentation result

The electrical architecture was implemented in System Architect Tool from Telelogic [27]. The 10.1 version of the tool comes with high customization capabilities and functions to increase grammar and entity relation. A Visual basic module enables to query the database and check constraint. In standard version many grammars are available. The high expressivity of the tool requires a well defined methodology in order limit scope of exploitation.

Despite the fact that the demonstrator was not used at the operational level, the electrical repository was tested with a subset of stakeholders from business and IT departments. Several viewpoints were implemented, but the architecture was not used in configured multi-user project mode. We can draw general conclusion from the project.

In general, modelisation happens at a high level and deals with enterprise process. The intention is to capture key performance indicator and to provide guidance for process compliancy with business scorecard. Further detail model in order to describe how to do a process is not covered.

Our architecture intention was to describe an electrical operational level. This operational level describes the “How to do” more than “What to do”. Process, but also know-how and business data are in the scope of the architecture. At this level, a huge amount of information is processed by actor in day to day tasks. Process is more flexible and working hypothesis move rapidly during exchange and collaborative engineering work. Consolidated criteria for process evaluation depend on real data and uncountable number of situations.

In our case interviews’ provide actor knowledge about activity. It is a good input to create diagram, identified concept and built scenario. Numerous aspects of engineering activities imply numerous artifact and grammar. Exploitation and creation of diagram do not belong to the operational actors’ domain of competencies. We had to organize learning events to help users and to fill the gap. We noticed that the more user’ interests is taking into account, the more learning time is required.

Displays and views extractions play an important part for user adoption. The development of view extraction required customization out of the project scope.

As for the methodology used in TOVE [26] for ontology creation, we put effort in queries and user scenarios to handle complexity. Ideally, each object and each property should be a consequence of a user oriented scenario. As a result, in order to demonstrate how the user can have confidence in the model, our testing purposes were based on scenario. We believed that efforts in interface development can not be avoided for exploitation. The current exploitation was to developed architecture as a communication support but also as a knowledge base for insightful information extraction.

The most promising use at operational level, that encompasses both communication purpose and knowledge retrieval, deals with formalization of user guide and best practices in engineering tool such as CAD and PDM applications. In our opinion, architecture repository contains enough information and semantic data to structure a methodological web site for electrical engineering activities.

Concerning the tool, we acknowledge that implementations are not restricted by System Architect tool, but should be constrained by a methodology in order to provide means for a consistent repository. On the contrary, tool restricted by grammar or method does not allow a full expressivity required to formalize product engineering activities.

7 Conclusion

The analysis performed in this paper shows that enterprise architecture can be used to represent an overall picture of a business electrical process more than to provide performance indicator on business process. Complexity of knowledge representation was subdivided into manageable viewpoint. And viewpoint artefacts are linked through a metamodel based on a reference construct including element description, element depictions and cross domain reference.

In addition to methodological repository, enterprise paradigms can assist product decision making process. Terminology is one of the major challenges in the field of integrated architecture engineering. The ontology development approach used in this paper is more top down oriented. User requirement and scenario are the basis to deepen concept identification and syntactic definition. Modelling competencies acquisition is a prerequisite at an engineering user point of view to foster the deployment of operational architecture.

8 Reference

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In search of the elements of an Intra-organizational Innovation System for Brazilian automotive subsidiaries

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Abstract: The present study provides a theoretical basis for the development of product technological competence in global automotive organizations in Brazilian subsidiaries. It is argued that the necessary knowledge is fragmented in literature among studies on new product development, knowledge management and organizational learning, organizational competences and technological innovation.

It presents two concepts: (a) the concept of Intermediate Technological Leadership (ITL), as an enterprise purpose to be reached and (b) the concept of Intra-organizational Innovation System (IIS), as a model to be constructed and applied in local subsidiaries in order to enable the achievement of all necessary technological competences. The integration of theoretical sources reveals six fundamental elements for an IIS: strategic adequacy, interpretation of external environment, conception of internal organizational structure, integration of external structure, systematization of organizational basic processes, and consideration of human factors and relationships. It is expected that the theoretical basis presented in this study will serve as a reference to be validated in real-world applications.

Key Words: Technological innovation systems, organizational competences, new product and technology development, automotive industry.

Introduction

Product development in Brazilian automotive industry has been aggregating new methods and technologies due to the legislative requirements, market needs and new organizational strategies. Since the great market opening occurred in the nineties, this industrial sector has been experiencing a fast transformation of its subsidiary structures. Such transformation aims at a continuous preparation of these local organizations for a more competitive market.

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There are many purposes that motivate different countries to involve themselves in companies' Product Development Programs. Among them, the use of subsidiaries' competences and reduction in development cost can be emphasized. In the Brazilian case, local market demands and particularities have been the basis for investments in R&D [12]. Within this context, this paper will begin by presenting an analysis of the main theoretical studies that form the basis of this article's central argument. Following this, it will discuss the role played by the Brazilian subsidiaries of worldwide organizations. It will, then, present the concept of Intermediate Technological Leadership, and will propose a theoretical model that shows six fundamental elements for an IIS. It will be argued that this model should be the main theoretical foundation for a practical IIS implementation. The final section will discuss the applicability and the relevance of this study.

The theoretical basis

Knowledge management and organizational learning

Nonaka and Takeuchi are seen as essential references on knowledge creation for technological innovation [17]. Representing the Japanese approach, these authors affirm that the success of Japanese companies mainly happened due to their abilities in organizacional knowledge creation, which they define as being the capacity a company has to create knowledge, to spread it within the organization and to incorporate it into products, services and systems.

The acquired learning or created knowledge takes the form of new concepts of products, archetypes, procedures or services. In the western approach, Senge, Dibella and Nevis, and Argyris and Shön, present strategies of organizational learning emphasizing more explicit knowledge than the Japanese does [24, 6, 1]. Nonaka and Takeuchi center their organizational knowledge creation theory in four mechanisms for knowledge conversion: Tacit-Tacit (socialization), Tacit-Explicit (externalization), Explicit-Explicit (combination) and Explicit-Tacit (internalization) [17]. Such mechanisms have been identified throughout studies and reviews of innovative processes in Japanese organizations. Both approaches recognize organizational characteristics such as managers' roles, people's autonomy, objectives, *etc*., and discuss the ideal conditions for learning process improvement.

Organizational competences

In any organization beginning to develop new products and technologies, there are activities, work processes, physical structures, organizational and professional profile definitions that have not been there before. Organizational Competences refer to the systematization of all these necessary elements which will sustain new abilities now present within the organization.

Prahalad and Hamel studied the concept of competences focused on product's base technologies. According to them, core competences are related to the product's base technological domain, and this would be the major argument to explain the difference between technology-based corporations [20]. Prahalad and Hamel present an important relation between competence formation and innovative dynamics as they recognize that companies, which are not focused on technological abilities, are increasingly more limited in identifying innovative ways in their current product line or simple expansions [20].

For the organizational competence formation, a careful consideration of local context is highly necessary, as the differences between local and foreign environments are very relevant. It is also important to consider strategic alliances which are normally focused on the complementarity of strength and weakness. Such strategies are commented by Fleury and Fleury, Prahalad and Hamel and Medcof [11, 20, 14].

New product development process

Before launching a new product in a local market, there must be a stage-structured process that managerially leads it to market – a process called PDP (Product Development Process). PDP is applied from needs identification (customers' needs, technological tendency, legislative criteria, *etc.*) and choice of product concept up to its commercial launch. PDP divides the pioneering product into a list of stages, each one constituted by a list of prescribed, multifunctional and parallel tasks [4].

According to Cheng, different approaches and background of each author have produced different perspectives of PDP [2]. For instances, Clark and Wheelwright and Pugh are authors who bring us a product engineering perspective [3, 21]; whereas, Dolan and Cooper look at PDP from the marketing perspective [7, 4]. Meyer's concept of platform identifies the relationship between structural and technological approach and product development strategies [15]. Griffin and Page search for common points among companies and propose a list of best practices in New Product Development (NPD) environment [13].

Technological innovation taken from the economic perspective

In economics approach, technological innovation acquires prominence from the moment when it appears as a competitive advantage. The works from the economics perspective have origin in the neoclassic economic theories, in which Schumpeter constitute a very important reference [23]. It can be stated that this approach takes an external view of the organizational structures, but it does not make indepth discussions about Intra-organizational processes. Pavitt, Nelson and Winter, amongst others, are also considered reference authors [19, 16]. The most important elements of their analysis are frequently competitiveness, investment politics, innovative pay-back, rate of economic growth within organizations and countries, creation and conduction of strategies within subsidiaries, and the innovation as a dynamic market key element.

In Brazil, this approach becomes more relevant, mainly among those who see a sustainable way for economic and social development through technological innovation. It can be noted that they are mainly from research institutes such as IPEA and from the main local universities [22].

Innovation in companies from emergent countries

The theoretical bases examined in the previous sections consider complementary aspects of product and technological innovation within industrial organizations. However, very little integration of different theories could be found. This context reinforces the need to construct a model for technological innovation that is appropriate to emergent countries.

Few authors have tried to integrate knowledge from this theory in search of models applicable to the specific context of companies located in Brazil. Amongst those, Fleury and Fleury study Brazilian innovative context more actively, assessing Intra-organizational aspects [10]. More specifically, Figueiredo presents an integrated and contextual model for companies in emergent countries, examining the trajectories of accumulative technological competence, their relation to underlying learning processes, and their impact on the operational performance within companies [8].

Figueiredo explains "learning" as a two-dimensional term: the trajectory of accumulative technological competence within an organization and the processes by which individual knowledge is transformed into physical systems, production processes, procedures, routines, products and services. External and internal knowledge acquisition processes are crucial for companies in emergent countries, yet they do not have any previous knowledge background. Such study concludes with a close relation with the basic characteristics of knowledge acquisition process, the rhythm, the consistency and the composition of trajectories of accumulative technological competence [8].

R&D centralization and decentralization: the roles of Brazilian subsidiaries in worldwide organizations

R&D competence development will occur in a subsidiary according to its autonomous level within a worldwide organization. When local R&D occurs, it tends to be more directed to local market characteristics. Moreover, it is considered successfully accomplished when a subsidiary develops local competitive strategies, establishes complex organizational structures, develops products for local market, and also elaborates proper management systems. It is also observed that local governments are concerned with attracting foreign investments through local infrastructure creation that could potentialize the subsidiary competitiveness within global competition [9].

Fleury identifies three different subsidiary categories in Brazil. The first category is of subsidiaries that act as the operational arm of headquarter. The third one is of subsidiaries that work as a competence center, guaranteeing the autonomy in local market according to its own technological competence. The second category is of subsidiaries that remain in an intermediate phase as a relatively independent unit [9]. Other classifications in specialized literature concerning the subsidiary roles can be found [5, 12].

There are several evidences of increasing product and technological development activities in Brazil. The contact with new knowledge, new technologies, flexibility and agility for product adaptations, lower development costs, incentive taxes, and requirements for local performance are some of the main aspects involved in the process [12]. It is important to define an appropriate level of autonomy and also a suitable resource allocation for R&D within the subsidiary. It aims at best exploration of local opportunities.

The Brazilian automotive sector is dominated by foreign companies, which means that Brazilian insertion in technological development will also depend on strategies of those organizations. Dias affirms that Brazil can be consolidated as an important product development basis for worldwide market, by developing specific products for some market niches or by specializing in specific subsystem development. Thus, after developing satisfactory competences to local market, a subsidiary becomes a strong developed site for countries and markets with similar characteristics to its own [5].

Brazilian automotive engineering began to adapt some foreign vehicles transmissions in the sixties. Today, in some subsidiaries, there is competence to develop a complete vehicle. As examples of local competence development, General Motors do Brasil can be cited as one of the five development centers of GM group in the world. A few years ago Fiat presented its Brazilian product development center as the first one outside Italy. Ford and Volkswagen have gradually more Brazilian engineers involved in international product developments. The interesting point in these involvements is that the direction of knowledge flow has being inverted in many recent cases. Currently, Brazil is the 11^{th} automobile world-wide producer and the first in South America [18].

Intermediate Technological Leadership

In this article, we present the concept of ITL, or Intermediate Technological Leadership, to explain some purposes which have been recently observed in the context of Brazilian automotive industry. To be in search of Intermediate Technological Leadership consists in implementing a strategy to extend the local competence in product and technological development.

One of the main assumptions of ITL is the integration of product development site and its physical location within a local market limits. It can be regarded as the best alternative to a fast understanding of the specific market rules and to select and develop specific products and technologies to that market. So, it can be defined as "ITL stimulated by local market", considered here as an ITL sub-category that occurs when local market is the main factor that fosters the technological competence formation. A second sub-category of ITL is identified when technological competence development is justified by exclusiveness, business share, or when a development site seeks to become a technical reference in the development of new product or subsystem among other sites of the same industrial group. In this case, an internal competition is expected to happen within the subsidiaries. This sub-category is called "Intermediate Technological Leadership stimulated by internal competition".

The road-map to ITL: identifying the necessary elements of an Intra-organizational Innovative System

In the context of this article, a particular system that provides for any organization's accomplishment of ITL is called Intra-organizational Innovative System (IIS). This section summarizes the integration of different theories which contributed to the identification of the foundations of IIS .

Figure 1 tries to integrate the main points of view of each theory cited in section 2 and the industrial context identified in section 3. The theory contributions explored in this article have been organized into six distinct elements. Each element represents a vital area of a complete IIS:

- **Strategic adequacy:** it considers the subsidiary local autonomy, its defined role in the global organization, the headquarters' dependence in adopting or not of an ITL position, and the local capacity that influence it. The main sources that explore this element are found in the specialized literatures of organizational competence and technological innovation, more specifically within the topic of organizational arrangements.
- **Interpretation of external environment:** it aims to consider legislation, tax incentives, local market needs and many other constraints that influence directly the product portfolio strategy. The PDP literature approaches these points focusing on design inputs, whereas the technological innovation literature approaches them as strategical decision parameters.
- **Conception of internal organizational structure:** it aims to establish the characteristics of physical environment and work division. The literatures on PDP and Knowledge Management complement the topics related to the organizational structure for product development.
- **Integration of external structure:** it considers the contact with knowledge and competences which are outside the organization limits (universities, research centers, *etc*.). Strategic alliances are well takled by Organizational Competence literature, however, the other topics are more detailed by technological innovation literature.
- **Systematization of organizational basic processes:** it considers the New Product Development Process and those related to the continuous organizational learning. They are largely discussed in product development literature with great contributions from knowledge management studies.
- **Consideration of human factors and relationships:** this element is more related to human behaviors. Specific studies, focused on organizational culture, industrial psychology and human resources are potential sources of knowledge for these topics.

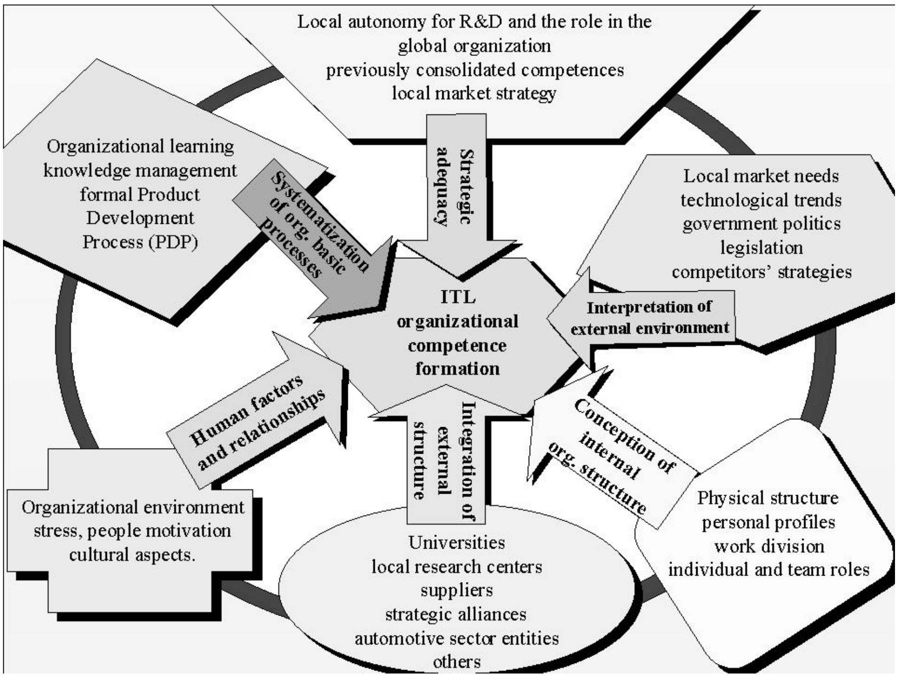

Figure 1. Fundamental elements of an Intra-organizational Innovative System

Conclusion

The formation of technological competence within the context of ITL presents great social and economic relevance for a country's development. This article aimed to provide an important way for changing the roles currently played by Brazilian subsidiaries within their organizations. This change includes setting new forms of investment attraction, valuing more highly jobs generated in Brazil, and also motivating the development of organizations that compose the structure for local innovative support system. Such reality, however, should be based on complete IISs, conceived from a rigorous theoretical search, and has to be carefully integrated into practical environment. Each singular organizational context will demand a specific and adequate system.

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Mectron's Innovation Management: Structural and Behavioral Analysis

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Abstract. This work aims at identifying the practice of innovation by Mectron – Engenharia, Indústria e Comércio Ltda., a Brazilian firm of the aerospace industry. The efforts are made in order to provide an overview of the company. Its organizational structure is also analyzed in order to provide a framework under which the innovations practiced by the organization can be observed. The attempts to understand the company's innovative vocation come to focus on the investigation of firm's attributes related to innovation. Conclusions are taken concerned the adherence of the firm's structure and behavior to the literature review. The authors are Master of Science students at Instituto Tecnológico de Aeronáutica (ITA). Overall guidance was provided by their research advisor, Professor José Henrique Damiani, PhD. The research was undertaken with the authorization of Mectron, and the authors counted with the direct collaboration of the company's systems engineering manager, Cel Eng Pelson de Souza Pinto, who provide most of the information collected and here exposed. The views expressed by the authors do not necessarily represent those of Mectron. The concepts adopted alongside this work concerning innovation are based on the Oslo Manual.

Keywords. Innovation, strategic management, technology.

1 INTRODUCTION

The objective of the present work is to identify, based on the literature related to the technology and innovation management, structural and behavioral aspects that foment innovation in the scope of Mectron – Engenharia, Indústria e Comércio Ltda, a Brazilian company performing in the aerospace industrial area.

A literature review is provided, seeking to establish the theoretical basis upon witch the company's structure and behavior are analyzed. In the sequence, the authors expose elements that compose the history of Mectron and its organizational architecture; in addition to that, Mectron's mission statement, vision and quality policy are showed, on an attempt to characterize the company according to its principles and values.

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After that, the work exposes the environment in which the company exerts its activities. At this point, the intention is to comprehend how the company and its environment influence each other. Then, it’s made an attempt to demonstrate how the company performs innovations and how these innovations are disseminated to the market.

Finally, the authors analyze the information collected, attempting to identify any adherences from Mectron’s structure and behavior to the theoretical expectation foreseen in the literature review.

2 LITERATURE REVIEW

The present section aims to expose the theoretical basis upon witch the company’s structure and behavior will be further analyzed in chapter 5. The concepts used throughout the work emanate from the following approaches.

2.1 Strategic Management

According to Rocha [11], strategic management refers to management techniques, evaluation and respective tools conceived to help companies in strategic decision making.

Strategic decisions are taken, as any kind of managerial decisions, concerning occurrences in organizations’ lives. However, what distinguishes strategic management processes from others is the nature of the events about which decisions are taken. As a rule, strategic management processes are more complex than daily ones, as purchase, production, maintenance, storage, sale, etc.

The strategic benefit is characterized by the attainment and/or maintenance of competitive advantage, in the light of determinants of competitiveness.

2.2 Competitive strategy

The concept of competitive strategy emanates from the relationship between the Organization and its environment. On one hand, the environment represents a conditioning to the Organization’s activities. On the other hand, the environment offers important opportunities.

Porter understands competitive strategy as actions that aim to create a defendable position in an industry, in order to successfully confront competitive forces, getting a superior return on investments. The same author also establishes that “competitive strategy is a combination of the ends (goals) for which an organization is striving and the means (policies) by which it is seeking to get there” [5].

2.3 Competitive advantage

According to Saloner, Shepard and Podolny [12], the competitive advantage is divided into two main categories: position based and competency based advantages.

Position based advantage reflects the condition of the company in terms of remaining in the market as one that does not have a competitor who can break that position of dominance. That position seems to be enough in order to guarantee superior incomes, even though the firm is not endowed with superior capacities.

The competency based advantage is characterized for endowing the company with a capacity where it enjoys market recognition. The company is seen as the best amongst its competitors in the performance of certain activities. In this point of view, the competitive advantage is reached when an organization is able to get resources and to offer products and services with superior quality, inferior cost, or in lesser stated period than competitors, or is well succeeded in those three aspects. However, these factors can be modified throughout the time.

2.4 Diversification, competences and competitive coherence

For the traditionalist and neoschumpeterian theoreticians, the enterprise is seen as an organism in continuous growth, as observes Britto [1]. In accordance with such a conjecture, the company is "constrained" to grow, that is, it has to reinvest productively the generated profits. The company constantly searches to disseminate its product in the market, and propagates its efforts by proper resources or externally financed.

In such a context, diversification allows the company to surpass the limits of its markets, as well as enhances its business capacity. There are lots of factors that can pressure the firm in the direction of the diversification. However, they shall be considered under the aspect of the original scope, and thus be grouped and distinguished between endogenous and exogenous factors.

As Britto [1] comments, the companies can be understood as organizations endowed with specific abilities, evolving with the time as a consequence of internal learning processes learning. Those learning processes, added to the capacity of the firm of being adaptable to the changes that happens in the conditions of its environment, exacerbates the knowledge accumulation processes significance, since they are able to modify the company's original abilities.

3 METHODOLOGY

The authors have examined the literature, in a search for the basis upon which the company's characteristics would be evaluated. Then, the authors contacted some Mectron's managers. At that first meeting, the steps throughout the research would be carried out were established, and the confidential level was set.

The participants of the meeting have reached an understanding concerning the formularization of a questionnaire, which would be submitted to Mectron's Chief Systems Engineer (CSE).

The company has also supplied the authors with an electronic copy of its institutional portfolio [4], which contained Mectron's history, as well as the description of its products. Relevant information could be acquired from the examination of that, providing support to the present work.

The methodology adopted throughout the research also involved the accomplishment of three interviews with Mectron's Chief Systems Engineer, Mr. Pelson de Souza Pinto. Mectron's CSE answered to a series of questions, adding fundamental topics by his own. His contribution for this work was crucial.

4 Results

The previous chapter exposed the procedures adopted for the conduction of the research and consequent collection of information. The following section presents the data collected, according to the methodology previously described.

4.1 The company

Mectron acts in the development and manufacture of intelligent weapons, sensors, avionics and aerospace equipment [4]. Its portfolio inserts the company in the restricted market of technological innovation in the defense area [10]. This insertion makes Mectron one of the most important enterprises in the Latin America defense market.

Currently Mectron has its organizational structure framed in order to cope with its needs, aiming at the flow of information and the managerial skills of each one of its constituent sectors.

The products are distributed among three business-oriented departments, called Business Unit (BU), according to the nature of each product. Each BU is managed by a project manager, which reports directly to the Council of Directors (CD). The CD is formed by the five owners of the company.

The Business Units take charge of the development of the products. The Missiles and Space units group the products by similarities, whereas the Sensors unit makes it by activity. The three business-oriented units are supported indistinctly by the industrial department, in what it refers to production. The decisions tend to be decentralized in each one of the units, and the hierarchy is moderate.

The company's work force is about two hundred employees. Four of them are PhDs, twelve are MDs and twenty are post graduated, besides forty collaborators with university graduation. This total corresponds, approximately, to thirty eight percent of its work force with some level of superior education. Fifty two percent of Mectron's personnel are directly connected to R&D.

4.2 Mectron and the market

Mectron competes mainly in terms of product differentiation. In the standpoint of one of the company owners, Mectron sells research and development in accordance with the customer's needs, and this concept fits to all its products [7]. The company is the only organization in Latin America endowed with technology for the production of intelligent missiles and airborne radars [8]. This situation guarantees the monopoly of the activity in the Brazilian market and, moreover, enhances the credibility of the company among international customers [10].

As cited in [4], the company is technically able to perform projects, development and production in the areas of Aerodynamics, Propulsion, Control and Guidance, Digital Processing of Signals, Analogical and Digital Electronics, Microprocessors (embarked software), Radio-Frequency, Materials, Structural and Thermal Calculation, Electro-Optics, Pyrotechnics and Fine Mechanics.

4.3 Innovation

In 2006, Mectron won the FINEP prize of Technological Innovation, in the small/medium enterprise category, carried out by Fundação de Amparo à Pesquisa do Estado de São Paulo – FAPESP, a Brazilian governmental Foundation that supports research and innovation. The prize was granted thanks to Mectron's performance on R&D, devoted to the aerospace sector [3]. This award has recognized the commitment of the company concerning innovation.

Carrying on the discussion about innovation, we have observed at the ambit of the company that, referring to effective contracts, the innovation is requested for the proper customer, through the contractual requirements. Moreover, throughout the development, the necessity of process innovation may arise, as it becomes possible to identify better and easier ways of developing the products. The model of development adopted by Mectron is based on the product life cycle approach, easily found in the concerning literature.

The identification of business opportunities, from the perception of market needs, also happens within the ambit of the company. For instance, Mectron has established, years ago, with proper resources, a line of products for the medical area: BioWare EEG-2008, for the diagnosis of epileptic crises and BioWare PSG-2008, for the diagnosis of sleeping diseases. Recently, the company submitted to FINEP a project, referring to the development and manufacture of a transponder. There's no production of this kind of equipment in the Brazilian market, and the company has recognized this opportunity to deal with it. However, this type of development represents only a small part of the company's productive effort.

4.4 Diffusion of Innovation

Concerning diffusion of innovation, it was possible to be seen that the commercialization of the products developed by the company is restricted, basically, to the contracting customer. The company has not still implanted a specific strategy to spread out the collection of products already developed. Due to the strategy of growth adopted so far, is not possible to invest in necessary publicity, aiming the diffusion of the products among international markets. However, this reality tends to change. According to Rogério Salvador [2], Commercial Director of Mectron, the company has plans to catch private resources, in order to become able to offer its products overseas. This is part of the company's expansion plans.

The company is known world-wide due to its contracts with the Brazilian Armed Forces. Specialized magazines in military technologies have contributed massively to this spreading, moved for proper publishing interests, as they collect and diffuse information regarding Mectron and its products.

4.5 Management

The company shows managerial flexibility, as it adjusts its organizational structure in order to face actual scenarios. If there is much development and little production, all manufacturing activities rely on the industrial division. When a production peak occurs, the business unit directly involved takes care of its own production.

Mectron practices a very high degree of profit reinvestment. According to Pinto [8], this practice provides the necessary push towards technological leadership and quality improvement. The infrastructure (also laboratories and equipment) is the main focus of those resources.

The company is seeking for external financings, with the purpose of developing new products. The intention is to act in a classical manner, commercially speaking, in the sense of identifying business opportunities to produce articles of continuous consumption, therefore supplying the market. The Studies and Projects Financier - FINEP is one of the Brazilian institutions in which this financing has been requested. Moreover, the company revealed the interest of going public. Doing so, Mectron would be able to apply for financing provided by BNDES, The Brazilian Economic and Social Development Bank. BNDS participates as shareholder in such projects. Rogério Salvador, Commercial Director of the company, declares that IPO is part of the company’s expansion plans, on the purpose of spreading its expertise in aeronautic technology to different markets [13].

5 ANALYSIS

In the previous chapter, we exposed the information collected throughout the research. The present one endeavors to analyze the facts in the light of the literature review exposed in chapter 2.

It was perceived that Mectron performs product innovation pushed by exogenous influences. Its proper business orientation seems to be responsible for that. The company sees itself as an entity that commercializes research and development solutions, with capacity to meet the requirements stipulated by the contractors.

On the other hand, it was possible to identify that there is place for endogenously motivated innovations, inspired by observation of market needs. The company has done it in the past already, as it was commented in 4.3, and Mectron seems to be motivated to operate in this manner again, since the company has manifested the intent of going public in order to rise external financings, making use of its expertise in aerospace industry for the development of new complex products.

The research allowed verifying a strong inclination of the company to learning. Mectron usually incorporates in its productive processes techniques developed internally, absorbed throughout previews developments. This characteristic allowed inferring that the endogenous innovations are widely focused on improvement of the productive processes.

It was also possible to identify that Mectron self-perception of its competitive advantage inhabits primary in its core competences. Corroborating with the displayed in Saloner, Shepard and Podolny [12], such a view seems to affect the way the company perceives its opportunities. The search of external investment for new products, a novelty in the history of the company, indicates the disposal of the firm to profit on its own abilities to act in new businesses, from the perception of market chances.

On the other hand, it has been perceived, however, that the body of knowledge that Mectron possesses locates the company even more distant from its competitors, especially when speaking about Brazilian industrial scenario. For that reason, Mectron's competences reinforce the positional competitiveness of the company, as they make the company become closer to a monopoly in the market where it performs, in terms of capacities.

This interrelationship between the competitive advantages of the company meets what is theoretically foreseen in literature. The easiness of new concepts and processes incorporation presented by Mectron fortifies the interaction between positional and competency-based advantages. As the company learns, it goes further in its position and becomes more distant from the other companies. This learning capacity, in its turn, contributes very much to make competency-based advantages sustainable.

Mectron has a flexible organizational structure. In conformity with what is stated in section 4.5, Mectron usually adapts partially its structure according to the different productive moment faced. The company adjusts itself in order to fit its purposes.

However, despite that demonstration of flexibility, the company does not behave according to a small innovative company model, established by the entrepreneur's "creative genius". It was evidenced, throughout the conduction of this work, characteristics that have allowed categorizing Mectron as a large-size company, which runs itself close to a systematic and routine management of technology and innovation model.

6 CONCLUSION

In the present work, the authors have sought to answer how Mectron Engenharia, Indústria e Comércio Ltda is structuralized and how it is positioned in the market, in view of the strategic management of innovation approach.

The company was characterized according to its history and its organizational architecture, as well as its guiding values, exhibited in its declaration of mission, vision and quality policy, that last one constituting the company's body of values.

After that, the authors described the environment in which the company exerts its activities and in what manners that environment influences the company and the other way around. The authors attempted to demonstrate how the company performs innovations and how those innovations are disseminated into the market. The authors have also commented about some strategies used by the company in order to manage its business.

Finally, the authors accomplished an analysis of the collected information, verifying the adherence of the investigated characteristics to the theoretical expectations foreseen in literature. Therefore, it was possible to conclude that the company presents structural and behavioral characteristics directed to the routinely practice of innovation.

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Completeness of Development Projects Assisted by QFD: a Case Study

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Abstract. To assess the completeness of a Business Development Project (BDP) is not a simple task. The usage of some design method such as QFD eases but does not solve completely the problem, because the information displayed in the QFD matrices is highly dependent of the experience and intuition of the design team. This paper presents a case study of a BDP, where the completeness of the project was assessed through a slightly modified view of QFD: instead of looking at the market requirements themselves, it is proposed to find out the ways the requirements are accomplished. This procedure made possible the identification of the not covered portion of the market requirements and guided the project revision.

Keywords. Quality function deployment (QFD), completeness, business development.

1 Introduction

The strategy management process has been recommended by many authors e.g. Porter [9], Lobato [8] and Shapiro [10], to guide organizations toward a desired position.

A small educational enterprise in Brazil set-up its business development project to achieve this goal. Araujo and Trabasso [1] describe the initial planning phase of this project where the quality function deployment (QFD) was used to assist the deployment of the project requirements into a determined set of action plans which were further deployed into the organizational business processes.

The analysis done by the authors has endorsed the hypothesis that the QFD methodology can assist the deployment of company strategic objectives and eases the planning stage of a Business Development Project (BDP). The quality of the BDP, measured by its completeness, for instance was not within the scope of that analysis. This paper addresses this very aspect and proposes slightly changes on QFD methodology in order to assess the completeness of business development projects.

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The text is organized as follows: initially, it is presented the BDP applied by the case study enterprise; then, completeness of business development project is analyzed and a literature review is presented. Next, the proposed procedure to analyze the project completeness is described. Finally, the conclusions concerning the specific case study and the modifications suggested in the QFD are presented and discussed.

2 Business Development Projects Assisted by QFD

The business development project presented by Araujo and Trabasso [1] has been running since 2005 at an educational enterprise in Brazil, which operates since 1983, has 85 employees and around 500 students. The quest for excellence is a tradition of that enterprise and received special push when the Brazilian National Quality Award (PNQ) [5] was selected as the guideline for its business improvement.

Once the PNQ requirements were identified as strategic objectives for the business development project, the planning phase has been derived through the QFD methodology. Because QFD is a tool suitable for product development, some adjustments were made to QFD in order to apply it in the business environment. Essentially, the adjustments were made on the inputs and outputs of the QFD matrices, as shown in Table 1, and on the requirements weights that were replaced by the PNQ [5] score values.

Table 1. QFD matrices comparison between product and business development

QFD Matrix	Product development		Business development	
	Input	Output	Input	Output
1	Customer needs	System requirements	Stakeholder needs	Model requirements
2	System requirements	Characteristics of parts	Model requirements	Action plans
3	Characteristics of parts	Production processes	Action plans	Business processes
4	Production processes	Manufacturing operations	Business processes	Critical tasks

The action plans were identified after an extensively internal survey to find out the actions, programs and efforts performed by the enterprise that could be correlated to any PNQ requirement. These were grouped into a set of 12 action plans and an initial QFD matrix with their relations with the PNQ requirements was drawn, as shown in Figure 1.

PNQ Requirements		Legend: Relationship Intensity ● - Strong (Value = 9) ⊙ - Average (Value = 3) ○ - Weak (Value = 1)	1 Pedagogic Excellence	2 Customer Satisfaction	3 General Administration	4 Enterprise Resources Planning	5 ISO9001:2000	6 Child care	7 Human Resources Excellence	8 Students with Special Needs	9 Social Responsibility	10 Making the Student a Citizen	11 External Communication	12 Balanced Scorecard (BSC)	PNQ Point Value
	Leadership	Senior Leadership			●				○			⊙			40
		Continuous Improvement Culture	●	○	⊙	○	⊙	●		○	○	⊙	○		40
		Organization Performance Review	⊙		●		○	⊙				⊙		●	30
	Strategic Planning	Strategy Development		⊙	●				○		○				30
		Strategy Deployment	●		●			⊙		⊙	○	○	⊙	●	30
	Customer	Customer and Market Knowledge	●	●	○			⊙		⊙		⊙	●		30
		Customer relationship and satisfaction	⊙	●	○		○	⊙		⊙			●		30
	Social Responsibility	Social responsibility		○	○					●	●	⊙	○		30
		Ethics and governance	○		○				⊙	●	●	●	○		30
	Measure and Knowledge Management	Information Knowledge Management				⊙	⊙					⊙		○	20
		Benchmarking information Management	⊙			○						○		●	20
		Intangible assets management	○						●					○	20
	Human Resources	Work Systems					⊙		●						30
		Employee Learning and Motivation	⊙				○	○	●	○				○	30
		Employee Well-Being and Satisfaction					○		○	○	●				30
	Process Management	Value Creation and Support Processes	●	○		●	●	⊙		○					50
		Vendor Processes	⊙			○	●						○		30
		Economic and Financial Processes				●	○					⊙			30
	Results	Customer-Focused Outcomes	⊙	●	⊙			⊙		○			⊙	○	100
		Economic and Financial Outcomes	⊙	●	⊙	⊙		⊙		○		○	○	○	100
		Human Resource Outcomes			⊙				●	○				○	60
		Vendor Outcomes				○							○	○	30
		Social Responsibility Outcomes	⊙		⊙			○	○	⊙	●	⊙	○	○	60
		Processes Outcomes	●			●	●			○		○		○	100
															1000
		Action Plan Absolute Importance	3500	2550	2370	2100	2040	1560	1510	1500	1450	1360	1250	1240	
		Action Plan Relative Importance	16%	11%	11%	9%	9%	7%	7%	7%	6%	6%	6%	6%	

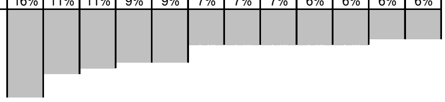

Figure 1. Initial QFD planning matrix.

The QFD matrix shown in Figure 1 depicts how the action plans support the PNQ requirements. The action plans are rated according to its relative importance; the more important plans can be recursively deployed toward the company structure up to their critical tasks that would support the plan execution.

Although the QFD matrix shows the relationship between all PNQ requirements and the selected set of action plans, the recognition of the full coverage of the requirements is not easily assessed. For instance, observing Figure 1, it is possible to infer that the requirement “Vendor Outcome” is weakly associated to the set of action plans, due to only three weak relations were found, whereas the causes of this poor relationship intensity are not directly presented.

On the other hand, it was identified three strong relations for the requirement “Value Creation and Support Processes”; however the associated action plans could be correlated leading to an overestimation of the overall relationship intensity.

From the enterprise view point, the completeness of the business development project i.e. a plan that addresses every portion of the PNQ requirement, is worth knowing to evaluate the actual effort required to complete the business improvement process.

3 Literature review: QFD flaws

A literature review reveals that many authors have analyzed how the QFD methodology and the design team aspects can affect the results of the QFD matrices. The main finds were classified and presented in this section.

3.1 Relations are arbitrary and subjectively determined.

Kim *et al* [7] report that "The limitations of the current QFD practices mainly come from the fact that a HOQ (House of Quality) requires subjective, interrelated and complicated information", additionally Chen and Chen [2] state that the design teams should use its own experience, knowledge and intuition to determine the engineering characteristics that would support the client requirement. These observations grant an intrinsic uncertainty to the QFD methodology.

3.2 Engineering characteristics could be insufficient to cover up the requirements.

Fehlmann [4]; Kim *et al.* [7]; Shin and Kim [11]; Chen and Chen [2] observed that the selected engineering characteristics could be dependent to the others (multi-co-linearity) i.e. they could enlighten the same portion of the requirements, leading to an over or underestimation of the requirement coverage.

3.3 Absence of formal criteria to identify the intensity of the relation between requirements and the engineering characteristics.

Some authors e.g. Cohen [3]; Kim *et al.* [7] and Franceschini and Rupil [6] proposed directives to analyze the intensity of the relations between the requirements and the engineering characteristics; however these procedures are not able to clearly assess the sufficiency of the engineering characteristics to fully support the requirement accomplishment.

3.4 Relations do not address how a requirement is accomplished.

Even though the relations inferred in the QFD matrices can be associated to a measure of effectiveness (MOE), as recommended by Cohen [3], they are not specific or reference how a requirement is achieved or verified. Chen and Chen [2] corroborate this statement: "Wasserman formulated the QFD planning process as a linear programming model that select the mix of design features which resulted in the highest level of customer satisfaction. The model focused on prioritizing the allocation of resources among design features, rather than determining the target levels of engineering characteristics".

4 Improving the Business Development Project

In order to overcome the QFD limitations stated above and consequently, assess the completeness of the business development project, it is proposed an alternative procedure to identify the relations between the action plans and the PNQ requirements. This procedure modifies slightly the way of viewing the QFD relations: instead of looking at the market requirements themselves, it is proposed to find out the ways the requirements are verified i.e. through the PNQ assessment criteria.

The PNQ assessment criteria are used to measure the actual enterprise performance. The assessment procedure evaluates the PNQ requirements classified as "approach and process" on seven distinct areas: adequacy, proactive, refinement, innovation, dissemination, continuity and integration; and those, classified as "result", according to their relevancy, actual result and tendency.

In the case study, the relationship between the action plans and the PNQ assessment criteria has been determined in two steps: (1) identification of the most relevant action plan for all the performance areas of the requirement under analysis, see example on Table 2; (2) establishment of the relationship intensity based upon a heuristic rule presented on Table 3.

Table 2. PNQ assessment criteria and relevant action plans and for the requirement: "Information Knowledge Management".

PNQ assessment criteria	Relevant Action Plan
Adequacy	Not related
Proactive	General Administration
Refinement	Balanced Scorecard
Innovation	Not related
Dissemination	Balanced Scorecard
Continuity	General Administration
Integration	Not related

Table 3. Heuristic rule used to determine the relationship intensity between PNQ requirements ("approach and process") and action plans.

Intensity of the relationship	Symbol	Value	Remark
Strong	●	Four or more	performance areas associated to the action plan.
Average	⊙	Two or three	
Weak	○	One	
Inexistent		No	

Naturally, many possible alternatives could be used instead of the heuristic rule presented, e.g. the usage of different weights for each performance area or the association of more than one action plans to a single performance area. These rules could lead to slightly differences of the relation intensity.

Even though some uncertainty is expected in the relation intensity, some interesting results were gathered when the procedure was applied to the case study.

The new QFD planning matrix shown in Figure 2 has substantial differences as compared to the first draft presented in Figure 1:

- The superposition among the action plans was reduced as only one plan was labeled as relevant to each PNQ assessment criterion;
- Some action plans were not identified as relevant to any of the PNQ requirements;
- It was possible to identify the portion of the PNQ assessment criteria that was not covered by the selected set of action plans. The column “Not related”, added in Figure 2, highlights this information.
- The priority order of the action plans was modified, as a consequence.

Legend:
Relationship Intensity
● - Strong (Value = 9)
⊙ - Average (Value = 3)
○ - Weak (Value = 1)

		Action Plans													
		3	2	NR	1	7	5	9	12	11	4	8	10	6	
PNQ Requirements		General Administration	Customer Satisfaction	Not Related	Pedagogic Excellence	Human Resources Excellence	ISO9001:2000	Social Responsibility	Balanced Scorecard (BSC)	External Communication	Enterprise Resources Planning	Students with Special Needs	Making the Student a Citizen	Child care	PNQ Point Value
Leadership	Senior Leadership	●				⊙		○							40
	Continuous Improvement Culture	⊙			○		●								40
	Organization Performance Review	⊙	○		○				⊙						30
Strategic Planning	Strategy Development	⊙	⊙	⊙				○							30
	Strategy Deployment	⊙	○	○	○				○			○			30
Customer	Customer and Market Knowledge	○	⊙	○	○					○					30
	Customer relationship and satisfaction	○	⊙		○					⊙					30
Social Responsibility	Social responsibility			○	○			●				○			30
	Ethics and governance		○	●				⊙							30
Measure and Knowledge Management	Information Knowledge Management	⊙		⊙					⊙						20
	Benchmarking information Management			○					●						20
	Intangible assets management	●			○	⊙									20
Human Resources	Work Systems	⊙			○	●									30
	Employee Learning and Motivation	⊙			⊙	⊙									30
	Employee Well-Being and Satisfaction	●				⊙									30
Process Management	Value Creation and Support Processes		○		⊙		○				○	○			50
	Vendor Processes			○	○		●								30
	Economic and Financial Processes	⊙		●											30
Results	Customer-Focused Outcomes		○		○					○					100
	Economic and Financial Outcomes		⊙		○										100
	Human Resource Outcomes	○				⊙									60
	Vendor Outcomes			⊙			○								30
	Social Responsibility Outcomes		○					⊙							60
	Processes Outcomes		○		○						○				100
															1000
	Action Plan Absolute Importance	1650	970	920	810	810	710	610	360	220	150	110	0	0	
	Action Plan Relative Importance	23%	13%	13%	11%	11%	10%	8%	5%	3%	2%	2%	0%	0%	

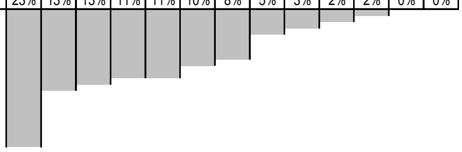

Figure 2. QFD planning matrix: relations determined with PNQ assessment criteria

The outcome of this analysis has compelled the project team to review the business development project and a new set of action plans was determined. Some plans had their scopes enlarged, new were added and non relevant were merged into more significant plans e.g. “Child care” and “Making the student a citizen” were merged into “Pedagogic Excellence”. Figure 3 shows the final result yielded from the steps just described.

Legend:
Relationship Intensity
● - Strong (Value = 9)
⊙ - Average (Value = 3)
○ - Weak (Value = 1)

PNQ Requirements		3 General Administration	1 Pedagogic Excellence	2 Customer Satisfaction	7 Human Resources Excellence	9 Social Responsibility	12 Balanced Scorecard (BSC)	13 Corporate Governance	5 ISO9001:2000	11 External Communication	4 Enterprise Resources Planning	NR Not Related	PNQ Point Value
Leadership	Senior Leadership	●			⊙	○							40
	Continuous Improvement Culture	⊙	○	○					⊙				40
	Organization Performance Review	⊙	○	○			⊙						30
Strategic Planning	Strategy Development	⊙		⊙		○		○					30
	Strategy Deployment	⊙	○	○		○	⊙						30
Customer	Customer and Market Knowledge	○	○	⊙				○		○			30
	Customer relationship and satisfaction	○	○	⊙						⊙			30
Social Responsibility	Social responsibility		○			●		○					30
	Ethics and governance			○		⊙		●					30
Measure and Knowledge Management	Information Knowledge Management	⊙					●				○		20
	Benchmarking information Management						●	○					20
	Intangible assets management	⊙	⊙		○			○					20
Human Resources	Work Systems	⊙	○		●								30
	Employee Learning and Motivation	⊙	⊙		⊙								30
	Employee Well-Being and Satisfaction	●			⊙								30
Process Management	Value Creation and Support Processes		⊙	○		○			○		○		50
	Vendor Processes		⊙	○					●				30
	Economic and Financial Processes	⊙					⊙	⊙					30
Results	Customer-Focused Outcomes		○	○						○			100
	Economic and Financial Outcomes		○	○				○					100
	Human Resource Outcomes	○			⊙								60
	Vendor Outcomes		⊙						○				30
	Social Responsibility Outcomes			○		⊙							60
	Processes Outcomes		○	○							○		100
													1000
	Action Plan Absolute Importance	1530	1000	840	770	690	630	590	470	220	170	0	
	Action Plan Relative Importance	22%	14%	12%	11%	10%	9%	9%	7%	3%	2%	0%	

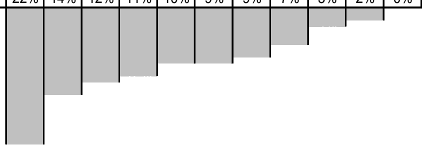

Figure 3. QFD planning matrix: relations determined with PNQ assessment criteria.

5 Conclusions

Although the QFD methodology might be worth using to draw the planning phase of business development projects, the completeness of the derived plan is not easily confirmed, because:

- The QFD methodology calls for relations which are arbitrary and subjectively determined;
- engineering characteristics could be insufficient to cover the requirements and even might support the same portion of the requirement;

- the absence of a formal criterion to identify the intensity of the relations between requirements and engineering characteristics makes difficult the requirement coverage analysis;
- the relations do not address how a particular requirement is accomplished.

In the case study presented, the completeness of the business development project derived primarily from QFD has been analyzed with the help of a procedure that, instead of looking at the market requirements themselves, it finds out the manner the requirements are accomplished: for the case study, this manner is the PNQ assessment criteria. The well defined scope of the PNQ assessment criteria and the choice of only one action plan to each single PNQ assessment criterion lead to a revised QFD planning matrix which has significant gains:

- The superposition among the action plans was reduced;
- the portion of the PNQ assessment criteria that was not covered by the action plans was easily identified;
- the assignment of the "not related" items has triggered a project review which resulted a comprehensive coverage of the PNQ requirements.

Even though the case study discussed herein is from the business sector, the problems identified and the proposed solutions are not exclusive of this environment. New studies shall be performed to find out whether the results of this paper could be extended to the product development environment and how the QFD methodology could be improved to incorporate more objective evaluations.

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The Effects of Teams’ Co-location on Project Performance

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Abstract: This paper aims to present an analysis between teams’ co-location and project performance. In order to achieve product development project success many decisions shall be made before the project kick-off. One of these decisions is to whether co-locate or not the project team. But, what are the effects of teams’ co-location on project performance? The paper provides a literature review about teams’ co-location, its advantages and disadvantages, virtual teams and project performance parameters. A table is then proposed to be used as a guide to determine the degree of success of projects. This paper also presents a case study where 3 pairs of similar New Product Development (NPD) projects were analyzed. In each pair of cases, the first NPD occurred using a co-located team and, in the second case, a virtual team (not co-located team) was adopted. The project performance parameters for each case were identified using the proposed table from which we concluded that co-located teams appears to deliver better performance at least in the “internal project efficiency” parameters. Further research involving a larger sample of cases is still necessary to confirm these conclusions.

Keywords: Co-location, Project Teams, Virtual Teams, Project Success

1 Introduction

NPD project performance has been widely studied in the last 20 years by researchers both from the Product Development and the Project Management arenas. According to these authors [1, 2, 3], many factors may result in a project failed. Within these reasons, it may be pointed a classic reason: the project is not structured appropriately (see, for instance, [3]).

Within the broad topic “project structuring” we find the theme “project organization approach”. Many authors [4, 5, 6] and practitioners believe that one ideal situation for project organization is getting the team members on a physical common area, which it is called team co-location. Some other authors, on the other

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hand, believe that co-location is not always a must, and that in some cases it is completely unnecessary and even counter-productive [7, 8]. For the companies, on the other hand, co-location always means extra-costs in the expectation of better team results.

In this context this paper aims to present and discuss the early results of a study at a major aerospace company which tries to shed some light on the complex relationship between teams' co-location and project overall performance.

In order to achieve this goal we start by providing a literature review on project teams, describing teams' co-location, its advantages and disadvantages, and virtual teams (Section 2). In the third section, we propose a table with project performance parameters to be used as a guide to determine the degree of success of a certain project after a number of dimensions. In the fourth section, we present a case study performed in an aerospace company showing the project performance parameters with teams co-located and not co-located. Finally, it concludes with limitations and future research.

2 Literature Review on Project Teams

2.1 Teams

The concept of a "team" is described as a small number of people with complementary skills who are equally committed to a common purpose, goals, and working approach for which they hold themselves mutually accountable. It is important to notice that getting a group of people to work together (physically) is not enough to make this group of people into a "team". Teams are different from working groups. The first one promises greater performance than the last one [8]. In this paper, the word "*team*" means a real team not just a working group.

When the team members are co-located there is a common physical area specifically allocated to the execution of the tasks related to the project. The team members shall seat close together. By close, it is defined as close enough that they can overhear each other's telephone conversations [5].

In the other hand, the not co-located teams or virtual teams as consider in this paper, is a team comprised of members in different locations and in same cases are also culturally diverse.

2.2 The Advantages and Disadvantages of Co-location

The probability of communication is high with small physical separation distance and falls off drastically when people are located more than 10 meters from one another, as showed in the Figure 1 [9].

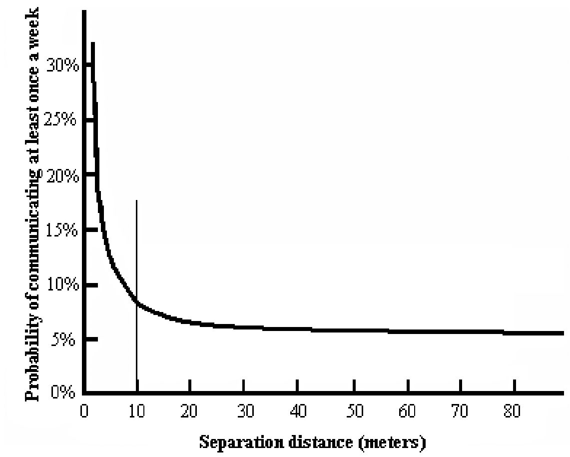

Figure 1. Project Communication frequency versus separation distance [9]

The key point is that co-location enables the informal communication. The water cooler metaphor is used to explain this phenomenon. The water cooler effect represents a belief that conversations that develop in and around a water fountain, or in a cafeteria, significantly enable knowledge transfer, which indirectly contributes to positive work relationships [10].

When the team members are co-located, they can focus their collective energy on creating the product. This situation can result in lasting camaraderie among team members, resulting in a huge project challenge: The **team spirit** [4].

As advantages, besides communication and team spirit, the literature shows that co-location provides an adequate environment condition for decision making, collaboration, trust between team members, and effective interpersonal relationships [11, 12, 13].

Co-location is regarded as one of the key ingredients in shortening development cycles at many companies, such as Chrysler, Black & Decker, and Motorola [5].

However, team co-location means a representative project cost increase, sometimes including the need for people re-location or even the requirement for new infrastructure to allocate the complete team. During the development of its ERJ 170/190 series, for instance, Embraer Aerospace had to build an entirely new building in order to accommodate the entire product team of around 600 engineers from various Countries. This collocation costs indeed increases drastically when we consider that in some industries such as the aerospace; the needed specialists are spread around the world. Some more concerns are summarized below:

- Lack of a permanent office home and as a consequence, the employee will be distant from his functional area, loosing some technological up date [5];
- Functional bosses worried about losing control of theirs employees [5].

Further, based on the authors' experience, some more concerns would be included:

- The fact that moving very often represents an inconvenience and/or a trouble for the involved people;

- Adaptation difficulties in another place, sometimes in other countries (cultural differences and operational difficulties, e. g.: need to move the entire family).

2.3 Virtual Teams

Communication versus separation distance studies have been performed by authors such as Allen [9]. At the time of his studies (1977), modern electronic systems and solutions were not widely available as today, such as e-mail, video conferencing, internet, intranet, web, voice mail, faxes, etc. More recently various authors have put forward the proposal that these electronic resources are able, to different degrees, to supersede the physical co-location and make the virtual teams possible.

Smith & Reinertsen (1998) [5], for instance, believe that the virtual co-location tools available today can supplement physical co-location but not supersede it.

Katzenbach & Smith (2003) [8], on the other hand, assert that "electronic" interactions can work, especially if they are supplemented from time to time by traditional get-togethers.

However, studies from the human communication point out the enormous importance of the human aspects which can be observed in a conversation; as body language, intonation, etc [5]. According to these studies, face-to-face conversation is still much richer than an electronic conversation due to the fact that available media and technology is not able to capture and transmit these human behavior characteristics [5, 6, 7]. It does appear that NPD projects that have more frequent face-to-face meeting enjoy better success [14].

Many firms apply project teams spread around the world in their development efforts. Management either believes that such spread is essential, or is not willing to pay the high price of co-location. But, sometimes, management just is not aware of how inefficient its dispersion makes its teams. These authors [5] mentioned an example where there were three teams located in sites with the time differences of about as high as 8 hours: When the first team finished its work, it was shipped electronically to the next office, which then worked on the design for a shift. Then the design was moved to the next office so that they actually get three times as much effort per day as the design circles the globe. However, what really happens: they saw firsthand how designs tend to get redesigned each time a new designer takes over. It was three redesigns per day [5].

Literature in virtual teams states that this type of teamwork has still not achieved the same performance as teams co-located [5, 6, 7].

3 Parameters of Project Performance

To evaluate the relationship between teams' co-location and project performance, this paper uses a parallel between project performance parameters proposed by Clark et al. [15] and the key success indicators proposed by Shenhar et al. [16].

The project performance parameters proposed by Clark et al. [15] are: quality, lead time and productivity.

1 – Quality: The project affects quality at two levels: the level of the design; design quality, and the organization's ability to produce the design; conformance quality [15].

2 – Lead time: To achieve a high performance considering the lead time is not just meeting schedule. Lead time is a measure of how quickly an organization can move from concept to market. It is important to development lead time because the time to market is shorter than ever [15].

3 – Productivity: It is considered as the level of resources required to take the project from concept to commercial product. This includes engineers hours worked, materials used for prototype construction, and any equipment and services the organization may use. Productivity has a direct though relatively small effect on unit production cost, but is also affects the number of projects an organization can complete for a given level of resources [15].

Figure 2 shows the interaction among these 3 dimensions of project performance.

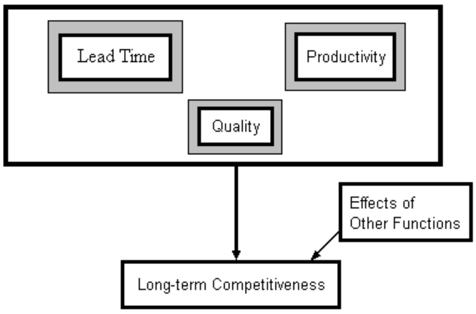

Figure 2. Project Performance [15]

In addition, the key success indicators proposed by Shenhar et al. [16] is a set of measurable success criteria, divided in four:

1) Project efficiency: Internal project objectives such as meeting time and budget goals.

2) Impact on the customer: Immediate and long-term benefit to the customer.

3) Direct and business success: Direct contribution to the organization.

4) Preparing the future: Future opportunity (e.g. competitiveness or technical advantage) [16].

The Table showed on the Figure 3 is proposed as a guide to determine if the analyzed projects achieve the success or not. It is applied in the case studies discussed in the following section.

	Key Success Indicators	Parameters
	Internal Project Efficiency (Pre-completion)	
1	How quickly is the project	Lead Time
2	Meeting schedule	Lead Time
3	Completing within budget	Productivity
	Impact of the customer (Short term)	
4	Meeting functional performance	Quality
5	Meeting technical specifications & standards	Quality
6	Favorable impact on customer	Quality
7	Fulfilling customer's needs	Quality
8	Solving customer's problem	Quality
9	Customer is using product (e.g. aircraft despachability)	Quality
10	Customer expresses satisfaction	Quality
	Business and Direct Success (Medium term)	
11	Immediate business/commercial recognition	Quality
12	Immediate revenue & profits enhanced	Quality
13	Larger market share generated	Quality
	Preparing for the future (Long term)	
14	Will create new opportunities for the future	Quality
15	Will position customer competitively	Quality
16	Will create new market	Quality
17	Will assist in developing new technology	Quality
18	Will add/has added capabilities & competencies	Quality

Figure 3: Primary success categories, key success indicator, and project performance parameters

4 Case Study

What are the effects of teams' co-location on project performance? What are the relationship between co-location and lead time; co-location and productivity; co-location and quality? In order to try to answer these questions a case study was performed in a major aerospace company. Figure 4 illustrates the relationships to be investigated empirically through this case study.

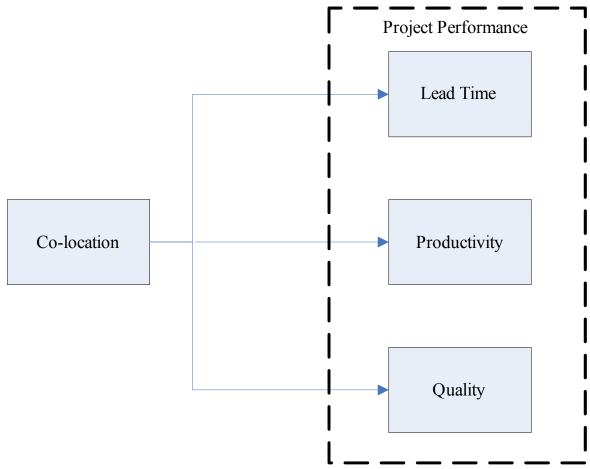

Figure 4. A framework of the possible relationship between teams' co-location and project performance

4.1 Case Study and Data Collection

3 pairs of similar NPD projects were chosen and analyzed. In this study we defined "similar NPD projects" as those involving the development of systems with similar design characteristics and identical or close number of technologies. It was also used as selection criteria the following items: Minimum of seven different technologies involved in the project (including manufacturing) and a minimum of 10 people involved in each project team. For each pair of projects, the first occurred with a co-located team whereas the second was carried out by a non co-located team.

The previous proposed table (Table 1) was used to evaluate the success project. The project performance parameters were identified according to ranking below. Values from 1 to 5 were attributed for each parameter.

Very low (1) About 20% do total
Low (2) About 40% do total
Medium (3) About 60% do total
High (4) About 80% do total
Very high (5) About 100% do total

The data used to attribute the values were: data from project planning, as planned project duration and real project duration, time to market, planned budget and real budget, data from commercial and marketing areas as customer daily report, marketing perception, customers complains, and people interviews.

The case study results are presented in Figure 5.

	Key Success Indicators	Parameters	Co-located	Not Co-located	Co-located	Not Co-located	Co-located	Not Co-located
	Internal Project Efficiency (Pre-completion)							
1	How quickly is the project	Lead Time	5	3	5	1	5	1
2	Meeting schedule	Lead Time	5	5	5	1	5	3
3	Completing within budget	Productivity	5	3	5	3	5	1
	Impact of the customer (Short term)							
4	Meeting functional performance	Quality	5	5	5	5	5	5
5	Meeting technical specifications & standards	Quality	5	5	5	5	5	5
6	Favorable impact on customer	Quality	3	3	5	5	5	3
7	Fulfilling customer's needs	Quality	3	3	3	5	5	3
8	Solving customer's problem	Quality	3	3	5	5	5	3
9	Customer is using product (e.g. aircraft despachability)	Quality	3	3	5	5	3	3
10	Customer expresses satisfaction	Quality	3	3	5	5	5	3
	Business and Direct Success (Medium term)							
11	Immediate business/commercial recognition	Quality	5	5	5	5	5	3
12	Immediate revenue & profits enhanced	Quality	5	5	5	5	5	1
13	Larger market share generated	Quality	5	5	5	5	5	3
	Preparing for the future (Long term)							
14	Will create new opportunities for the future	Quality	3	3	5	5	5	3
15	Will position customer competitively	Quality	3	3	5	5	5	5
16	Will create new market	Quality	5	5	5	5	5	5
17	Will assist in developing new technology	Quality	5	5	5	5	5	5
18	Will add/has added capabilities & competencies	Quality	5	5	5	5	5	5
			4.2	4	4.9	4.4	4.9	3.3

Figure 5: Project performance parameters for the analysed projects

4.2 Data analysis and Results

In the 1st Case, the performance achieved with the co-located team is little higher than the performance achieved with the not co-located team (4,2 and 4 respectively). The difference appears in the Internal Project Efficiency (Pre-completion) in the parameters: how quickly is the project and completing within budget which indicate lead time and productivity.

In the 2nd Case, the performance achieved with the co-located team is also little higher than the performance achieved with the not co-located team (4,9 and 4 respectively). The difference appears in the Internal Project Efficiency (Pre-completion) in the following parameters: how quickly is the project, meeting schedule and completing within budget which indicate lead time and productivity. In addition to this, a difference appears during the Impact of the customer phase (Short term), when the NPD with a co-located team has achieved a performance lower than the not co-located team, in the fulfilling customer's needs parameter which indicates quality.

In the 3rd case, the performance difference between the 2 projects is highest (4,9 and 3,3). Besides the differences in the Internal Project Efficiency (Pre-completion), there are also differences which appear in Impact of the customer phase (Short term), Business and Direct Success (Medium term) and Preparing for the future (Long term). These differences are showed in figure 6.

The common differences in the 3 cases, related to the NPD with co-located and not co-located teams, are associated to the Internal Project Efficiency involving parameters which highlight lead time and productivity, such as: project duration, meeting schedule and completing within budget. Excepting the 3rd case, the performance in quality are most the same in the NPD with co-located and not co-located teams, in parameters which represent Impact of the customer (Short term), Business and Direct Success (Medium term) and Preparing for the future (Long term).

Analyzing the collected data, it was also observed that the number of product's modifications in the NPD with not co-located teams was much higher than the number of product's modifications in the NPD with co-located teams. These product's modifications probably provoke a lead time increase, however, it seems that they also contribute to the NPD with not co-located teams achieves the same quality as the NPD with not co-located teams.

5 Conclusion, limitations and Future Work

This paper presents an analysis of 3 NPD-project performance, in terms of lead time, productivity and quality. These 3 parameters were analyzed not only related to project efficiency, but also related to the impact on the customer, direct and business success and preparing the future, short term, medium term, and long term respectively, according to key success indicators proposed by Shenhar et al. [16].

Study findings indicate that the NPD with co-located teams achieves a shorter lead time and a higher productivity when compared to a NPD with not co-located teams. There is no empirical evidence found in this study which indicates that co-location impacts quality. However, besides co-location, others project's factors, as team manager, team experience among others could be influented these results.

The decision of co-location shall be made by the organizations before the project kick-off. Besides effects of co-location on project performance, researches should study the relationship between project contextual characteristics and their impact on teams' co-location. Based on effects of co-location on project performance it should be traced a relationship between project contextual characteristics and the decision of co-location.

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Product Development Management

A DEA Benchmarking Methodology for New Product Development Process Optimization

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Abstract. Developing new products on time within budget constraints is a crucial issue to survive in today's competitive marketplace. However, unpredictable incidents occur during new product development (NPD) processes, which often cause expenses, resources and schedule overruns. Traditional project management tools lack of efficient and effective methods to solve these problems and challenges. Hence, this study applies the data envelopment analysis (DEA) concept to develop a novel project planning and management decision support methodology for NPD that can optimally allocate resources and dynamically response to unexpected delays and budget overruns. The research adopts the methodology to a mobile phone NPD project case to demonstrate the method's real-world application and illustrate the effectiveness of the proposed methodology in-depth.

Keywords. New product development, DEA, resources and schedule overruns

1 Introduction

Introducing new products on time within resource and budget constraints is a key to success in today's competitive market place. Thus, distributed and collaborative product development paradigms are emerged considering time-to-market and cost efficiency for the complexity of modern product design. However, unpredictable incidents usually occur during new product development (NPD) processes, which cause expenses, resources and schedule overruns. Conventional project planning methods, estimating time, budgets and resources of NPD activities, are often based on project managers' expertise and subjective judgment.

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The NPD project managers lack objective benchmarking models to gain valuable insights into the relations between various resource allocations and activity times in order to support NPD engineers in the best collaborative practices, especially for the planning and execution phase. During the planning phase of NPD, the proposed schedule may not satisfy the due day. Thus, the project managers need to alter the plan accordingly. In addition, during the execution phase, the initially proposed schedule may become infeasible due to the unexpected delay of NPD activities. Therefore, modification of the project plan, while the project is being executed, is needed. However, traditional project management tools cannot provide mechanisms to dynamically modify NPD projects to avoid schedule and cost overruns. This research is to develop a novel project planning and management decision support methodology and tool for NPD process. In order to demonstrate the method's real-world application, a mobile-phone development project scenario is used as a case study to illustrate the effectiveness of the proposed methodology.

2 Literature Review

Many published papers on NPD management have put forward a wide variety of models related NPD planning and performance evaluation. By using a simulation model, Yang and Sum [8] investigate the performance of due date, resource allocation and activity scheduling rules in a multi project environment. The results show when due day nervousness is not mitigated, first in system first served (FISFS) resource allocation rule performs better than the due day sensitive resource allocation rules. Sicotte and Langley [5] examine the efficacy of five types of integration mechanisms for project performance in a sample of 121 R&D projects. This study shows the managers adjusted their use of horizontal structures, planning and process specification, and informal leadership to project uncertainty. In order to identify the key determinants that affect the project performance, artificial neural network (ANN) technique is used to check whether these performance metrics can reasonably predict design-build project performance [4]. Vandevoorde and Vanhoucke [7] compare three different methods to forecast the duration of a project. By using real-life project data, they find the planned value rate [1] and the earned duration [3] are unreliable. Instead, the earned schedule method [2] seems to provide reliable results through the project lifecycle.

3 The Methodology for NPD Process Optimization

Figure 1 shows the architecture of the proposed benchmarking methodology for NPD process optimization. There are includes six modules into the framework, i.e., (1) the process modification, (2) the estimation of project completion time, (3) the resource allocation given most-likely time spent, (4) the time estimation given resource allocation, (5) the time estimation with added resource allocation and (6) relative economical efficiency for the NPD processes within a product portfolio.

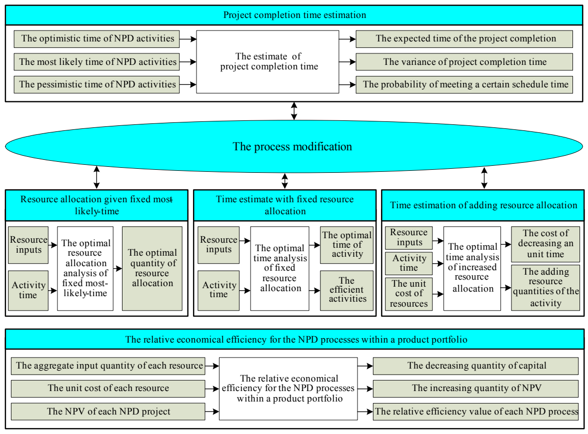

Figure 1. The architecture of the benchmarking methodology for NPD process optimization

In the planning phase, the feed-forward modification mechanism (FFMM), first, applies the module of project completion time estimation to calculate the probability of project time set by customer. If the estimation satisfies the customer's requirement, the FFMM, then, employs the resource allocation given most-likely time to benchmark and adjust all resource allocations of activities. On the other hand, if the time estimation cannot satisfy the customer's requirement, the FFMM utilizes the modules of the time estimation given resource allocation and added resource allocation to reduce the expected NPD process time. Figure 2 displays the feed-forward modification mechanism (FFMM).

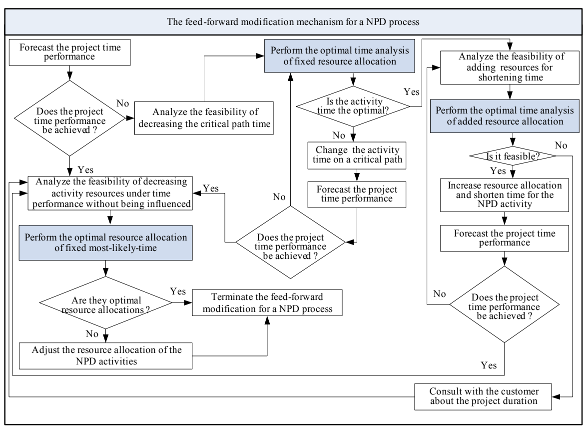

Figure 2. The process architecture of the FFMM.

During the execution phase, if a certain NPD activity delays, the feed-back modification mechanism (FBMM) is activated to assess whether the subsequent

NPD activities need to be modified by applying the time estimation with added resource allocation. Figure 3 shows the process architecture of the FBMM.

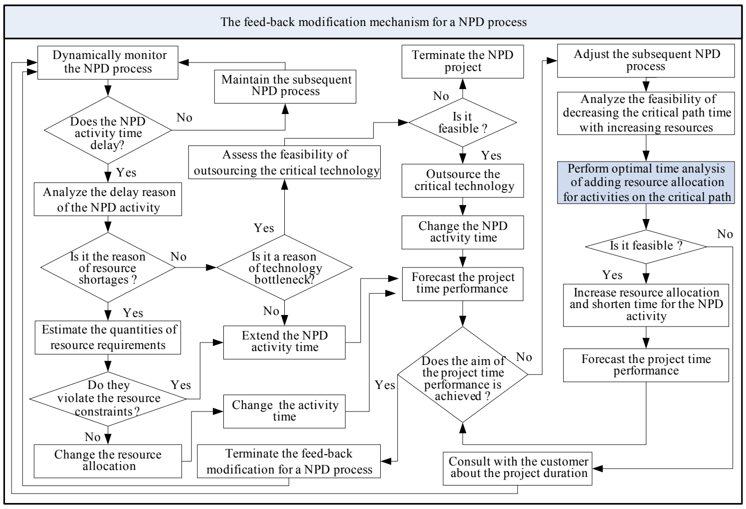

Figure 3. The process architecture of the FBMM.

3.1 Estimation of project completion time

In this functional module, the PERT/CPM approach is adopted to calculate the expected value and variance of the NPD completion time and the probability of meeting the specified project deadline. First of all, a project manager defines a "project network" diagram based on the logical sequence of NPD activities. Then, the NPD manager and participants jointly define the three time estimates of the optimistic time, the most likely time and the pessimistic time of each activity respectively under different executive conditions. The expected value and variance of a NPD activity time can be obtained. This research shortens the expected activity time by adjusting the most likely time. The expected time of a path are given by summing up the expected activity durations along the path. And, a path with the largest expected path time is called the critical path. Furthermore, the variance of a project completion time is the sum of variances of the activity times on the critical path.

3.2 Resource allocation given the most likely completion time

This model investigates the feasibility of reducing the NPD resource allocation given the most likely time. Resource allocation given the most likely time is represented as follows.

$$Min\ \theta_f - \varepsilon\left(\sum_{\forall e\in E} fs_e + \sum_{\forall m\in M} hs_m\right) \qquad (1)$$

s.t. $\sum_{j=1}^{n}\lambda_j\ ht_j = t_f$, (j=1, 2, …, f, …, n), $\sum_{j=1}^{n}\lambda_j\ if_{ej} + fs_e = \theta_t\ if_{ef}\quad \forall e \in E$,

$\sum_{j=1}^{n}\lambda_j\ ih_{mj} + hs_m = \theta_f\ ih_{mf}\quad \forall m \in M$, $\sum_{j=1}^{n}\lambda_j = 1$, $\lambda_j \geq 0$, where

θ_f is the output-technical efficiency of the NPD activity f,

t_j is the time of the past similar NPD activity j,

t_f is the most-likely-time of the present activity f,

if_{ej} is the input time of the facility e for the activity j,

ih_{mj} is the input time of the human resource m for the activity j,

fs_e and hs_m are slack variables.

If $1/\theta_f < 1$, then it represents the facility and human inputs of the activity f can be reduced without being influencing the most-likely-time. Equation (2) and Equation (3) show the decreasing input quantities of facilities and human resources.

$$\Delta if_{ef} = if_{ef} - \left(\theta_f^*\ if_{ef} - fs_f^*\right) \quad (2) \qquad\qquad \Delta ih_{mf} = ih_{mf} - \left(\theta_f^*\ ih_{mf} - hs_m^*\right) \quad (3)$$

3.3 Time estimation with fixed resource allocation

This model analyzes the feasibility of shortening a NPD project time without adding resources as shown in Model (4).

$$Min\ \phi_f \qquad (4)$$

s.t. $\sum_{j=1}^{n}\lambda_j\ t_j \leq \phi_f\ t_f$, (j=1, 2, …, f, …, n),

$\sum_{j=1}^{N}\lambda_j\ if_{ej} \leq if_{ef}\quad \forall e \in E$, $\sum_{j=1}^{N}\lambda_j\ ih_{mj} \leq ih_{mf}\quad \forall m \in M$, $\sum_{j=1}^{N}\lambda_j = 1$

If $1/\ \phi_f < 1$, it shows the time of the activity f can be diminished without adding the resource inputs of the activity f. The decreasing time of the activity f, $\Delta \mathrm{T}_f$, can be obtained by using Equation (5).

$$\Delta t_f = t_f - \mathrm{t}_f \times \phi_f^* \qquad (5)$$

3.4 Time estimation with added resource allocation

This model further analyzes the feasibility of shortening NPD time through adding activity resources. First, we calculate the decreasing activity time and the increasing resource quantities of the activity *j*, and then the project manager confirms whether the increasing resource quantities violate the resource constraints. If these resource requirements do not exceed the resource limits, we can obtain the CTP value using Equation (6).

$$ctp_f = \frac{\sum_{e \in E} \Delta if_{ef} \times cr_e + \sum_{m \in M} \Delta ih_{mf} \times ch_m}{\Delta t_f}\text{, where} \tag{6}$$

fc_e is the input cost of the facility *e* per unit time,

hc_m is the input time of the human resource *m* per unit time.

3.5 The relative economical efficiency for the NPD processes within a product portfolio

The completion-and-review phase analyzes the relative economical efficiency on the market for the NPD processes with a product portfolio by employing the VRS-DEA approach as shown in (7) . If $1/\ \gamma_k < 1$, then it represents the *k*th NPD project should increase the NPV amount $\Delta npv_k = \gamma_k\ npv_k - npv_k$.

$$\text{Max } \gamma_k \tag{7}$$

$$\text{s.t. } \sum_{p=1}^{n} \lambda_p\ npv_p - npvs \geq \gamma_k\ npv_k\ ,\ p = 1, \cdots, k, \cdots, n$$

$$\sum_{p=1}^{k} \lambda_p \left[\left(tif_{ep}\ fc_e \right) + \left(tih_{mp}\ hc_m \right) \right] \leq \left[\left(tif_{ek}\ fc_e \right) + \left(tih_{mk}\ hc_m \right) \right],\ \sum_{p=1}^{n} \lambda_p = 1\ ,\ \lambda_p \geq 0\text{ ,where}$$

tif_{ep} is the total input time of the facility *e* of the project *p*,

tih_{mp} is the total input time of the human resource *m* of the project *p*,

npv_p is the net present revenue of the NPD project *p*.

4 Case Study

Figure 4 shows the network diagram of a new product development (NPD) process for a music mobile phone (MMP) project. In order to evaluate the completion time performance of a MMP project, the project manager and NPD engineers provide the optimistic, pessimistic and most likely time estimations for each activity within the MMP NPD process. By using the PERT/CPM approach, we can obtain the expected value and variance of each MMP development activity time.In this case, we can understand that the network diagram for the MMP development project has four paths. The longest expected time path A-D-E-F-G-M-O is the critical path.

Thus, the expected MMP project time is approximately the sum of the expected activity time on the critical path, i.e., 197 days. Furthermore, the variance of the MMP project time is 56.

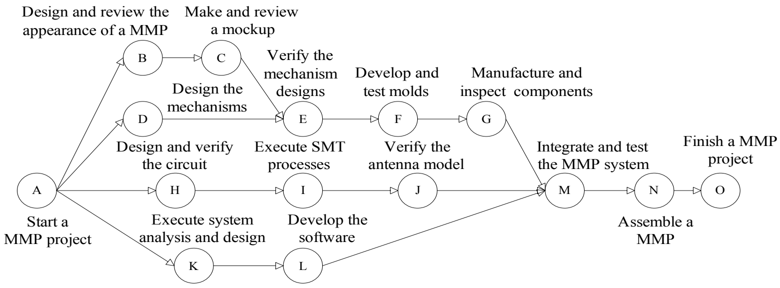

Figure 4. The network diagram of the MMP development process.

In this case, the customer requires that the probability of meeting the MMP project deadline (within 200 days) is 98%. The expected deadline is unlikely to be met because the estimated probability of meeting that deadline is only 64%.

Firstly, the FFMM analyzes the feasibility of diminishing the activity times on the critical path without adding resources by employing the time estimation with fixed resource allocation. Except the activity of mechanism verification, the output oriented technology efficiency of other activities is less than one. Therefore, the FFMM employs Model (4) to optimally shorten the most-likely-times of these activities without adding resources. The expected project time and the probability of meeting the deadline are adjusted to 191 days and 97% respectively. It cannot achieve the time-performance goal of the MMP project. Further, the FFMM analyzes the feasibility of increasing resources for shortening the time of critical path. Through using the time estimation of added resource allocation, the FFMM calculates the CTP values of critical path activities for optimally reducing the critical path time. The CTP value of the mechanism verification is the largest. Hence, the FFMM increases the activity resources of the mechanism verification. The expected project time and the probability of meeting the due day change to 185 days and 98% respectively. Because the mechanism-verification activity has no other benchmarking activities, the FFMM selects the best CTP, i.e., development and test of the molds. The probability of meeting the project's completion day changes to 99%, which satisfies the customer's requirement.

Then, the FFMM analyzes the feasibility of decreasing the resource allocations of non-critical path activities under time performance without being influenced. From the analytical results, we can see the efficiencies of the design and verification of the circuit, the verification of the antenna module, and the system analysis and design are less than one. By employing resource allocation given most likely time, the FFMM adjusts resource allocations of these activities. Finally, the FFMM achieves the MMP development process optimization in the planning phase.

In execution phase, the FBMM detects the delays of development and test of the molds of the MMP project. By understanding the reason of the delay, the project manager decides to maintain the resource allocation and modify the three time estimates for this activity. The probability of meeting the deadline is changed into 96%. Hence, the FBMM is activated to adjust the following activities of the MMP project. By increasing the working time 208 hours of testing engineers, the most likely time of the integration and test of the system and the probability of meeting the project schedule change into 32 days and 98% respectively, which achieve the customer's requirement level.

The third phase evaluates the performance of NPD processes with a product portfolio of 3 NPD projects, i.e., MMP, smart mobile-phone (SMP), and multimedia mobile-phone (MMP2) projects [6]. By employing Model (7), we obtain the performance assessment values of these projects. Because the efficiencies of SMP and MMP2 projects are less than one, this research further analyzes and provides the improvement directions for both projects. The output-oriented efficiency analyses suggest the NPD strategies and improve the expected profits of SMP and MMP2 projects to US$2,457,000 and $2,457,770 (increasing US$910,000 and US$660,000) respectively.

5 Conclusion

Currently, most performance evaluation methods, which focus mostly on the planning and completion phases of a project, cannot utilize the assessment results to further support the feasibility of NPD process improvement by providing consistent and quantitative comments and suggestions. From the entire process lifecycle point of view, this research develops a novel DEA benchmarking methodology, which consists of modification mechanisms to optimize NPD processes and avoid unexpected delays and budget overruns (during the planning, execution and completion phases). By applying the DEA methodology to a real product development project, this research shows that the methodology can be adopted to generalized NPD applications with significant advantages.

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Critical success factors on product development management in Brazilian technological based companies

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Abstract. In order to minimize the proportion of unsuccessful projects in new products development (NPD), managers have become concerned in understanding which factors have an impact on the success of new products. The aim of this paper is to identify and analyze the critical success factors (CSF) when developing new products in technological based companies (TBCs). The data was obtained through a survey in 62 small TBCs of two sectors: the medical and hospital equipment and the process control automation, in the State of São Paulo, Brazil. This has resulted in a sample of 62 new product projects considered successful and 42 unsuccessful, from the firms' point of view, developed in the last five years. The questionnaire was structured based on eleven management factors, deployed in 64 variables. The association of these variables with the project result (successful or unsuccessful) was measured through their respective contingency coefficients. Thus, we sought to determine which variables, considered in isolation, could explain new product's success. We also tried to reduce the individual variables by using factorial analysis techniques, where three main components were associated to new product success: target-market characteristics, execution quality of NPD activities and integration between the areas involved in NPD.

Keywords. Product development management, Technology Based Companies, Critical success factors.

1. Introduction

In the developing countries small and medium technology-based companies essentially operate within market niches, not occupied by the bigger companies,

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and normally to substitute imports. Nevertheless, their economic potential should not be neglected. Although TBCs may mostly be small sized, they frequently develop innovative products, and thus are likely to boost the economic growth in their operations regions [6, 12], influencing with their technological innovation culture both their partners, customers, suppliers and competitors.

Most field researches involving small and medium size TBCs in Brazil, according to [1] focus primarily the development of technological poles and business incubators. Thus, according to those authors, a lack exists of empirical studies which reveal management factors critical for the success of those organizations. Furthermore, Process Development is a process critical for those companies and barely known from the academic point of view.

The study of management of product development process (PDP) in small and medium size TBCs is yet in a beginning phase in Brazil. As attested by [9], those companies face significant managerial difficulties, influencing the success rate of the products they develop.

According to [8], best practices for small and medium companies can only be recommended upon consideration given to their peculiarities. Therefore, it is relevant to identify the management practices, taking into account companies of a specific industry, their size and peculiarities of their organizational structure.

Taking into consideration the context pointed at, the objective of this paper is to describe and analyze the main practices and success factors relative to PDP management in small and medium size TBCs operating in the Process Control Automation (PCA) sector, and Medical and Hospital Equipment (MHE). These sectors stand out for their proven technological dynamics found in Brazilian innovation research, in addition to their economic relevancy within the small-sized Brazilian TBC.

The concept of success and failure projects was based on comparison between a company's original expectation and the product's real performance in the market. During the research components associated to the market were investigated, such as technical factors and practices adopted in managing these projects, since such elements collectively influence the new project's success or failure.

The purpose of this paper is outline by this introduction. The following section discusses critical success factor in PDP management. Following are the research method, results and conclusions.

2. Critical Success Factors in the Management of the Product Development Process

A research line in the area of PDP management is finding success factors, namely, differentiating practices (tactics, methods, tools and techniques) that, provided they are thoroughly and well executed, contribute to increase the probabilities for success in launching new products [7]. Many authors [3, 11, 12] point out a set of factors associated to the success of new products.

According to [4], the first study in this field was carried out by the consulting company Bozz, Allen and Hamilton in 1968, which verified that almost 1/3 of the products launched, ended up in failure. The vast amount of literature in the area produced a collection of factors associated to the success of new products [3, 12].

For the purpose of this paper the following factors were investigated: new product innovation degree, characteristics of the target markets, product characteristics, technology sources, company skills/ability, project leader skills, integration of PDP, PDP organization and execution quality of PDP activities. These factors are to be briefly discussed below.

The market orientation is critical to the success [3, 12]. This factor approaches aspects such as company capacity to evaluate market potential for a new product, understanding the needs of the target market and translating such information into PDP language [10].

There are numerous products characteristics that propel them to success: low cost, high quality, superior performance and unique attributes [2, 10]. The need to integrate the strategy of product development with company strategies at program and project levels is also recognized [2].

Technology sources can also contribute for the success or failure of a new project, because they demand acquisition, adaptation and managing skills [5].

The main organization aspects of PDP mentioned in the literature include the company organization for product development, the degree of integration between the functional areas, level of PDP structuring and characteristics of key-individuals involved in the project execution [10]. Reference [3] indicates five important factors linked to organizational characteristics of PDP: setting up multifunctional teams, authority and responsibility of the project leader, the scope of responsibility over the project by the development team, commitment of the team members and high degree of communication during the entire project.

Regarding to carrying out PDP activities, [10] recommend paying attention to the pre-development phase, handling of technical and market studies, and feasibility analysis. Reference [4] emphasizes the need for quality in activities concerning generating and analyzing ideas, technical development and market introduction.

As regards PDP management in TBCs, [13] indicate that many studies of product development are carried out in companies located in relatively stable vicinities, a quite different reality from the areas or markets where Technology-based companies (TBCs) are usually established.

3. Research Method

The research was projected in three phases. Initially, the bibliographic revision of PDP management, critical success factors in product development and in technology-based companies was accomplished. This phase enabled the formulation of a set of factors that could explain the success of a new product.

The second phase consisted of choosing the participating companies of the research and data collection. Based on criteria as size, operation segment (manufacturers of medical and hospital equipment and process control automation), location (Sate of São Paulo) and existence of their own and active PDP, the sample amounted to 62 TBCs, totaling to 104 products, out of which 62 were considered as successful and 42 considered as unsuccessful. Table 1 synthesizes the stratification of these projects/products according to the industrial segment.

Table 1: Project/ Product Classification

Product	*Success*	**Unsuccess**
Medical and Hospital Equipment	30	19
Process Control Automation Equipment	32	23
Total	62	42

Success or unsuccess was the denomination given by the answerer, who compared the performance of the product in relation to the company's expectations regarding the launching. In the cases where the performance was equal or surpassed expectations, they were classified as successful, however in the unsuccessful cases, they corresponded to products whose performance was considered below or extremely below expectations.

For data collection, a questionnaire was employed, which by means of 64 close-ended questions recuperated information about managing and handling of product development that gave rise to successful or unsuccessful product.

In the third phase, statistical techniques were applied to data collect. Initially, the association of the variables investigated was measure with the result of the product project (successful and unsuccessful) through the respective contingency coefficients. Hence, it was sought to determine which variables considered isolated, explained the success or failure of the new product. Also, reducing and summarizing the individuals variables was tried by using factorial analysis among factors was carried out.

The interpretation of the generated results from statistical procedures enabled finding a set of factors that affect the success of product development in the TBC, thus indicating priorities and information focus in PDP management.

4. Analysis of Results

The results in table 2 show correlation coefficients and their respective levels of significance (p) among ten main components (critical factors) and the result of new product for the companies of medical-hospital equipments (MHE), as well as for the companies of process control automation (PCA). In agreement with the methodology, each main component corresponds to a set of isolated variables, which by applying the multivariate analysis technique were reduced, aiming at facilitating data interpretation. Table 3 demonstrates the isolated variables considered equally significant for both sectors.

Table 2: Correlation between main components and the result of new product

Main Components	***Correlation Coefficient and Significance Level among the Main Components and the Result of the New Product***	
	PCA	**MHE**
Innovation degree	0,5382 (p=0,000)*	0,441 (p=0,002)**
Characteristics of market - target	0,3908 (p=0,003)**	0,592 (p=0,000)*
Product characteristics	0,4474 (p=0,001)*	0,449 (p=0,001)*
Technology sources	0,0983 (p=0,475)α	0,055 (p=0,709)α
Company competence	0,2011 (p=0,141) α	0,143 (p=0,328) α
Competency of project leader	0,4088 (p=0,002)**	0,489 (p=0,000) α
Integration	0,3061 (p=0,023)**	0,530 (p=0,000)*
Organization	0,1622 (p=0,237) α	0,097 (p=0,503)*
Execution quality of PDP	0,3988 (p=0,003)**	0,612 (p=0,000)*
Execution quality of others activities	0,1654 (p=0,227) α	0,424 (p=0,002)**

* Significant at p≤0,001 **Significant at p≤0,05 α Not significant at p≥ 0,10

Table 3: Association between isolated variables and the result of new product

Isolated Variables	***Contingency Coefficients and Significance Level Between Isolated Variables and Results of New Product***	
	PCA	**MHE**
Characteristics of market target		
Potential of well executed market	0.432 p=(0.015)**	0.426 p=(0.034)**
Interpretation of needs	0.478 p=(0.03)**	0.567 p=(0.000)*
Product characteristics		
Superior technical performance against competitors	0.509 p=(0.001)*	0.483 p=(0.006)**
Competency of project leader		
Interpersonal skills necessary for the project	0.447 p=(0.008)	0.394 p=(0.029)**
Managing skills necessary for the project	0.432 p=(0.013)	0.487 p=(0.004)**
Team participation in decision-making	0.419 p=(0.20)	0.423 p= (0.014)**
Quality of PDP activities		
Generating and selecting ideas	0.384 p=(0.023)**	0.513 p=(0.001)*
Analyzing viabilities (technical and economical)	0.479 p= (0.003)**	0.437 p=(0.021)**
Technical development (product project)	0.406 p=(0.014)**	0.458 p=(0.005)**
Preparing documents – homologizing product	0.502 p=(0.024)**	0.486 p=(0.042)**

* Significant at p≤0,001 **Significant at p≤0,05

The results suggest that the sectors emphasize different aspects in their PDP managing systems to generate the success of new product. It can be concluded the PCA companies are more product oriented, while the MHE companies are more process oriented.

The PCA companies are more concerned with product characteristics and the innovation degree that is incorporated. For this reason, they should give priority and much attention in structuring the technical and economic requisites of the product that will be developed (detail stage of product project and fabrication process), depending on the characteristics of the project leaders during this process. For the MHE companies, these components also were found to be relevant, however with moderate degrees of correlation.

Success in MHE is more dependent on the organization characteristics of the company, such as proficiency in carrying out PDP activities and marketing skills of the company. The successful projects are those in which marketing evaluation were carried out well and user requisites were well interpreted concerning new product specifications. Thus, it's important that such companies place more concern in the proficiency of PDP activities, above all, those related to pre-development (generating ideas, selecting ideas, formulating concepts and analyzing viability), because they were pointed out as being critical for success. These results were compatible with studies performed in many countries [12].

The values of main components referent to market-target and quality of PDP activities in the PCA sector of the companies present a reasonable correlation with the result factor of the new product (table 2). In the first component, besides the variables showed in table 3, the need for synergy between the new product and already explored markets by the companies could also be indicated as critical success factor. From the isolated variables that form the quality component of PDP activities, it can be verified that pre-development and project are factors that should be carefully managed in PDP activities by such companies.

The results in table 3 regarding preparation and follow-up of documents and reports necessary to homologize the product were considered equally significant by the companies of both sectors. While for the PCA companies, the quality need of this stage is connected to pressure by clients, in MHE companies it is due to legal norms imposed on the product.

It is presumed that in small companies, integration in the functional areas occurs naturally and freely, since proximity of individuals emphasizes the level of contact, facilitates communication and information exchange during PDP. Integration is substantially correlated to the result of new product in MHE companies; however, the same is not true for the other sector. The integration need in this sector was verified as being decisive during the execution of pre-development activities, which strengthens the results previously described.

According to [3], the project leader plays an important role in handling the development process of a new product, since he is directly responsible for organizing and directing the team members of development. Besides leading the team, he must know how to negotiated with the directory in order to obtain the necessary resources for the project. In order to perform this role, the leader must be endowed of managerial qualification and relationship skills to create and environment of trust, coordination and control.

Considered that the results of tables 2 and 3, corroborate [3] affirmations, reinforcing the importance of a leader that has technical and managing competencies related to project activities in order to develop a new product.

Three main components (skill levels of the company, technology sources and types of organizations structures applied to the development projects) contribute little or not at all in the success of the products developed by such companies.

Regarding levels of competency, two hypotheses can be viewed as an explanation of these results. The first one would be a more compliant judgment of the responders, in which they not directly hold the functional areas accountable for the eventual problems and mistakes that occurred in the unsuccessful projects. Another hypothesis suggests that successful projects as well as unsuccessful ones relied on appropriated effort and application by the individuals of the departments involved. In this case, the failure could be explained by another reasons and not the lack of technical competence.

The TBCs have a basic characteristic of developing high technology products and in the cases of successful products as well as unsuccessful ones; they predominately employ informal and internal company mechanisms for technological developments applied to the products they produce. That is the reason why technology achievement sources do not appear to be correlated to the result of new product.

Owing to the fact that small and mid-sized companies were research, that is, productive and informal companies in terms of organizational structure, the models of functional or matrix organization practically did not influence the success and failure of the products developed; since satisfactory level of communication and collaboration between the areas are facilitated by the characteristics of small-sized companies.

5. Conclusions

This paper analyzed management practices and critical success factors during the realization of new product development projects. Product development is a complex process and any research in this area shows limitations. The main restriction of this paper is related to the option made to examine critical success factors in the new product development projects, although just within specifics sectors of the Brazilian small and medium size TBCs. Future research may lead to investigate the core subject within other sectors, software and biotechnology, for example. Despite the limitations, some considerations can be made in view of the results obtained.

By interpreting the results obtained, it can be understood that such companies assign priority and be concerned with the characteristics of the products and their articulation with the company strategy. By so doing, they should pay much attention to the pre-development stage, when technical and economic requisites of the products to be developed are being structured (detail stage of the product project and manufacture process), and keep this in mind and attitude so that future products have a characteristic that pursues convergence with strategy and the company's target market.

The pre-development stage tends to be effective when right decisions are made to properly articulate product project and company strategies, capture desired technology and market information, and to analyze in early stages cost and prices of the product to be produced. Good decision making in this phase can be facilitated by creating a "multifunctional development team" right at the beginning of PDP steps, as suggested by [10].

Thus, from the PDP beginning, analyses and screenings within the areas of Production, Engineering, R&D (develops technology to be incorporated into the product) and Marketing, will be intensified and concentrated on the product to be developed. That integration can be deemed as an important management mechanism, since the multifunctional team boosts the accumulated knowledge exchange, by and amongst each company's function. Integration also diminishes uncertainties and consequently increases decisions quality as made during the beginning of the development; this is likely to lower project cost due to the probable reduction of problems occurrence throughout the PDP.

That type of organizational arrangements for product developments can be implemented more easily in small and medium companies, as those object of this research; due to their size, integration and inter-functional communication, the organizational arrangement tends to occur more naturally. It is a management mechanism to be better explored by the small and medium size TBCs in the PCA and MHE sectors.

Some results are not compatible with success factors in the literature concerning critical success factors in PDP. Since they are TBCs, there were expectations that the process of acquisition and technology transference were critical for such companies. However this hypothesis was not verified thought the results of this research. Lastly, it is hoped that the results of this work are able be added to the theoretical body concerning success factors in specific management environments of product development, and at the same time, contribute for improvements in PDP indicators when evidencing practices that condition the success or failure of new product.

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The Main Problems in the Product Development Process by Large-sized Companies of the Brazilian Agricultural Machines and Implements Sector

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Abstract. In Brazil, the industry of agricultural machines and implements represents a significant growth potential, focusing on the increase of product exportation as an alternative to reach better-distributed merchandise value throughout the year, thus aiming at overcoming the problems of internal seasonality. It is therefore necessary for the industry to develop products, whose lesser cost and adequate quality levels allow meeting the needs of major producer customers and the Brazilian market, which is characterized by a constant search for technological solutions and sophisticated products. Even with the growth potential of this sector, its products development process continues to present problems, management included, resulting in poorer performance of projects and products and Companies should accept those problems as actual and concrete facts, so that actions may be initiated to prevent long lasting unsolved situations and eventual barriers to the company competitiveness. By means of a descriptive exploratory study, the purpose of this paper is to identify and analyze the main difficulties encountered by large-sized Brazilian companies, located in the State of São Paulo, which manufacture agricultural machines and implements.

Keywords. Product development process, agricultural machines industry, product development process management

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1 Introduction

The Brazilian agricultural machines and implements industry (AMIs) shows a high potential growth for the years to come, which is linked to the domestic agriculture growth, being the increased utilization of agricultural machines and implements one of the main reasons of agriculture good productivity performance. Such demand for MIAs calls for the development of products that yield better performance and best fit the territorial topographic conditions; namely, a MIA utilized in a flat region should be adapted to operate in more irregular terrains. However, product development departments face many daily difficulties that directly affect the performance of such process.

Some of those problems are rooted in historic aspects of the origin of such industrial sector, since grounding projects on equipments developed in other countries was a common practice by the local industry. That resulted in various difficulties due to climate and topographic characteristics different from the Brazilian territory, jeopardizing the products performance and, consequently, the culture [6].

Amongst the main problems experienced by the MIAs, those related to work accidents due to product dimensioning [7] can be mentioned, as well as precision problems and, chiefly in seeding and spraying activities [6] and [4]. Those problems are failures due to product development process (PDP).

This paper discusses the difficulties MIAs face during PDP and which directly affect their performance.

It is important that companies be aware of what their difficulties are, because, with the aid of a diagnose it is possible to work on problems solutions to prevent their consolidation and build up of a competitiveness blocking barrier.

This paper aims, thru an exploratory descriptive research, at identifying the main difficulties faced by large-sized MIAs located in the State of São Paulo. To achieve the objective, all the agricultural machines companies matching this profile were identified. The screening yielded five companies, which were later visited to interview the person responsible for Product Development, to identify the main difficulties those companies cope with during the product development.

Despite the fact that all five companies showed the same profile, the heterogeneous nature of their problems was observed, leading to at least three group categories: financial difficulties, personnel difficulties and technical problems like product project and validation, each one of them adversely affecting PDP specific aspects.

2 The Product Development Process and its Management

The new product development takes place thru a business process, PDP, starting with the identification of a market need, which is later turned into a new product. To allow that, it is necessary to identify and translate the market needs, the technological possibilities and limitations, into product project specifications and its productive process. Parallel to those activities, production and product market launch planning are two important activities to take place. After the product launch, PDP is responsible to watch the new product behavior, in actual use and production, carrying out, whenever necessary, eventual product specifications or process changes, until the product withdrawal from the market [5].

PDP is the manner how the company realizes and manages the set of products that will originate new products. Namely, product projects flow along PDP, which in any given company shows some basic phases common to all the projects, although phases of each project are individually treated [5].

PDP shows some peculiarities, like high degree of uncertainties related to this process; administration of multiply sourced information, like customers, suppliers and various company areas; diversity of requirements the new product project must meet, involving customer requirements, manufacture capacity to realize the project, necessary technical assistance services and recycling at the end of the product life cycle [5].

Any organization searching for competitiveness thru a new product should focus on time-quality-productivity based indicators [5]. Good PDP performance depends on characteristics such as well defined project objectives, focus on time and market, internal integration to the project, integration amongst company areas involved in the project, high quality prototyping and strong leadership exercised by the project team. Thru those management characteristics, a quick and efficient development is sought for, which will yield competitive processes [1].

Nevertheless, depending on the complexity inherent to PDP, companies commonly face difficulties in managing this process that directly affect its performance.

2.1 PDP - Related Problems

Not always does the reality of a new product development process matches theory, problems commonly surge along this process that are to be known by companies to prevent their repetition.

Amongst the most common causes of product development problems [1], following can be mentioned:

- *Moving objectives*: frequently, do not the basic product or process consider changes, whether technological or market wise, taking place during the project. This is likely to occur when the project is based on an apparently stable technology aiming at a specific market that suddenly changes, or assumptions are made on distribution channels that are fairly constant.

- *Isolation of the product development department (DP)*: when the company developing a product owns more than one productive unit, the product development department DP commonly performs isolated, which is likely to cause communication problems amongst the DP and marketing, production, finance, departments, etc., etc

- *Misunderstandings amongst the company functional areas*: what a given area of the company expects or imagines from other area may be unreal or impossible to be achieved. Frequently, the areas involved in PDP do not understand each other, use different languages or measure results in a different manner. Frequent misunderstandings between the marketing and technical areas, for example, are due to unreliable market research.

- *Time to identify need or opportunity versus time to market*: a considerable time segment may exist between the decision to develop a new product, namely, the surge of an idea, and its effective development; besides, not always will the product discoverer company be the one that most will benefit.

- *Lack of product differentiation*: new product development frequently ends up in frustration because the new product is not absolutely innovative in the market, or it is easily imitable.

- *Unexpected technical problems*: product development involves activities with a certain degree of uncertainties, however, it is common that companies allocate resources almost entirely for known project requirements, leaving nothing or very little available for unexpected events.

- *Problems solution delay:* delays or exceeding costs may overload the company technical capabilities or simply result in lack of resources.

- *Personal issues*: as explained above, the product development process may fail and, in such cases, it is necessary that the organization refrain from hunting people to blame for the failure. Rather, learning with mistakes so as to prevent their repetition, should be the company-wide managerial behavior; nevertheless, the search for a guilty makes the work ambient conflictive and unfavorable to innovations.

Summarizing, most common failures in a new products and processes development process are related to: focus on the individual project to ensure fastness, manufacture execution, provision of sufficient *initial information* to plan ahead, and articulate individual projects with the company competitive strategy.

3 Research Method

The research was carried out by means of an exploratory descriptive study involving the following activities: bibliographic research on the subject, mapping and identification of companies matching the intended profile, design and preparation of an interview semi-structured check-list, visiting companies and check-list application while interviewing the responsible for PDP, obtained data description and analysis.

The bibliographic review included the product development process and its management as well as the main related problems; this activity also involved getting to know outstanding characteristics of the Brazilian agricultural machines and implements industry.

Based on the knowledge acquired on PDP management and the industry, a semi-structured checklist was prepared so as to identify noteworthy difficulties those industries face during the PDP.

Data obtained from ANFAVEA - Associação Nacional dos Fabricantes de Veículos Automotores and also from IBGE - Instituto Brasileiro de Geografia e Estatísticas, allowed to identify in the State of São Paulo, within August 2005 and January 2006, five national capital large companies (according to the head count). All those companies, when visited, showed evidences they had developed products between 2003 and 2005. After the visits and interviews, the data obtained were analyzed.

4 Field Research

This item will show the results of the field research conducted in five large size national companies located in the State of São Paulo, denominated herein as EA (Enterprise A), EB, EC, ED, EE.

4.1 General Characterization of the Companies

The head count of each one of all the companies under study had, between August 2005 and January 2006, of more than 500 employees, the largest one having 2000 employees and less than 600 the smallest one. Three companies out of the five, exhibited total sales above one hundred million Reais; it was not possible to establish a direct relationship between total sales and head count, since the smallest company presented one of the highest total sales.

As regards company administration, a trend was observed showing the migration from family to professional style; currently, two companies are in the transitional stage, one has already professionalized its administration and two are still family run.

Four out of the five subject companies are certified in conformance with ISO 9001, what evidences their interest to meet stringent requirements and increase their export operations, since the export business contribution is fairly low in all the companies except one, whose export contribution to total sales is 50%. However, the leading customers of such company are developing countries, not very stringent as regards quality and advanced technologies. Chart 4.1 summarizes the mentioned information.

Characteristic analyzed	Company EA	Company EB	Company EC	Company ED	Company EE
Management style	Family	Family	Professional	Transition (from family to professional)	Transition (from family to professional)
Head count	2000	1600	500 thru 700	900	500 thru 600
Manufacturing sites	2	1	2	1	2
Annual total sales (Million Reais)	Above 100	75 - 100	30 - 50	Above 100	Above 100
New product sales contribution	20 - 40%	50 - 60%	20 - 30%	20 - 30%	20 - 40%
Export business contribution	30%	30%	50%	35%	15%
Certifications	ISO 9001	ISO 9001	No	ISO 9001	ISO 9001

Chart 4. 1 General Characterization of the companies under study

4.2 The Main Problems Encountered by Companies during PDP

According to Chart 4.2, it can be seen that problems encountered by companies are peculiar to each one, although they can be reunited in 5 groups: Group 1- quality related problems, Group 2- time related problems (meeting target times), Group 3- leadership related problems as well as overall development process management, Group 4- personnel related problems and Group 5- finance problems. Thru this grouping, it is observable that most difficulties relate to process management.

The variables related to development time are also quite critical, due to delay in new products launch or due do difficulties in meeting established targets or deadlines. Companies B and C face problems due to the frequent need of changes in the original project, which is also a time related problem, because changes end up delaying the running project.

	Problems	*E A*	*EB*	*EC*	*ED*	*EE*	*Frequency*
Group 1	**Developed product quality**	✔	-	-	-	-	*1*
Group 2	**Delay to develop new products**	✔	✔	-	-	-	*2*
	Difficulties to meet deadlines	✔	-	-	-	✔	2
Group 3	**Lack of periodic reviews along PDP**	-	✔	-	-	-	*1*
	Frequent changes in the original project	-	✔	✔	-	-	*2*
	Slow PDP information system	-	-	-	-	✔	1
	Lack of integration between product project and process project	-	-	-	-	✔	1
Group 4	**People management**	-	-	-	-	✔	1
	Small development teams	-	-	-	-	✔	1
	Difficult communication amongst engineering and other company sectors	-	-	-	-	✔	1
Group 5	**High development costs**	-	-	✔	-	-	1
	Lack of financial resources	-	-	-	✔	-	1

Chart 4.2 Main problems as stated by companies

If compared to other industrial sectors, the new product development time spent by MIAs is extremely short, however, as previously discussed, that variable is vital for products success. When a new product launch delay occurs, besides the problem of having to wait until the next harvest, some worsening factors exist. A competitor may launch a similar product, heavy financial loss for the delayed company, since those equipments have a long useful life and the customer who purchased from a competitor most likely will purchase a similar one in no less than 10 years.

Development costs are also a problem for companies EC and ED. For EC the development cost is high, as long as for ED the problem is the lack of financial resources to invest in new projects.

EE faces many people management problems as well as small development teams. Beyond that, the company has problems managing the information flow amongst Engineering (responsible for PDP) and other company areas.

Although separately grouped, problems interrelate. For example, delays due to changes in the original project are frequent. Companies face difficulties to meet deadlines due to the small project teams, communication difficulties amongst departments and lack of quick response of the information systems. Indications exist showing that, by solving any of those problems, there will be a contribution to solve the others.

5 Conclusions

By studying the various problems which were detected, the companies concern to hire employees with technical knowledge is noticeable, what can be one of the causes of PDP management related problems. Hiring professionals with solid PDP background would facilitate the solution of such problems due to their wide vision of PDP and not only isolate activities. This fact would also allow the early identification of most critical functions and activities as well as a better integration amongst PDP involved areas.

Time related problems, together with changes in original projects, are likely to provoke misunderstandings between the PDP team/department and Commercial area. In such situation it is ideal that the companies foresee clients' future needs ahead of time, thus preventing projects with moving targets over time. Also, the lack of integration between product project and process project may result in faulty prototypes or a manufacture incapable to produce the new product, thus causing further delays. Carrying out tests and project validation, involving both product and process, emerge as an alternative prior to the actual scale production, which will help avoid customers dissatisfaction and complaints about product performance.

Starting from the problems identification and their categories, it is important that companies may concentrate themselves on their respective causes to prevent them, since all the identified difficulties result in delays or even in products performance lower than expected.

In more complex situations, the new product project and its development are likely to provoke conflicts amongst the different company areas, thus harming the overall PDP. The ideal situation, during the PDP, is to have clear project objectives, shared throughout the organization and articulated with the market needs and the company's strategy, thus facilitating the early solution of problems in all the hierarchical levels.

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Identification of critical points for the implementation of a PDP reference model in SMEs

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Abstract. Numerous practices and principles are available to improve the company's Product Development Process (PDP), including multifunctional teams, integrated development process, integration of market evaluation to product development, and product life cycle analysis. Indeed, the importance of PDP systematization and organization is widely recognized, and the existing reference models offer a representation of the PDP. However, most companies fail to incorporate these practices into their routine to improve their PDP, since the implementation of a reference model or the PDP transformation process are influenced by the companys organizational structure. This paper identifies and discusses several critical aspects of the PDP transformation process of SMEs, based on an analysis of the implementation of a reference model in a Brazilian SME. The analysis of this experience enabled us to pinpoint various difficulties attending the transformation of the PDP, which we then compared with the literature on the transformation process. This comparison led to the identification of critical points for the SMEs structure and organization for PDP improvement. These observations are expected to support the design of PDP transformation models, thus helping SMEs to enhance their competitiveness.

Keywords. Small and medium enterprises; Product Development Process improvement; Transformation model

1 Introduction

The product development process (PDP) management knowledge gradually evolved accompanying the management theory evolution. The product view was amplified and the process involves several knowledge areas participation. To this purpose, the PDP become composed by multifunctional teams and concurrent activities. Nevertheless, several companies although have an initial stage PDP, without standardization and with a sequential development process.

The other aspects highlighted by the new approaches are the initial stages of the PDP, the very well defined information flow, and the customer focused philosophy. A PDP reference model comprises activities, tasks and tools related to

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the product development steps execution. Those models are developed to indicate the PDP best practices. Those best practices comprise the principles indicated by the reference philosophies, tools and approaches, as the Concurrent Engineering, the Product Based Business, and the Integrated Product Development. There are many authors describing several models. The most known are Hollins and Pugh[1], Pahl and Beitz[2], Roozenburg and Eeekels[3], Copper[4], Crawford and Benedetto[5], Dickson[6], and Kotler[7]. They summarize the answer to a PDP's improvement need in order to reduce the development time and costs. The high competitiveness made that the development process steps incorporate the strategic items, focusing on the customer needs [8].

The PDP literature is largely disseminated, and offers different models. The difficulties are on the reference model implementation on the companies practice, especially on the small and medium enterprises (SME).

The most common way to classify companies is the company's size. Nevertheless, the SME do not have homogenous culture and practices. The specificity of the management of SME tends to disappear with the modern practices as net business, risk capital use, and global market. In this context, those companies tend to have the similar management as the great corporations [9]. In this paper we suppose that the initial approach on low maturity level companies is the sequential development. On this context, the reference models are presented as an important guide providing benchmarking to PDP structuring.

Hunter [10] emphasizes that the organizational structure is related with the company's innovation posture. As the author says, the organizational structure design is defined by contextual and structural elements. The **contextual elements** include the strategy, environment, technology, business size/ life cycle and the culture. The **structural elements** include reporting relationship, decision making processes, communication processes, coordination of work, forms of complexity and distinguishing characteristics.

This paper objectives the identification of the critical points for the PDP reference model implementation on the SME. Those points are identified from the characterization of a medium sized company.

2 Method

The Hunter's [10] elements are related to the company's behavior on its ambient. This paper characterizes those elements in a low to moderate maturity level company's reality. From this evaluation, some aspects to understand the low to moderate maturity level company's culture were identified.

The evaluation of the Hunter's elements was conducted based on the management areas. The relationship between the Hunter's elements and the management areas is presented in the Figure 1. The closed cell represents the management areas contemplated by the Hunter's elements.

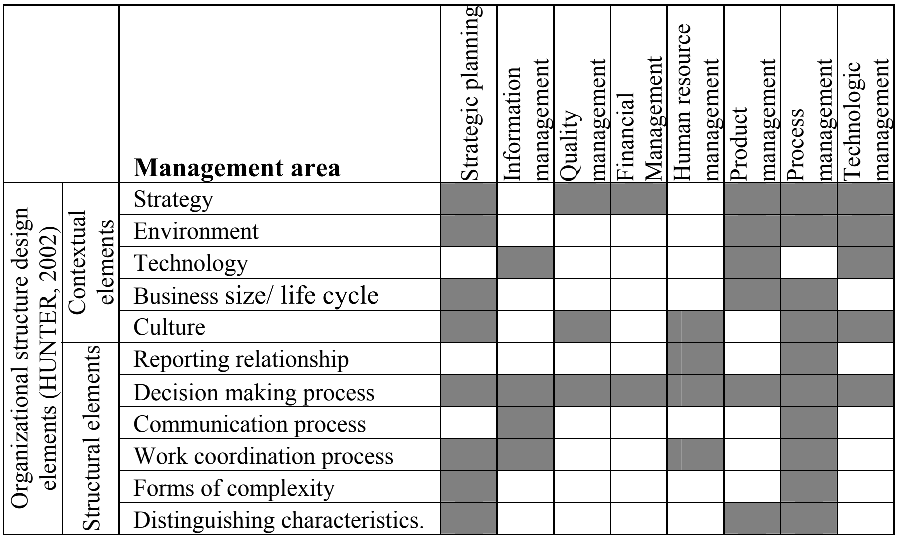

Figure 1: Management areas and Hunter's (2002) structural and contextual elements

The critical points identified on the management areas are related to the contextual and structural elements and will assist the diagnostic step on the reference model implementation. The management areas to be evaluated are Strategic Planning, Information Management, Quality Management, Financial Management, Human Resource Management, Product Management, Process Management and Technologic Management.

3 Literature Review

The small to medium sized and low to moderate maturity level companies' related literature was investigated. The literature suggests that all companies need some level of flexibility, depending on their environment, despite their size [9]. Some new tendencies for modern management views that define the high maturity level companies were identified. The new approaches highlighted the organizational structures that present flexibility, empowerment of employees, power decentralization, communication systematization as advantageous to innovative capacity in an instable environmental context [10; 14; 15; 16; 17].

The change management related literature understands that the techniques, tools and conceptually (technologically and scientifically) correct systems must be resultant from the company's learning to bring a proper innovative culture. This innovative culture must be capable to conduct the company to generate itself knowledge to continuous improvement.

The literatures related to the change management [18; 19; 20], the situational method construction [13], and the action research [21; 22] converge to a central idea. Those literatures emphasize the individual person's role on the company's and social group's context as critical for an effective change implementation.

It is expected that the company becomes more innovative after the PDP improvement by reference model implementation. The innovativeness is constructed by learning favorable structure, that propitiates actively capture of data from the environment, transforming more efficiently them into information, using them to generate knowledge [23]. This system is important both for the new structured PDP, as for the transformation (and continuous improvement) process - the reference model implementation. This system will propitiate the organizational memory vehicle to help on an innovative product generation.

The company's structure consideration is important for the evaluation tool selection on a process improvement [13]. This description correlates with the situational method construction. The process improvement project must start considering the company's maturity level and structure to select the most adequate evaluation tool.

Several tools for maturity levels are available in the literature. One adapted for the theme product development is useful for the reference model implementation. A possibility is to adapt the Sturkenboon et al. tool [15], directed to SME.

4 Case study

The selected company is median-sized, by the traditional employee's number based classification. It is located on the south of Brazil and has a familiar origin. Its products had been developed a long time ago, on the company's activities beginning. It has a Product Development Department, but new products are not launched for a several years. The developed products are inspired on market available products.

The company belongs to the pharmaceutical sector. Locally, this sector is characterized as low maturity level on the production process, as the product development process. The local sector's companies have a quality view focused on control. The company has an intention to improve, searching to use some management practices, as strategic planning and use of metrics.

The company's used representation of its functionality is the organogram. This kind of representation shows the hierarchic organizational structure. The existing metrics did not help the management system improvement. In fact, the company did not have an effective performance measurement system.

The strategic planning was not effectively deployed to the tactic level. The company did not present investment planning or financial evaluation. This observation is applied to the equipment and technology substitution politics and to the product development projects. It was observed that the company did not have the habit to planning, evaluate and control projects.

In this company, the pharmaceutical product development was understood as different from the other segments. This idea is the same emphasized by Sharp [11]. This author related that the existent posture is that the product development project quality does not necessary affect the quality perception on the pharmaceutical sector. The pharmaceutical area, as observed on this company, did not consider other product dimensions than the generic dimension (the technical characteristics).

The training system had essentially technical emphasis. The managers appeared to understand the knowledge as coming just from the professional formation. They did not comply with the need on the more structured training on management practices and tools, for example.

The company exists for more than 50 years. It had difficulties to invest on new technologies. For this reason, the company had old technologies on its production processes. The raw materials are imported in its majority, as the country has low number of companies that produce them.

4.1 Discussion

The company's management is oriented by functional departments represented by an organogram. This view, as Mintzberg [12] emphasized, does not allow the competitive advantages visualization. It is recommended that each company have different ways to represent its organizational structure. Those different representations show the company's objectives, the people and department interactions, the company's products and the involved information.

The low to moderate maturity level company presented a low use of the management practices and tools. Considering this, it is important that the pre-implementation assessment (as process and company evaluation) system to be simpler than the used for the high maturity level companies [13]. As the results indicated, the training focus was technical. In this situation, it will be difficult to use complicated assessment systems.

A required feature to reference model implementation to the PDP improvement is to allow the creation of a more amplified vision of the company. On this view, the implementation process must emphasize the front end (pre-development) steps. The main objective must be to convert the definition of what the product means to the company and to the market view. The product must not be just the combination of its components or its technology. The product concept must be more abstract and broad. The product must be considered as the conjoint involving the services, the information, the knowledge, more than technology and components.

On this new and mature view of PDP, the product presentation form, the involved services, the final customer perception and the divulgation and distribution forms are discussed on the product development process. On this more mature view of PDP, the central aspect is the manner that the information flow management will be conducted.

From those descriptions, it is possible to identify some considerations on the management areas for the PDP reference model implementation in low to moderate maturity level companies.

Strategic Planning: It is necessary to deploy the strategic objectives to the tactic level, with the all department managers.

Information management: The efficient information flow is important to the new structured PDP be able to create innovative products. The great number of information must be flown on the company to innovation. Information technologies that would help the PDP should be initially based on the improvement of the already available management systems. If the company decided to incorporate new systems, they must be created just after the process definition.

Quality management: To create an innovative culture that lead to innovative products, the quality concept must be changed. The company and its departments must not more emphasize on quality as resultant of control system. The company must think about quality as the customer satisfaction. For customer satisfaction, other dimensions of product, broader than technical components, must be considered. The metrics must spotlight this view and be used in the related services, as distribution and customer attendance.

Financial management: The company must incorporate in its routine the financial and economic evaluation of the project. This evaluation must incorporate other factors than product component costs. A demand evaluation system must be gradually developed based on the information already available in the company.

Human resource management: To develop innovative products, the involved people must be creative. To be creative, a person must have other training than technical one. It is necessary an innovative and continuous improvement culture to identify the innovative opportunities. For this reason, it is necessary motivated employees and teamwork. Several departments must interact and must have as common objective the customer necessity achievement.

Product management: The product concept must become broader. This concept must incorporate the market definitions. It is recommended the launched products evaluation. The existence of a marketing department is recommended.

Process management: The production planning and control practices implementation is important for launched product performance evaluation. Some technologies might be needed.

Technologic management: In some environments or markets, it will be very important the technologic vigilance as an important part of the PDP. The available tools must be valorized on the PDP improvement.

Project management: the practice of project management is a good tool for PDP conduction. The planning and evaluation practice incorporation on the company's routine will help company's maturing. This practice allows saving money by identifying and stop investments on not rentable projects, for example.

Another important element is related to the reference model selection. The several reference models available on the literature are directed to specific sectors. It is suggested, for this reason, that the selection of the reference model should be conducted considering the type of developed product and the similarities of the model to the company's environmental elements.

5 Critical points identification

The management areas analysis enabled the stabilishment of some successful reference model implementation critical points.

The selection of the the reference model implementation tools and practices is one of the first step elements of the PDP improvement project. For this reason, this work discussed the company's structure evaluation elements. The process mapping is the fundamental step for the process improvement. The process mapping allows the process steps, material and information flow identification.

The literature allied to the case study management areas observation propitiated the critical points identification to the reference model implementation. Those points supply the PDP improvement project needs with methods, tools, or techniques. They are the implementation process requisites. The project management is a well structured practice that allows the planning, conduction and control of the PDP improvement project.

The following critical points for PDP improvement are summarized from the previous discussion: (1) conversion of the sequential PDP to an integrated PDP, with concurrent activities; (2) implementation of an information capture systematic; (3) change management theory contemplation; (4) maturing in context of the project management knowledge.

To define a method for a PDP improvement, those critical points must be converted to method principles. Those principles define the deployed directives that guide the implementation process. They are: (1) mapping of existing PDP, identifying the existence of a process view, the needed interactions between departments, the existing problems, and the existing management mechanisms; (2) Existing information capturing system mapping, and incorporation of company's reality customized tools; (3) change resistance avoiding statements establishing to propitiate a existing culture and philosophies based on learning to allow continuous improvement; (4) analysis of and project management concepts implementation.

6 Conclusions

The present work identified some principles to guide the reference model implementation. A method created for reference model implementation using those principles would be useful to conduct the low to moderate maturity level company to improve its PDP allowing more competitiveness.

This paper based on the organizational structure defining elements proposed by Hunter [10] identified by theoretical review. These elements were associated to the PDP interrelated management areas. The SME improvement aspects for each management area were detailed. Based on those improvement aspects, the critical requisites were identified. Those requisites were denominated the PDP implementation critical points. The paper presents the PDP improvement guiding principles that allow the critical points implementation.

For more details see Gusberti [24].

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A Reference Model for the Pharmaceutical PDP Management – an architecture

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Abstract. The purpose of this article is to introduce the reference model architeture used in the development of a reference model for pharmaceutical Product Development Process. The model was created founded on renowned methods as Concurrent Engineering, Stage Gates and Product Based Business. It was developed using legislation and information from interviews with professionals of Brazilian pharmaceutical companies and information from Project Management. This architeture supported the development of a reference model for the pharmaceutical PDP management, which is adjusted to the Brazilian companies' reality and demand.

Keywords. Reference Model, Concurrent Engineering, Pharmaceutical Product Development Process (PDP)

1 Introduction

Since the 1990's product development has been considered under a broader standpoint, in which the idea of development centered in technical activities was substituted by the concept of business supported by product development. This new concept has been called, afterwards, Product Development Process (PDP) [5-9, 19]. Along the last twenty five years several product development approaches were proposed, supported by methods and tools [6]. Each of them has particularly contributed to the evolution of this knowledge area. Among the development approaches, outstands those that are considered under the expression *Integrated Product Development* (IPD) as *Concurrent Engineering* (CE) [22]; *Stage Gates methodology* (SG) [6,7]; *Product Based Business* (PBB) [9,19]; and more recently the *Lean* (L); *Design for Six Sigma* (DfSS) and *Maturity Models* (MM) considered as new IPD approaches [23]. Some authors [1,16] discuss IPD as a separate methodology, but Rozenfeld et al. [23] group CE, SG and PBB as being Integrated Product Development expressions.

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Historically speaking, in the same decade (1960), NASA (National Aeronautics and Space Administration) and the US Department of Defense (DoD) have developed tools to improve Project Management (PM) activities and to enhance project success. They were compiled, afterwards, by PMI (Project Management Institute) in the renowned PMBoK (Project Management Body of Knowledge) [15,21,24]. Accordingly to Kerzner [15], the tools mentioned in PMBoK have influenced the Product Development area and, inversely, the Product Development methodologies have influenced and supported the PM subject growth.

Global pharmaceutical corporations, even dominating large markets and presenting a typical very long lasting product development process, have adhered, in the 1990's decade, to the product speed development concept. The two approaches adopted by them include new PDP management practices [3,10,14] and special technology development, directed to new drug discovery, identification and analysis [2,4,11,13,18,26]. The changes in the pharmaceutical field may be attributed to the expiration of many drug patents in the 1980's what boosted the 'generic product' development by competitors, a medicine that presents the same properties of the reference product, and therefore may be interchanged with it, but which presents lower prices. The generic medicine production in Brazil has been encouraged by the government in year 2000, mainly viewing the AIDS drug cocktail price reduction.

In this context, the development and launching of generic products in a fast pace is decisive for competition. Some Brazilian companies observed that the existence of a formal product development process may reinforce product development success. To formalize companies' PDP practices is a global tendency and product development reference models, in addition to PDP methodologies and PM tools, play an important role in such formalization. For this reason, the main objective of this paper is to introduce and discuss the architecture which has lead to the development of a reference model for the pharmaceutical product development process, focused in generic products, a Brazilian pharmaceutical companies' demand.

2 Reference Models

A reference model serves as a description of how a product development process progress, providing a common language, a minimum global vision of the project development or a perception of the expected contribution that project will bring to the company. The reference model may assume several formats. Some of them represent only the activities that must be performed in product development; other models detail what procedures and methods are supposed to be adopted; they may include an evaluation criteria and may mention what literature has to be consulted in order to accomplish a specific activity. The model may be a manuscript, manual or even a graphical representation available in intranet [23]. They may be classified as generic models which may be adopted by different production companies or specific models, that describe a particular type of product development, as the model proposed in this paper.

3 Description of the pharmaceutical reference model architecture

The reference model for pharmaceutical product development architecture was based and is supported by: (*i*) the Brazilian pharmaceutical companies' professionals experience and legislation; (*ii*) the best product development practices from literature, and (*iii*) information from project management.

3.1 The Brazilian pharmaceutical companies' professionals experience and legislation

The qualitative approach was used for data collection and it was performed in two interview blocks. The objective in the first interview block was gathering information for construction of the reference model. The objective in the second interview block was the reference model validation. The latest was performed by submitting the reference model to pharmaceutical professional analysis of performance and applicability in the field.

Five national companies' professionals were interviewed in first block, from two large and two medium size companies, from the medicine and cosmetic fields. The interviewed professional areas were those considered important for product development and it was respected the company development team or professional interview availability. The areas included: marketing, and Sales, R&D, Quality assurance, Production planning and control, Medicine registration, Finances, Information Technology and High Administratrion. A referee for generic product registration from ANVISA (Agência Nacional de Vigilância Sanitária), the Brazilian medicine registration body from the Government Health Ministry, was also interviewed for the reference model construction. Only one referee was interviewed at ANVISA, since the legislation information is of deterministic nature. Concerning validation, the reference model was analyzed by professionals from seven companies, three large and four medium sizes (medicine, veterinary and cosmetic fields). The analysis was conducted in a collective approach inside each company, where the interviewed group exchanged ideas and impressions about the model. The interviews lengths were two hours in average, in both blocks, and semi-structured questionnaires were used.

All interviews were recorded and, afterwards, transcript. The First block interviews were analyzed through internal comparison: between companies' information, and between the latest and the ANVISA referee information. The data gathered were important for construction of the reference model macro-phases and activities. The Second block interviews were analyzed through consensus ordination and importance ordination. Thus, the elements mentioned by the interviewed professionals about which they agreed or disagreed were identified; as well as the model elements considered by them as interesting or object of concern. The elements mentioned by interviewed professionals from one company were compared with the opinion of interviewed professionals from other companies, characterizing the internal comparison in Second block either. The data gathered in validation block interviews were important for changing, excluding or including phases and activities in the reference model, or for reinforcing its value as a reference for generic product development in pharmaceutical companies.

3.2 The best product development practices from literature

The product development methods that support the reference model are Concurrent Engineering, Stage Gates and Product Based Business.

Concurrent Engineering (CE) focuses in multidisciplinary teams, co-localized and simultaneous activities performance, mainly those which are independent. The physical co-localization of teams and multidisciplinarity will depend on company's culture, but the latest element is mandatory to development efficiency. Much rework may take place when the project of a new product is not simultaneously, but sequentially analyzed by organizational sector specialists. The application of tools and methods is important as IT (Information Technology); DfM (Design for Manufacturability among other methods and tools [12,16,23].

Stage Gates (SG) is a methodology which focuses in two aspects: business character of product development and product development process managerial control. The first aspect is guaranteed by the 'portfolio management methodology' that analyses what business-products are the companies investing in. It is normally performed along Corporate Strategic Planning (CSP) implementation. The process control aspect of SG is the phase transition evaluation/control which is systematically performed via process interruptions named 'gates'. The gates are generally located between important transition phases and they present a decision nature of process abortion; process modification or process maintenance. The gates may include control check lists that confirm the conclusion of the most important activities of that phase; although the document central managerial question is 'will the product development be continued in the next phase, changed or aborted?' The number of gates is a function of the risk level implicated in the product development process, but Cooper suggests six gates in his paper [6,7,23].

Product Based Business (PBB) is a methodology which reinforces the innovation mechanism, represented by two elements: the pair 'portfolio analysis-Corporate Strategic Planning' (from the strategic level) and by the activities of 'identification, selection and development of opportunities that were identified in the market' (from the tactical level). The business/company growth is a result of innovation in products or services since they must provide both, income and profit. The incomes from mature and new products maintain the innovation mechanism, since they may finance new market evaluation and technology acquisition. In this sense, a feedback mechanism is generated in terms of cash and information. The products must be followed after launch for all their lives (product life cycle management), and their performance in market must be measured. The information gathered from products feedbacks the development process for a new 'portfolio analysis-Corporate Strategic Planning' and the improvement cycle is maintained [9,19].

Summarizing, the IPD methodologies have in common: (i) a strong market orientation, based in the knowledge of clients demand; (ii) the practice of business opportunities screening, competitors benchmarking and portfolio management as support for decision in 'what projects to invest'; (iii) the practice of former technical, financial and economical analysis of projects, before product development; (iv) the continuous analysis of products after launching, providing the feedback character of the PDP. The grouped practices (i) to (iii) form the Pre-

Development Stage from product development process and the practice number (iv) outlines the Post Development Stage (see Table 2).

3.3 Information from project management

The first effort in organizing a project is the thoroughly description of its scope. Most authors in PM indicate the use of WBS (Work Breakdown Structure) as an efficient tool for scope definition [15,21,24]. WBS is a hierarchical decomposition (top down flow chart) oriented to the project deliverables, including internal and external project products, aiming to reach project goals. This tool organizes the project global scope by its division in work packages that are decomposed in activities. Therefore, WBS is the first step of project planning, since it provides the base from which the project scope, time, human resources, cost, quality, risk and other plans derive. WBS may be presented as an indented list or in a graphic manner as it may be seen in figure 1.

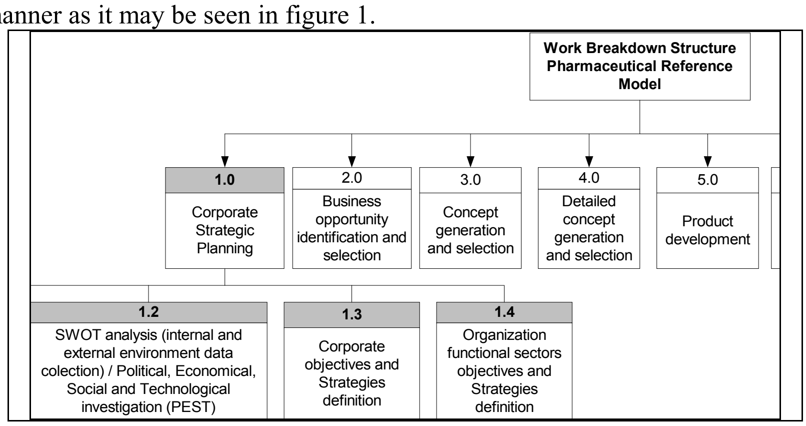

Figure 1. Part view of WBS from the pharmaceutical PDP reference model [20]

Besides WBS, project management methodologies recommend the use of matrices for human resources planning, in which the responsibilities for the project activities are established.

Aiming to control the PDP process, check lists were elaborated for phase transition as recommended in Stage Gates and in PM. Other tools from PM will not be discussed in this paper, although they may facilitate PDP implementation and management (see Table 2).

3.4 General view from the reference model architeture

The final reference model architecture is summarized in table 2. The control documents will not be described in this paper, nor will be detailed the activities. The final reference model graphical representation will be constructed using the architecture from table 2. It will contemplate three macro stages and seven phases, embracing from business opportunity recognition to product market launching. Macro stages and phases names are as prescribed in product development literature mentioned before.

Table 2. General view frome the reference model architeture [20]

Macro Stage	Phase	Gate	Control documents
Pre Development	Business opportunity identification and selection	**1**	Check list
			Product Innovation Charter PIC
			PIC archive
Development	Concept identification and selection	**2**	Check list
			Product Protocol
	Detailed concept identification and selection	**3**	Check list
			Detailed Product Protocol
			Project Plan
			Project Chronogram
			Activity x responsibility matrix
	Product and process development	**4**	Check list
			Phase Register Dossier reports
	Production and marketing plan performance	**5**	Check list
			Phase Register Dossier reports
			Product/Process master file
	PDP conclusion and product registration	**6**	Check list
			Register Dossier
Post Development	Product launching and marketing evaluation	**PDP**	Check list
		Feed back	PDP history and project lessons
			Marketing and technical information

4. Conclusion

The qualitative approach adopted in the construction of the reference model proved to be efficient, since it permitted to gather information from professionals in a deeper manner. The choice of companies from medium and large sizes was adequate, since their development processes and relationship with ANVISA presented particularities, and the different types of business these companies develop brought robustness to the final reference model architecture. The same differences would not be so clear if the interviews included small companies; moreover the smaller companies hardly ever produce generic medicines.

The interview with the ANVISA referee was important for the delineation of legislation related activities in all macro-stages and phases. Such details are not represented in this paper.

The interviews in the construction phase were important for the reference model configuration, since each company PDP was modeled in block 1 interviews. Besides that, professionals from seven pharmaceutical companies, totalizing 40 people with large experience in pharmaceutical product development, expressed their impressions about the reference model final graphical representation in block 2 interviews. All the interviewed experts recognized the importance of PDP management, although some of the companies still present a product development not fully formalized. More details from the final graphical reference model are not part of this paper.

The professionals in general appreciated the Pre-Development, concept identification and detailing descriptions in the model, since there is no parallel in pharmaceutical literature. They also valued the control documents suggested in the model. The generality of the model was considered large, since it was analyzed and approved by experts from companies that produce human/veterinary medicines and cosmetics. The macro-stages and phases are independent on the product under development, but the work packages and activities, specially the latest, have to be defined product to product, when adopting the model. Such activities detailing is not part of this paper.

The managerial aspects of the reference model were attributed to: the broad scope description guaranteed by the WBS; the process segmentation, that facilitates risk management, process execution and control, since its complexity is crescent from the begin to the end; the clear indication of organizational function sector activities and work packages in the graphic representation; the decision making and quality control gates, with their check lists and process documentation; the model feedback activity which stimulates the process cyclic quality improvement.

The combination between literature information and companies' professional experience (tacit knowledge from interviews) proved to be an efficient architecture for the reference model construction. The validation of the model structure by interviews with professionals was decisive for the reference model graphical final configuration (not presented in this paper) since it provided the model fine tuning in relation to the Brazilian companies demand for product development.

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Supply Chain Collaboration

Product Development Process Managing in Supply Chain

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Abstract: Today, businesses depend on strategic relations with their customers and suppliers to create value to develop product and to obtain better market-share. Designing products to match the processes and supply chains, processes to match product platforms and supply chains, and supply chains to match the product platforms and process are the ingredients in today's fast developing markets. If this co-design is done well up front with sufficient focus product development process managing, product will cost much less overall and the time-to-market will decrease substantially. However, the evidence supporting supplier integration is to less clear than evidence on the positive contribution of customer integration in product development process. Considering this problem, the purpose of the present paper is to supply a path aiming to identify managing techniques and practice for the involvement of suppliers in PDP. A model for product development process managing in supply chain was proposed. The model focuses on the following factors: outsourcing process, involving supplier into PDP, knowledge management and design considerations.

Keywords: Product development process, supply chain, outsourcing process

1 Introduction

This paper is introduced in the context of a study on the relations between the supply chain and product design. The importance of beginning the study of supply chains in product development process (PDP) is mainly because it is at this product of lifecycle phase that the decisions responsible for 80% (eighty percent) of a product's final costs are made [6,15].

In recent years a large number of papers have been published emphasizing the effects of the suppliers' participation in PDP, stating the benefits and drawbacks of the suppliers' involvement [1, 2, 3, 4, 7, 9, 10]. One of the main drivers behind involvement suppliers early in the in the PDP is to gain better leverage of supplier's technical capabilities and expertise to improve product development

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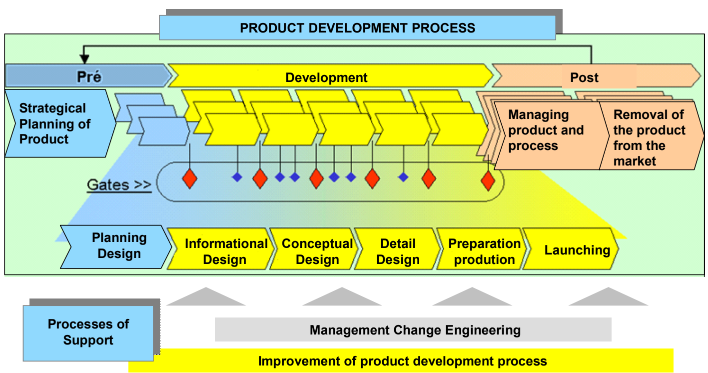
efficiency and effectiveness [19]. Using supplier's knowledge and expertise to complement internal capabilities reduce concept-to-customer cycle time, costs, quality problems and improved the overall design effort [14]. However, suppliers into PDP can introduce new problems: risk of losing proprietary knowledge, hollowing out internal competencies, eased accessibility for competitors to copy or acquire key technologies, increased dependence on strategic suppliers, and increased standardization of components through specified interfaces [10]. The supplier involvement into PDP increases complexity of activity management.

In this context, this article aims to present a four-stage model for the involvement of suppliers in the PDP process. It also presents a case study of suppliers' involvement with PDP in a company in the tile ceramic sector.

2 Supply Chain Management and Product Development Process

Supply Chain Management (SCM) refers to management between companies by means of their business processes; where they seek to maximize potential synergy, reduce waste, increase efficiency and the effectiveness of business processes, with the objective of adding value for the clients and stakeholders, making the supply chain more competitive.[6, 8]. Initially, the business processes were regarded as a way of integrating companies' corporative functions. Presently, companies seek to structure activities between the different members of a supply chain through the business processes, so as to make them manageable in the long run [8].

The PDP is one of business process of SCM [6, 8]. PDP involves technical and management aspects, in which an organization transforms market and technical possibility opportunities into information for the production of a commercial product. This process includes the development of a new product in a way that is coherent with the product's lifecycle, which starts with its planning and ends when it is discarded or taken off the market [15]. Aiming to supply a common reference, a holistic vision of the product development process, leveling knowledge within the different knowledge areas, a reference model for PDP was proposed, it is illustrated in Picture 1.

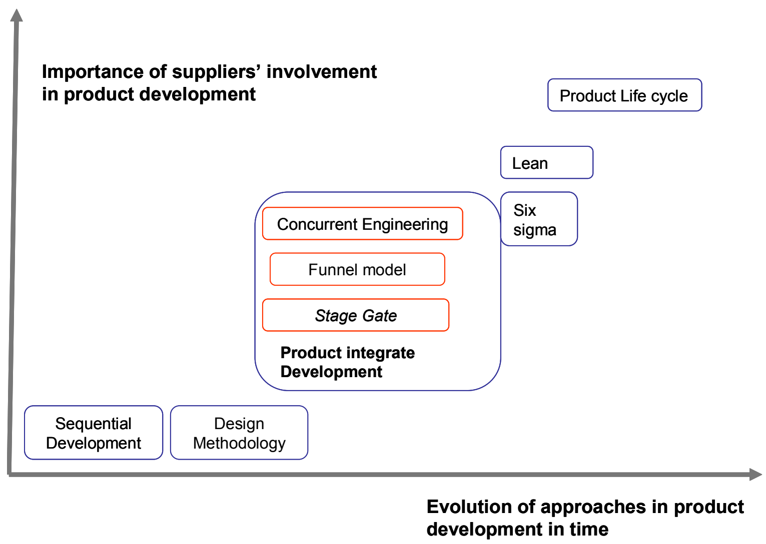


Picture 1 – Reference model for product development process. Source: [15]

3 Assessment of the supplier's involvement into PDP by product development management approaches

The product development management is divided nine approaches [15], they are: sequential or traditional, design methodology, simultaneous engineering, funnel model, stage-gates, lean, design for six sigma (DFSS), maturity model and product lifecycle management (PLM).

Picture 2 illustrates the relation of importance of the suppliers' involvement in PDP with the evolution of approaches in product development management. The simultaneous engineering, Lean, and PLM approaches emphasize the suppliers' involvement in the initial development phases as practice for becoming successful in product development in collaborative project environments.



Picture 2 - Relation between the importance of suppliers' involvement and evolution of product development approaches.

Motivation for supplier integration into PDP due to the possibility of product innovation is a critical process, which requires a long term strategic partnership between those involved. However, [14] points out that these rely on a long term relationship policy or the establishment of alliances for the development of both products and PDP managerial aspects.

Among the articles studied, of those presenting the greatest contributions to decision making related to supplier involvement with PDP, the [5] model applied by [11, 12] stood out for approaching the greatest number of decision-making factors. This model presents the unfolding of activities from the strategic to the operational level, to decide what kind of relationship to have with the supplier and when to involve the supplier in PDP. However, the model focuses on technical information systemization, putting temporarily aside aspects related to process management.

Concerning the evaluation of papers on supplier involvement with PDP, reports on how to involve the supplier with PDP are rare. In addition, many of these practices are already in use after the product design phases, during production.

There is a lack of papers that deal with the implementation of supplier involvement with PDP, of methods and tools to aid in this involvement. Literature focuses a lot on reporting what is being done, hardly approaching how to do it.

According to the concepts of practicing ESI, suppliers would be involved in the informational and conceptual project phases. However, cultural, economic and environmental aspects, and the market dynamics, show that such practice cannot always be implemented as commended by the Japanese.

4. Integration of outsourcing process into PDP

The outsourcing is a set of products and services used by a company (i. e a supply chain) which is provided by another company in a collaborative and independent relationship. [13]. However, there are few works which show the outsourcing as a process. In [18] the outsourcing process has four stages: motivation, making decision, implementation and managing. Based in study of literature it was possible detail the phases of the outsourcing process, shown [18], and identified activities, methods and technical need for involvement of suppliers in to PDP [16].

5 Model for Supplier Involvement in PDP

Based on the studies supplier involvement in PDP, integrating of outsourcing process in to PDP [16], and the PDP reference model proposed by [15], a model for the supplier involvement in PDP process is presented in Picture 3, as a means for supplier involvement in PDP.

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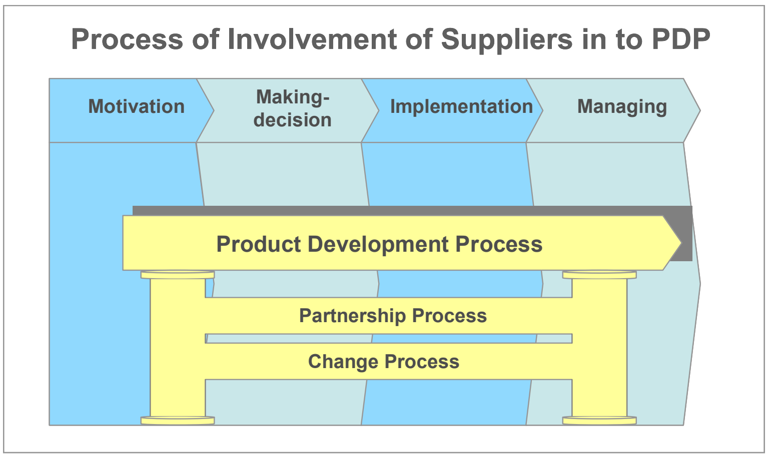

Picture 3 – Conceptual model for supplier involvement in PDP.

The process of supplier involvement in PDP is divided in 4 stages: motivation, decision making, implementation, and management. Partnership and change processes form two pillars for performing activities.

The company's internal and external connectivity are inserted in the model's stages. In this paper connectivity is understood as information technology resources, like the ones that allow real time connections, computer to computer, increasing companies' efficiency. By means of reduction of time and routines necessary for performing an activity. It involves the integration of the information flow with the supply chain to create value for the final client. Considering a (individual) company, included in the network are the suppliers (upstream) and the distribution channel (downstream). The internal suppliers of the same company are included as well.

Based on the study of the art of supplier involvement in PDP the implementation stage was divided in a quadrant square, illustrated in Picture 4

	Partnership Process	**Change Process**
Strategic Activities	1st Quadrant The main activities is this group involve the definition of guidelines for supplier involvement in PDP based on company strategies	2nd Quadrant The main activities is this group aim to define company structure to carry out the change process in the company to have supplier involvement in PDP.
Operational Activities	3rd Quadrant The main activities in this group involve the definition of technical activities for supplier involvement in PDP. The main characteristic is its focus on (technical) engineering activities for supplier involvement in PDP based on the established strategic activities.	4th Quadrant The main activities involved in this group are the definition of methods and tools for implementation of the change process in the company to supplier involvement in PDP.

Picture 4 – Conceptual model for implementation of supplier involvement in PDP.

The first quadrant focuses on strategy activities in the partnership process: the main activities in this group involve the definition of guidelines for supplier involvement in PDP based on company strategies.

The second quadrant focuses on strategy activities in the change process: the main activities involved in this group aim to define company structure to carry out the change process in the company to have supplier involvement in PDP.

The third quadrant focuses on operational activities in the partnership process: the main activities in this group involve the definition of technical activities for supplier involvement in PDP. Focus on (technical) engineering activities is the main characteristic for supplier involvement in PDP based on the established strategic activities.

The fourth quadrant focuses on operational activities in the change process: the main activities involved in this group are the definition of methods and tools for implementation of the change process in the company to supplier involvement in PDP.

6 Case Study of Supplier Involvement in PDP in a Company in the Tile Ceramic Sector

The company for the case study was selected as it is considered the tile ceramic benchmark in Brazil. However, due to an information confidentiality agreement, specifics on the company were omitted from this article.

The case study at the company involved a questionnaire preparation phase, interview preparation and execution phase, and data (the diagnosis) consolidation phase.

Company policy concerning supplier involvement in PDP is not to involve suppliers in strategic planning and conception of the product, in other words, a black box type relationship. Involvement in strategic planning or conception is done with international suppliers. The main reason claimed by the company is insecurity of information with national suppliers.

The main reasons for supplier involvement in PDP listed by the company are connected to short term advantages. However, when questioned on the main advantages of supplier involvement in PDP, the company associates advantages reached with long term objectives, with the: improvement of supplier technology access, contributions to product differentiation. This illustrates a contradiction between objectives concerning what is desired from the supplier and what the supplier will accomplish.

The organization has a formal model to make the decision on supplier involvement in PDP. Among the 27 decision making factors listed, 10 factors are used by the company for making the decision concerning supplier involvement in PDP.

The factors pointed out by the company as critical to supplier involvement in PDP are: essential competences; main technologies (product and equipment); supplier technological change rate; existing and future intellectual capital; supplier responsibility or risk level.

Geographical, location and information technology factors, which are pointed as of minor importance, and information technology are contradictory. Also to note are aspects regarding the way the company manages its supply chain. This reflects directly on company connectivity to its clients and suppliers.

The geographic location measures physical distance, information technology is manifested through resources that facilitate communication. Theoretically, one of the two factors would have an advantage over the other.

Concerning supplier involvement management, the company reports having a corporate strategy that evaluates how the supplier influences the organization's manufacture, logistics, and marketing strategies.

Management of suppliers' performance by means of indicators is only visible internally.

Concerning connectivity, one notices a decision on the part of the company for automatization of downstream processes of their chain, in other words, with links closer to the clients, whether through acquisition of new ERP modules, integration of these modules, development of intranet/extranet portals for internal and/or commercial partners use, among others.

But when questioned on computer-computer connectivity between the company and its suppliers and outsourced services, sharing and integrating common interest information, the grade given was 3 (three) on a scale of one to ten. The main obstacles identified by the company are: organizational culture; lack of knowledge on the benefits; human resources. An interesting fact is that there was no manifestation of obstacles of a financial nature, technical and technological aspects and/or company costs. This shows that the financial factor is not a drawback to implementation, but cultural points and management methods between the company and its suppliers are an obstacle to be overcome.

7 Conclusion and Future Work

It is believed that through the supplier involvement in PDP model, a basic conceptual structure has been generated that can help the connection between the supply chain management process and the product development management process.

Use of the model in the diagnosis of supplier involvement in PDP in a company in the ceramic sector showed that the model can be used as a foundation for building a managerial structure between PDP and SCM. After the diagnosis of the present situation, the next step with the company is to create the plan for supplier involvement in PDP, using the resulting model as a reference.

This model is part of an ongoing doctorate thesis entitled “the product development process as a business process for managing supply chains". The objective of this paper is within the theoretical realm: the possibility of there being a theoretical reference that supplies information on how to involve a supplier in PDP, in other words, building this reference is the main point of the ongoing study.

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Level of knowledge and formalization of logistics and SCM in the Brazilian automotive industries suppliers

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Abstract. The companies of vanguard understood that the real competition is not made among companies, but among supply chains. The supply chain management (SCM) concept is the logistics extension, while the logistics management is concerned with the organization flows optimization. This paper intends to divulge the level of the knowledge and the formalization of logistics and SCM already set up by the suppliers of Brazilian automotive industries. The SCM recognized that the internal integration is not enough for the competitiveness achievement. The automotive segment can be considered representative in logistics and SCM practices in Brazil deserves to be noticeable. In order to achieve this, it was accomplished an applied, exploratory, descriptive and qualitative survey, through inductive approach. The technical procedure used was a survey. The data collection was carried out through questionnaires sent to fifty representative suppliers of automotive industry, with the return of 64% answers. The results of the survey showed that the main impediment in the implementation of the SCM concept is precisely the incoherence in the culture of the companies surveyed about the logistics and SCM, concerning the partnerships and the exchange of information.

Keywords. Supply chain management, automakers, suppliers, partnership, enterprise culture

1 Introduction

Presently, the trend is the integration of all logistics activities in the companies, since the client's order to the supplier until the delivery to final consumer, involved by services and information that aggregate value. In order to make feasible this integration, the supply chain management – SCM concept is paramount. This concept cover, not only the business processes, but also the relationships between clients and suppliers, aiming the strategic partnerships, benefiting all the members of the supply chain.

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The automotive segment can be considered prominent in this sense, because presents important initiatives in the supply chain management. According to [5], during the last one hundred years, the Brazilian automotive industry developed its potential and became one of the more representative manufacturing segments. Moreover, some reports show that approximately 10% of global trade occurs in the automotive industries. Due to its pioneering and competitiveness level, it becomes a truth reference to industrial environment in terms of technological and managerial innovations.

Brazil had, during the last ten years, approximately US$ 30 billions of foreign investments in the automobile industries. One part of this amount was applied in the technological upgrade of the existing industrial plants. However, the major part was driven to build new and innovated plants with the SCM perspective. To sum up, this fact makes possible to Brazil, becomes a world example, because has industry installations of all the great brand of automotive automakers, which is very up-to-date in terms of logistics processes and SCM.

The supply chain of automotive industries involves automakers, suppliers, retailers and the final consumer. One simple delay generated by any members could cause production stops, and consequently, high damages. Due to the complexity of operations, pieces and components for the automotive industry, is more than necessary to obtain success in the supply chain management, mainly reducing logistics costs and integrating the members. The automakers tend to coordinate this supply chain, while the suppliers work in the product development and in the execution of assembly processes.

This paper intends to divulge the level of the knowledge and the formalization of logistics and SCM already set up by the suppliers of automotive industries. In order to answer this question, it was accomplished an applied, exploratory, descriptive and qualitative research, through inductive approach. The technical procedure used was a survey. The data collection was carried out through questionnaires sent to fifty representative suppliers and also to twenty three automakers.

The results of the survey showed that the main impediment in the implementation of the SCM concept is precisely the incoherence in the culture of the companies surveyed about the logistics and SCM, concerning the partnerships and the exchange of information.

2 Logistics *versus* Supply Chain Management

Presently, the logistics management searches the integration of company activities and the intense information interchange, because all these activities form an only process, which main objective is to satisfy the final consumer needs. There are no reasons to manage these activities separately, incurring in unnecessary risks to the company.

According to [2], the high performance of integrated logistics chain, requires greater quality in processes, focus in service needs to client, providing improvement in the cost structure through all the process, and reduction of delivery time.

The concept of integrated logistics, according to [1], is an organized form of perceive all the processes that generate value to final client, regardless where the process has been executed, it can be in own company or in other to which maintains some kind of relationship.

The supply chain management is the compartment of the business key-processes with other members of supply chain that requires a conceptual change in the behavior of the companies to how to manage the relation with the goods offered to the market [1].

In the integrated logistics management, the processes involved are: Plan, Supply, Make and Delivery. The Plan starts the logistics process; the Supply is inserted in the Supply Logistics; Make is treated in the Production Logistics, and Delivery is managed in the Distribution Logistics. In another hand, [6] asserts that, the SCM, is a more complex task than the logistics management of goods, information, and services flow related to origin point to consumer point.

To sum up, this concept involves, besides the integrated logistics management, strategies of relationships with suppliers and customers aiming greater life span in business, through the partnerships based in trust and collaboration. These factors generate sustainable competitive advantages, where many companies discovered that through these partnerships could improve the product project, marketing strategies and service to clients, and besides that, discover forms to work more efficiently together. A close relationship between supplier and buyer allows that the both skills will be applied to mutual benefit.

Thus, according to [4], one of the main SCM objectives is to attend the final client with greater efficiency, through costs reduction and add more value to final products. The cost reduction has been obtained through reduction of transactions, paperwork and information sizeable, besides the reduction of transports and stocks, elimination of the quality control points and demand variability of products and services. The creation of goods and services customized, the joint development between suppliers and clients of competences through productive chain, add value to products and increase the profitability to all the chain.

In automotive industry, approximately, 12% of materials costs to automakers are accounted by suppliers logistics costs. Thus, when the reason is the lack of integration between suppliers and automakers, there is a great opportunity to costs reduction. In the traditional relationship of opponents, the automaker could reduce the materials costs exerting pressure on profit share of components suppliers [3].

3 Data collection and analysis

The data collection of this research was carried out sending questionnaires to 23 automakers and 50 suppliers of automotive industry, which were selected in the site of ANFAVEA – National Association of Auto Motors Vehicles Automakers, due to the accessibility rather than statistics methods. The questionnaires were sent by conventional and electronic post informing about the deadline to the answerers. However, as this deadline was not carried out, this was extended. As a conclusion, it was obtained a return of 9 questionnaires from automakers, representing 39%, and 32 questionnaires from suppliers, which constitute 64%.

It is important to emphasize that this research did not have statistics awareness, thus it was not intended to assert that this is the reality of industries population of the segment researched, with the limited intention to demonstrate the trend of behavior. In the Chart 01 are the results found, besides the comparison between automakers and suppliers.

Chart 1. Knowledge and formalization

Items researched	**Automaker %**	**Supplier %**
Knowledge of logistics concept:		
Enough knowledge	44	44
High knowledge	44	25
Medium level of knowledge	12	19
Low knowledge	-	9
No knowledge	-	3
Knowledge of SCM concept:		
Enough knowledge	67	44
High knowledge	33	28
Medium level of knowledge	-	19
Low knowledge	-	9
No knowledge	-	-

Through Chart 01 is possible to visualize that 44% of automakers asserted that has enough knowledge about logistics, 44% demonstrate that have high knowledge, and only 12% a medium level of knowledge. These results are similar to suppliers, 44% asserted to have enough knowledge, while 25% alleged to have a high level, and 19% a medium level.

On the other hand, regarding to SCM concept, 67% of automakers asserts to have a sufficient level, 33% denoted a high knowledge, while 44% of suppliers researched, answered to have enough knowledge, 28% a high level, and 19% a medium level of knowledge. These results demonstrate that the majority of suppliers believe to know these two concepts, these concepts intrinsically linked, will yield greater profitability to supply chain members. However, it perceived that in the automakers segments the SCM concept is more consolidated, because the most of them are foreign companies.

Chart 2. Formalization and adoption

Items researched	Automaker %	Supplier %
Formalization of logistics and SCM:		
There is a logistics department	56	71
There is a SCM department	22	3
There are both	22	13
There are not both	-	13
Adoption of SCM concept:		
Yes, partially	56	59
Yes, totally	44	25
Not	-	16

Regarding to logistics and SCM formalization, 56% of automakers have a structured Logistics department, while only 22% have a SCM department, and also

22% have both. Furthermore, 71% of suppliers have a Logistics department, only 3% have a SCM department, 13% have both, and 13% have no one.

When these results are compared, is possible to verify that suppliers have not yet formalized the SCM activities like automakers. Meanwhile, it has denoted that the most of suppliers formalize the logistics management in their processes, however, still there are suppliers that have neither one nor the other, whereby this fact can prejudice the production supply.

Analyzing the SCM concept adoption by the automakers, 56% asserted to adopt partially and 44% of them totally. Likewise, regarding to suppliers it was noted that 59% adopt partially, 25% adopt totally, and 16% do not adopt. It was perceived that the suppliers do not adopt the SCM concept totally, which can be considered an aggravating scenario. The SCM concept requires that both members of supply chain work conjointly, otherwise the automakers can not adopt the SCM concept successfully. This concept is relatively recent in the business environment and needs to mature by the time to come. This reason is justified why it was not implemented totally, however it is important to emphasize that according to the literature, the automotive segment is still that demonstrates greater success in the implementation of SCM.

Regarding to the main motivator factors to adopt the logistics management by companies researched, it was noticed that: 32% of automakers assert to be the resource rationalization, 32% confirmed to be the reduction of logistics costs with stocks, and 21% the reduction of logistics costs with transports. Furthermore, 79% of suppliers have the intention to reduce their logistics costs with stocks, 71% by satisfaction and demand of clients (automakers), 68% by resource rationalization, and 54% due to reduction of logistics costs with transports.

These results confirm the data collected in the bibliographic research, where emphasize that activities of stocks and transports management are the major generators of costs to companies, so that impacts directly in the service level offered to clients. These activities if well managed, rationalize financial assets, human and time resources. However, the suppliers present a high level of interest in this adoption, by satisfaction and demand of clients (automakers). This fact demonstrates that the evolution and improvement of suppliers is motivated or pulled by automakers.

It also was researched the interests by adoption of SCM concept, in which the automakers point out, respectively, the factors: optimization and integration of company processes with 38% of answers, elimination of costs and activities that not aggregate value, with 21%, and integration with clients and suppliers also with 21%. The suppliers emphasize the following factors: 25% by elimination of costs and activities that not aggregate value, 20% with the purpose to integrate clients and suppliers, and 18% to optimize and integrate the company processes. These results confirm the theory about the theme, that point out as main factors in the SCM adoption, the integration between suppliers and clients aiming partnerships and the optimization of company and their partners processes. Besides the reduction of costs and unnecessary activities, always having as main purpose to satisfy the final client, it maximizes the profitability of the supply chain. In this sense, both automakers and suppliers have the same view, which is favorable to both, and means a positive factor to success to consolidate the SCM concept.

Concerning to perspective of SCM concept implementation, and consequently, the logistics management, it has noted that 55% of automakers will do in short term, 34% medium term, and only 10% has the intention to implement in long term. Regarding to suppliers, 47% asserted that will implement in short term, 41% in medium term, 6% in long term and also 6% do not have perspective of implementation. Therefore, the suppliers and automakers converge in their perspective of SCM implementation.

Chart 3. Motivators factors and planning of adoption

Items researched	**Automaker %**	**Supplier %**
Factors motivators the logistics adoption:		
New business	4	21
Resources rationalization	32	68
Technological development	7	7
Satisfaction and/or demand of clients	4	71
Reduction of logistics costs with transports	21	54
Reduction of logistics costs with stocks	32	79
Market trends	-	29
No one	-	-
Factors motivators of SCM adoption:		
New business	3	4
Optimization and integration of the company processes	38	18
Integration with clients and suppliers	21	20
Satisfaction and/or demand of clients	-	11
Obtaining of competitive advantage	17	12
Market trends	-	7
Elimination of costs and activities that not aggregate value	21	25
Co-production	-	2
No one	-	-
Term perspective to implementation of SCM:		
Short term (until 2 years)	55	47
Medium term (2 to 5 years)	34	41
Long term (more than 5 years)	10	6
Without perspective	-	6
Factors that drive the companies to planning of the SCM adoption:		
Demand of suppliers/clients	5	19
Market trends	-	10
Optimization of company processes	39	27
Obtaining of competitive advantage	26	20
Costs reduction	30	24
No one	-	-

The research also verified about the factors that drive to SCM concept adoption, that the interest of automakers is motivated mainly to optimize the company processes. One of the factors was chosen by 39% of the companies researched; by the interest to reduce costs, the option was by 30%, and obtaining the competitive advantage with the option of 26% of the companies researched. In this context, 27% of suppliers believe that the optimization of company processes is the main driver factor to adopt SCM concept, 24% pointed out the costs reduction as relevant factor, whereas 20% the obtaining of competitive advantage, and 19% to attend the demand of clients and suppliers.

4 Final Considerations

The automakers incorporate the logistics management in their activities as essential requirement to appropriate development of their processes and also as competitive advantage source. Aims to attend the client with short terms, quality, reliability, and reduced costs. Regarding to the size of suppliers researched, the most are of medium size, whereby it was noticed that they adopt the logistics management in their processes. Also, the main reasons that drive to adopt this technique were the costs reduction with stocks and transports, also the necessity to satisfy the automakers demand.

However, concerning to the SCM concept, it was noticed that the suppliers still not have a satisfactory knowledge; many of them understand that logistics is the same as SCM. It is noted that still there is certain confusion in those concepts. In the automakers companies, this concept is more defined, and all they adopt the concept with their suppliers, mainly regarding to productive and business processes integration, incentivating the building of partnerships. In another hand, the suppliers do not perceive total interest of automakers in building the partnerships demonstrating the incompatibility of ideas.

Great part of suppliers believes that the SCM concept adoption is important, mainly to make possible the processes optimization, costs and stocks reduction, and to attend the automakers demand, besides that they pretend to implement the concept in short and medium terms in their operations. This fact can be considered positive because generates favorable environment for changes.

Despite the SCM concept still is not that much diffused in Brazil, considering that the automotive segment is pioneer in this sense, it can be concluded that there are some points to be developed, mainly regarding to partnerships and suppliers development. Probably, there are a distorted view of the SCM presuppose, since the partnership requires an intense cooperation among supply chain members and not only the responsibilities to transfer, as an example, automakers stocks being transferred to next supply chain link.

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An Evaluation of the Extended Logistic, Simple Logistic, and Gompertz Models for Forecasting Short Lifecycle Products and Services

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Abstract. Many successful technology forecasting models have been developed but little research has explored the relationship between sample set size and forecast prediction accuracy. This research studies the forecast accuracy of large and small data sets using the simple logisticl, Gompertz, and the extended logistic models. The performance of the models were evaluated using the mean absolute deviation and the root mean square error. A time series dataset of four electronic products and services were used to evaluate the model performance. The result shows that the extended logistic model fits large and small datasets better than the simple logistic and Gompertz models. The findings also show that that the extended logistic model is well suited to predict market growth with limited historical data as is typically the case for short lifecycle products and services.

Keywords. Extended logistic model, Technology forecasting

1 Introduction

With the rapid introduction of new technologies, electronic products and services are often replaced within a year. The product life cycle for electronic goods, which used to be about ten years in the 1960's, fell to about 5 years in the 1980's and is now less than two years for cell phones and computer games. As product life cycles become shorter, less data becomes available for analysis. Given this market situation, it is important to use smaller data sets to forecast future trends of new electronic products and services as they are introduced.

A product life cycle is typically divided into four stages: introduction, growth, maturity and decline stage [3]. At introduction stage, the product is new to the market and the product awareness has not been built, so the feature of this stage is

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slow sales growth. The growth stage is a period of rapid sales growth since the product is accepted widely by the market and the sales volume will boost. As the sales growth begin to slow down, the mature stage start. Therefore, the product life cycle curve can be illustrated with S-shaped curve from introduction stage to beginning of mature stage. Since lifecycle curve grow as sigmoid curve, growth curve method could be applied to forecast the future trend of products.

Growth curves are widely used in technology forecasting [4, 6-10] and are referred to as "S-shaped" curves. Technology product growth follows this curve since the initial growth is often very slow (e.g., a new product replacing a mature product), followed by rapid exponential growth when barriers to adoption fall, which then falls off as a limit to market share is approached. The limit reflects the saturation of the marketplace with the product or the replacement of the product with another. The curve also models an inflection or break point where growth ends and decline begins.

Many growth curve models have been developed to forecast the adoption rate of technology based products with the simple logistic curve and the Gompertz curve the most frequently referenced [1, 6]. However, when using these two models to forecast market share growth, care must be taken to set the upper limit of the curve correctly or the prediction will become inaccurate. Setting the upper limit to growth can difficult and ambiguous. If the product is a necessity or will likely be popular for decades, then the upper limit can be set to 100% of the market share. This means that the product will be completely replaced only after everyone in the market has purchased the product. However, when marketers consider new technology products such as a computer game or a new model cell phone, the value for the upper limit to market share growth can be difficult to estimate. That is, a computer game can be quickly replaced by another game after only reaching 10% market share.

In order to avoid the problem of estimating the market share growth capacity for the simple logistic and the Gompertz models, Meyer and Ausubel [8] proposed the extended logistic model. Under this model, the capacity (or upper limit) of the curve is not constant but is dynamic over time. Meyer and Ausubel also proposed that technology innovations do not occur evenly through time but instead appear in clusters or "innovation waves." Thus, they formulated an extended logistics model which is a simple logistics model with a carrying capacity $K(t)$ that is itself a logistics function of time. Therefore, the saturation or ceiling value becomes dynamic and can model pulses from bi-logistic growth. Bi-logistic growth represents growth where market share seems to reach a limit but then growth is suddenly rejuvenated or reborn and begins again. Therefore, the researchers extend the constant capacity (K) of the simple logistic model to the carrying capacity ($K(t)$). This study applies this idea to the study of electronics products with $K(t)$ representing an extended logistic model.

The proposition of this research is that the extended logistic model with a time-varying capacity feature will be better than the simple logistic model and the Gompertz model which require a set constant capacity. Therefore, this research studies the forecast accuracy of large and small data sets using the simple logistic, Gompertz, and extended logistic models. A time-series dataset describing the

Taiwan market growth rates for two types of electronic products and two types of services were used to evaluate model performance.

2 Technological Forecasting Models

2.1 Simple Logistic Curve Model

Most biological growth follows an “S-shape” curve or logistic curve which best models growth and decline over time [8]. Since the adoption of technology and technology based products is similar to biological growth, the simple logistic model is widely used for technology forecasting.

The model of simple logistic curve is expressed as $y_T = \frac{L}{1+ae^{-bt}}$ where L is the upper bound of y_t, a describes the location of the curve, and b controls the shape of the curve. To estimate the parameters for a and b, the equation of the simple logistic model is transformed into linear function using natural logarithms. The linear model is expressed as $Y_t = \ln(y_t / L - y_t) = -\ln(a) + bt$ and the parameter a and b are then estimated using a simple linear regression.

2.2 Gompertz Model

The Gompertz model was first used to calculate mortality rates in 1825 but has since been applied to technology forecasting [5]. Although the Gompertz curve is similar to the simple logistic curve, it is not symmetrical about the infllection point which occurs at $t = (\ln(b)/k)$. Gompertz’s model reaches the point of inflction early in the growth trend and is expressed as $y_t = Le^{-ae^{=bt}}$, where L is the upper bound which should be set before estimating the parameters a and b. Similar to the parameters of the simple logistic model, natural logarithms are used to transform the original Gompertz model to linear equation $Y_t = \ln(\ln(L/y_t)) = \ln(a) - bt$ and then the parameters are estimated.

2.3 Extended Logistic Model

The simple logistic model and the Gompertz model assume that the capacity of technology adoption is fixed and there is an a upper bound to growth for these models. However, the adoption of new technology is seldom constant and changes over time. As shown by Meyer & Ausubel [8], the original form of simple logistic model $\frac{df}{dt} = by\left(1 - {}^{y}\!/_{k}\right)$ is extended to $\frac{df}{dt} = by\left(1 - {}^{y}\!/_{k(t)}\right)$, where k is the upper limit of the logistic curve and $k(t)$ is the time-varying capacity and is the function which is similar to logistic curve.

This research uses the extended logistic model and assumes that $k(t) = 1 - D \times e^{-at}$, where the value of D can be any number and the value of A larger than zero. The setting of $k(t)$ comes from Chen's study [2]. This research also assumes that the capacity will fluctuate with time and the saturation level of a product could be 100% but may also just be 60% or 80% because some new products could be introduced to the market and substitute older products. Thus, a product may not achieve the 100% penetration of the market and may be replaced earlier than expected.

Finally, the extended logistic model can be expressed as $y_t = \dfrac{k(t)}{1 + C \times e^{-bt}} = \dfrac{1 - D \times e^{-at}}{1 + C \times e^{-bt}}$, where $k(t)$ is the capacity that is fluctuate with time, and a, b, C, D are the parameters computed using a nonlinear estimation method provided by a statistic software package like SYSTAT.

2.4 The Measurements of Fit and Forecast Performance

There are many statistics used to measure forecast accuracy. In this study, the Mean Absolute Deviation (MAD) and Root Mean Square Error (RMSE) are used to measure performance. The mathematical representations are shown below:

$$MAD = \frac{\sum_{i=1}^{n} \left| f_i - \hat{f}_i \right|}{n}$$

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} \left(f_i - \hat{f}_i \right)^2}{n}}$$

where f_i is the actual value at time t, $\hat{f}_i$ is the estimate at time t, and n is the number of observations. These measurements are based on the residuals, which represent the distance between real data and predicted data. Consequently, if the values of these measurements are small, then the fit and predicted performance is acceptable.

3 Data Collection and Data Analysis

The Taiwan market growth rate for color TVs, telephones, Asymmetric Digital Subscriber Lines (ASDL) and mobil internet subscribers were collected to test the forecast accuracy of the simple logistic model, the Gompertz model and the extended logistic model.

ADSL is a type of data communications technology which enables the use of the Internet over copper telephone lines. ADSL users must sign up for accounts so the application data models the growth rate of adoption of the technology service. Mobil internet subscribers also apply for accounts and the subscriptions for WAP, GPRS, and PHS represent this class of data service.

There are 1 data points for color TV set purchases (from 1974 to 2004) and 35 data points for telephone purchases (1964 to 2004). Twenty six quarterly data points for ADSL subscription were collected from the second quarter in 2000 to the third quarter in 2006 and 19 quarterly data points for mobile internet subscription were collected from the third quarter in 2000 to the third quarter in 2006.

Figure 1 shows the saturation rate for the four products. The growth rate for color TVs and telephones follows as S-shape curve and the curves for ADSL and mobile internet subscriptions also have basic sigmoid curve. As can be seen in Figure 1, it spent 20 years (1964-1984) for telephone getting into the mature stage whose characteristic is slower growth rate than that at the growth stage in product lifecycle. Further, color TV also spent 10 years (1974-1984) entering the mature stage. However, for ADSL and mobile internet subscriptions, it only took 5 years to begin the mature stage. Therefore, the data for color TV and telephones were categorized as long life cycle products, while the data for ADSL and mobile internet were as short life cycle products.

These four data are fitted to the models after removing the last five data points. The last 5 data points were reserved to test the prediction accuracy of the models. Further, to compare the performance of the three models using large and small data sets, the data for color TV and telephones were used to represent longer lifecycles (larger data sets) since these two products have more than 30 years historic data. Compared to color TV and telephones, the data for ADSL and mobile internet subscriptions rely on small data sets of less than 6 years and represent shorter lifecycles.

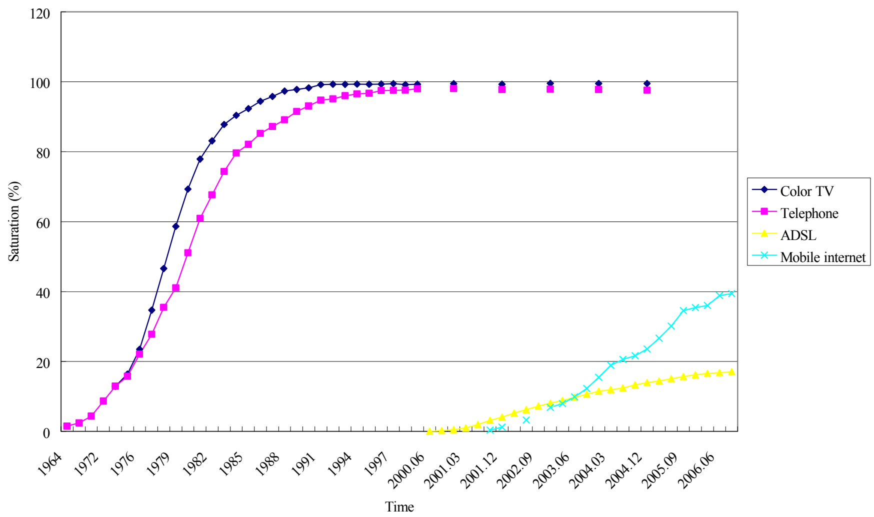

Figure 1. Market growth for Color TVs, telephones, ADSL subscription, and mobile Internet subscription

4 Analysis

The first step is to fit the data to the simple logistic, Gompertz, and the extended logistic models. After reserving the last five data points, the coefficients of the models and the statistics for MAD and RMSE are computed. The second step uses the derived models to forecast the five data points and compare the forecast with the true observations and compare.

Table 1 summarizes the fit and prediction performance of the three models. The evaluation rule is that the smaller the value for MAD and RMSE, then the better the prediction performance. Therefore, the results show that the extended logistic model has the best fit and prediction performance for both long and short data sets. Thus, the extended logistic model is suitable for predicting both long and short lifecycle products.

The simple logistic and the Gompertz model require that the values for the upper limit be set correctly, otherwise the accuracy of the models can be suffer. For the long data sets, the upper limit for color TVs and telephones is easy to see and is set at 100%. However, for the short data sets, the capacity for ADSL and mobile Internet service is difficult to determine. Thus, for the simple logistic and the Gompertz model, different upper limits are set for the short data sets. The upper limit for the saturation rate of ADSL is set to 100%, 50% or 30% whereas and the upper bound for mobile Internet is set to either 100% or 50%. As shown in Table 1, the extended logistic model with time-varying capacity yields the best fit and prediction performance.

5 Discussion and Conclusion

This study compares the fit and prediction performance of the simple logistic, Gompertz, and the extended logistic models for four electronic products. Since the simple logistic and Gompertz curves require the correct setting of upper limits for accurate market growth rate predictions, these two models may not be suitable for short life cycle products with limited data. Therefore, to solve this problem, the extended logistic model proposed by Meyer and Ausubel was used in this study. Since the extended logistic model estimates the time-varying capacity from the data, it tends to perform better for long data sets and for short data sets. Besides, the extended logistic model is also suitable for predicting both long and short lifecycle products.

There are limitations to the use of the extended logistic model. For example, Meade & Islam [6] use telephone data from Sweden to compare the simple logistic, extended logistic, and the local logistic models. They concluded that the extended logistic model had the worst performance. However, the growth curve of their data set was resembled a linear curve, not like sigmoid curve. Since the capacity of extended logistic model is time-varying and is a logistics function of time, it is not suitable for the data with linear curve. Therefore, we suggest that if forecasters wish to apply the extended logistic model, then they should confirm that the data is not linear. This research is concerned with accurate market predictions for short life cycle, small data set problems. For this study, we conclude that the extended logistic model is most suitable and research is planned to conduct a more rigorous and systematic testing of the model as proposed by Meade and Islam [8].

Table 1. Performance measures for the extended logistic, Gompertz, and the simple logistic models

Data length	Model	Statistic	Fit			Forecast		
			Extended logistic	Gompertz	Simple logistic	Extended logistic	Gompertz	Simple logistic
Long data	Color TV	MAD	0.0053	0.0297	0.0361	0.0025	0.0042	0.0045
		RMSE	0.0071	0.0502	0.0551	0.0026	0.0043	0.0046
	Phone	MAD	0.0063	0.0290	0.0323	0.0049	0.0125	0.0171
		RMSE	0.0083	0.0440	0.0453	0.0057	0.0130	0.0174
Short data	ADSL 100%	MAD	0.0036	0.0154	0.0329	0.0140	0.1037	0.2846
		RMSE	0.0043	0.0228	0.0483	0.0147	0.1060	0.2933
	ADSL 50%	MAD	0.0036	0.0140	0.0274	0.0140	0.0671	0.1688
		RMSE	0.0043	0.0170	0.0372	0.0147	0.0688	0.1716
	ADSL 30%	MAD	0.0036	0.0102	0.0212	0.0140	0.0345	0.0833
		RMSE	0.0043	0.0119	0.0264	0.0147	0.0352	0.0839
	Mobile Internet 100%	MAD	0.0057	0.0134	0.0337	0.0117	0.0627	0.2397
		RMSE	0.0073	0.0156	0.0439	0.0152	0.0699	0.2503
	Mobile Internet 50%	MAD	0.0057	0.0059	0.0217	0.0117	0.0146	0.0503
		RMSE	0.0073	0.0076	0.0248	0.0152	0.0166	0.0518

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Trans-regional Supply Chain Research Network: Developing Innovation Strategies Within and Between Regional Oil and Gas Clusters

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Abstract: Regional clusters at different stages in their life-cycle, provide opportunities for benchmarking regional and trans-regional strategies for innovation and change management. The paper reports on trans-regional knowledge transfer and benchmarking strategies used to enhance the alignment of SME, operators and other stakeholders in regional oil and gas clusters in two regions with ongoing projects. These were part of separate regional initiatives to enhance innovation and competitiveness in the supply chain through support for SMEs as key repositories of niche expertise and local knowledge relevant to the competitiveness of large operators in particular and to the cluster and the region in general. The Western Australia and the UK North Sea oil and gas clusters are used as examples to highlight the recurring sociotechnical problem: solution scenarios that arose in facilitating communication and coordination of diverse stakeholders within and across regional clusters.This is part of a wider set of case studies developed by the network in the oil and and gas and automotive supply chain sector.

Keywords: Supply chain cluster, trans-regional research networks, benchmarking, SME, innovation, human factors.

1 Introduction

The competitiveness of regions increasingly depends on their innovative ability. Clusters can be innovation drivers and are therefore key to economic development. The term “cluster”[82] was coined by Porter, who describes this as a geographical concentration of sector-specific companies, suppliers, service providers and associated institutions (e.g. universities, research institutes, funding bodies) all of

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[82] This articles does not discuss different concepts of clusters. We refer in this case to clusters as Porter [1] defines them.

which are interconnected [14].[83] Clusters are linked by extended enterprises and their supply chains. Therefore, some successful regions have set up knowledge-sharing networks [20, 18,12,16,25] across clusters and this is increasingly the focus of research and development funding and particular in the European Seventh Framework Programme [4] [84].

A cluster-based initiative is currently being carried out by the authors in the Western Australian (WA) oil and gas supply chain to identify stakeholder perceptions of gaps, barriers and opportunities to innovation in the supply chain, and also to support knowledge-sharing between the oil and gas regions of WA and the UK North Sea, highlighting the need to consider strategies that can develop the human communication infrastructure required for stakeholders to identify gaps and barriers and coordinate or reuse strategies and practices. In this case the focus is on strategies that can facilitate SME-led innovations to meet the needs of large operators in the supply chain.

2 Theoretical Background

Porter's theory of national competitive advantage [14] can help to understand the structure and dynamics of clusters. He suggests that four broad attributes of a nation shape the environment in which local firms compete: factor conditions (basic factors such as natural resources and advanced factors such as communication infrastructure, sophisticated and skilled labour, research facilities and technological expertise); firm strategy (different management ideologies), structure and rivalry; related and supporting industries; and demand conditions (sophisticated customers in the home market create pressure for innovation and quality). These four determinants promote or impede the creation of competitive advantage and constitute the so-called diamond which is a mutually reinforcing system, where the effect of one determinant is contingent on the state of others.

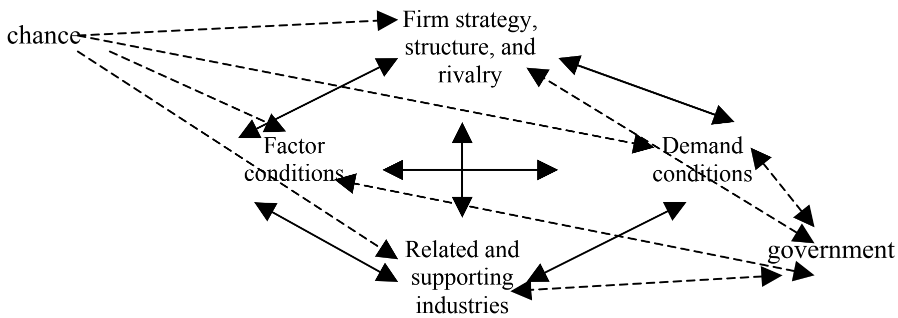

Figure 1. Porter's diamond model [1]

[83] The phenomenon of „industrial districts“ was discussed by the British economist A. Marshall [2] as early as 1890.
[84] Cp. also the Aho report 2006 [1].

Porter argues that two additional variables can influence the national diamond: chance (e.g. innovation) and government (e.g. policies such investment in education or incentives).

According to Porter, a precondition for a cluster to emerge is a critical mass of companies that agglomerate in spatial proximity and start combining their activities along a value chain. The cluster identification of related industries is one of the most influential findings of Porter's research. The diamond model is an ideal tool to analyse hard factors of a cluster and to identify a cluster structure. However, although it stresses that mutual reinforcement between the determinants is key to successful clusters, there is less clarity with regard to how to build up the communication structures (advanced factor) and to align the knowledge and interests of diverse and distributed stakeholders to common ends.

In global distributed markets clusters are networked globally through extended enterprises [3] and their supply chains [2]. As clusters, like organisms, pass through a life-cycle [15] - they are born, evolve and decline - there is an opportunity for cluster cooperation in a range of ways such as strategic process benchmarking [7] in core areas such as innovation, where emerging clusters can learn from more mature ones.

Innovation itself may refer to changes to products, processes or services. Tidd et *al.* [21] refer to four types of innovation as Product, Process, Position and Paradigm. From an organisational perspective it may be linked to performance and growth through improvements in efficiency, productivity, quality, competitive positioning, market share, *etc*. From a change management perspective it is increasingly perceived as a complex process that links many different players together - not only developers and users, but a wide variety of intermediary organisations such as consultancies, standards bodies etc. Sawhney and Parikh[17] and Molina [11] suggest that much of the most successful innovation occurs at the boundaries of organisations and industries where the problems and needs of users, and the potential of technologies can be aligned. This requires the development of sociotechnical constituencies, "dynamic ensembles of technical constituents and social constituents'' through a process of sociotechnical alignment - creation, adoption, accommodation (adaptation) and interaction (interrelation) to achieve these common ends.

3 The UK North Sea and the WA Oil and Gas Clusters – Opportunities for Benchmarking

The UK North Sea and WA oil and gas clusters present an example of opportunities for strategic process benchmarking, because they are at different stages in their life-cycle. Newer clusters have the potential to learn from the successes and failures of more mature ones that have addressed comparable challenges in maintaining competitiveness.

3.1 The evolving WA cluster – a rough diamond

The evolving WA oil and gas cluster can be regarded as the engine of economic development in WA, where the oil and gas industry is of strategic importance for a wide range of stakeholders in government, education und industry. All four determinants of the Porterian model can be found in the structure of the cluster. Oil and gas resources (basic factor) off the WA coast have stimulated related and supporting national and domestic industries to cluster around global operators like Chevron, Woodside, BP, Halliburn, Shell, Agip, Schlumberger. Advanced factors such as communication infrastructure, sophisticated and skilled labour, research facilities and technological know-how, which, according to Porter, are the most significant for the fostering of competitive advantage, are present in WA. However, the core question is how can conditions be created so that all determinants mutually reinforce each other and effectively support the change process so that the diamond begins to shine on value creation.

3.2 Identification of problem areas in the WA cluster

This is one of a set of regional studies where researchers and students on placement have used collaborative action research with a range of stakeholders in the supply chain to identify gaps and barriers, and stakeholder requirements. Students on placement in WA initiated interviews with a wide range of stakeholders, to identify gaps and barriers, moving from open interviews to more formalised questions with larger reference groups.

[85]

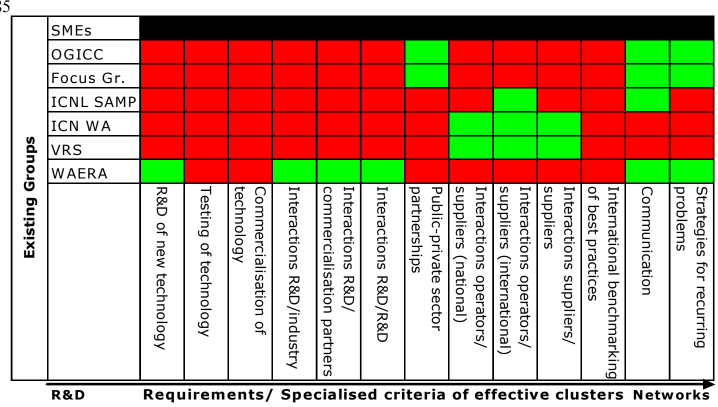

Figure 2. Gaps as perceived by SMEs [18]

Action research is a qualitative approach [8] to elicitation and discussion of multiple stakeholder perspectives as a basis for change in pursuit of common goals.

[85] OGICC – Western Australian Oil and Gas Industry Coordinating Council; OGICC: Action Plan Focus Group; ICNL SAMP – Industry Capability Network Ltd: Supplier Access to Major Projects; ICN WA – Industry Capability Network WA; VRS – Supplybase Vendor Registration Service; WAERA – Western Australian Energy Research Alliance

In many respects it is the equivalent to the benchmarking process, and ideal for contexts where knowledge transfer and negotiated change are important outcomes.

This involved an extensive number of institutions, groups and inititatives that had already been created to facilitate coordination, strategic development and sustainable economic development within the WA oil and gas industry. Students were able to work across boundaries, often bringing together groups who would not normally be able to discuss problems and strategies in this way, and appeared to have a catalytic effect in raising issues and fostering exchange. The study revealed that there is great potential in terms of organisational infrastructure (advanced factors, see above) to create a prosperous oil and gas cluster, however, there are big gaps in the fulfilment of stakeholder requirements for success, as indicated in Figure 2. This initiative has facilitated collective awareness and understanding of the gaps and barriers among stakeholders and provides a template for development.

In addition, the study detected that interaction between all of the above mentioned stakeholders was insufficient, with a significant lack of communication and coordination across the entire industry [19]. Thus, the possibilities of transferring competitive knowledge are very limited; technology diffusion cannot take place to the extent required. There was also evidence of a lack of awareness among large and medium sized operators of technical innovations by SMEs in the region which could address operational problems they were encountering. This was one of a series of gaps in the innovation process. Gaps such as these were a focus of the research, as for example in Figure 3.

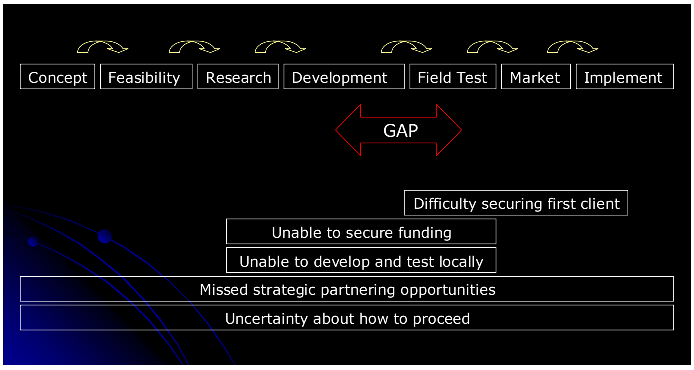

Figure 3. Identifying barriers in the WA Oil and Gas Supply Chain. [19]

It is of interest that a number of the gaps and issues encountered appear to be evident in the UK oil and gas sector, but across other industry sectors also researched such as the automotive industry supply chain [13, 9].

3.3 Lessons learned from leaders – the UK North Sea example

The Australian supply chain is now embarking on a range of approaches to SME led innovation/integration in the supply chain that has already been successfully used in the North Sea PILOT project [13][86]. The growing interest in strategies for developing innovation as a source of competitiveness (as opposed to the previous emphasis on cost-cutting) is also reflected internationally in current research by the European Community to identify strategies and practices that can support innovation [1].

The competitiveness of the UK oil and gas supply chain has been the focus of different government and industry sponsored initiatives, initially as part of a cost-cutting model in which the LOGIC [9] organization took a significant role and latterly through support for SME based innovation with the PILOT project, which faced very comparable issues to those uncovered by researchers in the WA project[87] in relation to the need to support SMEs. These were seen as holders of niche and local expertise underpinning innovation and implementation of complex technologies in difficult local terrains. It is notable that in both regions

- innovation has become a more significant feature of competitiveness in contexts where the supply chain is already very lean as regards cost
- the previous loss of SMEs as part of the initial approach led to a loss of a core resource for innovation
- SMEs were particularly vulnerable to unfair payment and contracting practices
- SME-based innovations were poorly supported at crucial stages, from funding and proof of concept
- SMEs were not made aware of the long term requirements of large operators and large operators were often not aware of the innovative technological solutions that had been developed locally by SMEs that could have been implemented.

From a benchmarking perspective, the initial exchanges with the PILOT project meant shared ideas could be implemented more effectively, and some new ones considered – notably the use of templates for fair contracting, and payment practices as an industry standard, and the setting up of operator/contractor/sme work groups to look at key issues. It became evident from discussion that the role of PILOT itself was perceived as effective because of the brokering role of the team, with very senior representatives of all stakeholders, and senior ministerial commitment underlining the importance of participation, and the potential of the process to execute change (i.e. not a talking shop).The intention is to extend this trans-regional process through the linkage now established at different levels across the regions through governmental, industry, support and higher education organisations.[88] From a socio-technical perspective, the technical networking

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[86] PILOT is a joint programme involving the UK Dept. of Trade and Industry , the aim of securing the long-term future of the Industry in the UK.

[87] One difference specific to mature fields was the more pressing requirement for more innovative technological solutions to extraction in the difficult pockets of recoverable oil and gas in mature fields which can extend the life of the field.

[88] Cp. tri-partite alliances between government, industry and education in the German Brazilian auto supply chain project where they have proven successful [23, 24].

within and across regions needing to be matched by the development of communication and collaboration networks between stakeholders who, through coordinated action, can create value through sharing knowledge and resources to common ends. The use of collaborative action research and benchmarking was both a means of jointly confronting these issues, and starting the process of building shared spaces [25] and regional/ trans-regional infrastructure for addressing them.

5 Conclusions

The paper demonstrates an approach to supporting cluster development within and across regions through the provision of 'shared spaces' for collaborative stakeholder communication as a basis for aligning efforts towards the common end of innovation in the supply chain. Porter's theory is a helpful tool to understand the structure of successful clusters, however, less is known about the means by which the stakeholders in these complex, dynamic, socio-technical systems can provide the human communication infrastructure through which some of these processes need to be realized. The research outcomes from the project in Australia reinforce the findings of earlier work on the automotive clusters in Germany and Brazil, and parallel work in Grid-enabled systems as complex hybrid systems [24] aligning technical infrastructures with and heterogeneous distributed human infrastructures across national boundaries. In conclusion, the intention has been to demonstrate the value of trans-regional action research networks and collaborative benchmarking as a framework for developing and sharing policies and practices between regions as a means of enhancing innovation to enhance competitiveness both for the region itself, and for the cluster in the wider global context [26].

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Procurement and Importing in New Product Projects of Brazilian Aerospace Program

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Abstract. New product development is a business process with many functional interactions in a company. The concurrency of these interactions must be managed in order to meet the preestablished schedule, budget and scope. The issue of procurement is central to a succesful project. When a new project belongs to an aerospace program this issue is even more crucial. And when the aerospace program belongs to a developing country such as Brazil, the core issue involves its budget and schedule planning. This article addresses the question of procurement in a small company designing a new satellite camera for the Brazilian Government. The procurement process was mapped, a monitoring structure was created and performance indicators were developed. The performance indicators are discussed to understand the leverage of each kind of purchased item and each process step on costs and schedule.

Keywords. New product development, aerospace projects, procurement, performance indicators

1 Introduction

In developing countries, new product development (NPD) is still an obstacle rather than a common practice. The same holds true for aerospace projects. What happens when a small Brazilian company attempts to develop a new product for the aerospace industry?

The purpose of this article is to address that question. However, an examination of the entire picture would require the analysis of too many aspects. Therefore, this article analyzes solely the question of procurement, since a new product in the aerospace sector requires the importation of numerous and miscelanous items.

The company under study has been engaged in the development of a new aerospace product since December 2004, to which end it set up a project

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management office to manage procurement. This article makes comparisons between purchases carried out in Brazil and in foreign countries. It compares lead-times for the acquisition of mechanical and electronic items, equipment and software. It discusses import costs and their impact on project overruns and delays.

2 Procurement and Importing in New Product Development

Procurement management is a knowledge area of the project management body of knowledge [5]. It includes the processes involved in purchasing products and services, or the results required from outside the company to execute a project.

In product development literature, procurement is analyzed more as a co-development strategy in which the company builds partnerships to design a product jointly. This kind of discussion was presented by [1], who described four types of supplier involvement in product development: proprietary parts, black box parts, detail-controlled functional parts, and detail-controlled body parts, and discussed the pros and cons of each approach.

Some discussions about procurement in new product projects relate this process with prototype generation. In [1] there is an argument that in-house "specialists" in prototyping tend to focus on asset utilization at the expense of fast feedback on prototypes. When subcontracting, design engineers have the flexibility to decide how much the company is willing to pay for fast cycles. Some authors as [7] considered the "black box" approach the most interesting one when the company's purpose is to relieve the internal engineering teams from additional responsibilities.

According to [2], capability maturity model integration (CMMI) locates procurement in two process areas called "integrated supplier management" and "supplier agreement management". The former is based on the aforementioned co-development philosophy and the latter is used for on-the-shelf and off-the-shelf items that are generally available and are not modified in any way. The basic work product prescribed by CMMI to perform these processes is a formal agreement, i.e., any legal agreement between the organization and its supplier

A few studies deal with procurement management in developing countries. In a study of procurement delays in highway projects in Nepal, [5] identified a possible correlation between the cost impact of an item and the schedule delay in both materials and equipment, and found that supplier defaults such as monopolies and importation difficulties are responsible for 79% of procurement delays. In Ghana, [4] interviewed owners, consultants and contractors of Ghana's groundwater drilling projects and found that the main factors affecting project delays and cost overruns are related to procurement management: absence of effective procurement management, late delivery of items and difficulties in importing.

3 Project requirements of the brazilian aerospace program

The Brazilian Aerospace Program utilizes the European Aerospace Standards as a reference. These standards are divided into three types: managerial, engineering, and quality assurance. Managerial standards are based on project management theories, such as those of the [3]. Therefore, when a new project is initiated by the Brazilian Aerospace Agency (BAA), it prescribes a milestone timetable and a detailed description of the deliverable scopes.

The company analyzed here is engaged in two aerospace projects, both of which involve the development of optical cameras and their processing electronics. In addition, a complex piece of optoelectronic equipment is necessary for camera verification. Table 1 lists the deliverables to be produced for the BAA, showing their composition in terms of imported items.

Table 1. Deliverable typologies in the aerospace project

Deliverable	Quantity	Imported items level
Bread-board model	1	Low
Engineering model	2	intermediate
Qualification model	1	High
Flying model	3	High
Ground support equipment (GSE)	3	High

All the projects for the BAA follow the phasing structure prescribed by the European Aerospace Committees. Therefore, there is a bread-board model, two engineering models – one for environmental and another for functional tests –, a qualification model, and flying models. Although qualification and flying models contain a large portion of imported items, their purchase is the responsibility of the BAA, according to the project contract. These items involve microelectronic components, whose trade is constrained by US anti-terror legislation. The purchase of the engineering models and GSEs are the supplier's responsibility.

The BAA's supplier selection criteria include penalty clauses. The amount of money foreseen in these clauses makes it less costly to invest in project management than to pay the fines. This article discusses the delivery of engineering models and GSEs.

4 Mapping and monitoring the procurement process

The first action to monitor purchased items was to map the company's procurement process. This was done by talking to buyers, engineers and operation managers. The process is described in the flowchart presented in.

Engineers are allocated to an engineering unit where they develop item specifications, make an initial supplier selection, and send it to the company's buyers. If the item is on-the-shelf, it is recorded in the configuration control system and its acquisition begins. If not, the engineers negotiate its price, specifications and timetable with suppliers before the formal purchase process is initiated.

Depending on whether the item will be purchased from a national or foreign company, there are two different flows. If it is an American item, it is purchased from the US subsidiary. If it is a European, Japanese or Australian item, it is purchased directly through the import department. In the latter case, the engineers draw up a procurement plan for senior management approval. If it is an on-the-shelf item and is purchased on the domestic market, a quotation is requested and submitted to senior management for approval. Senior management decisions are made after price and timetable negotiations have been completed.

After the negotiation, a supplier contract is signed, after which the item goes through the normal process of manufacturing, intercontinental transportation and customs release. The steps outlined in Figure 1 are related to parts, materials and processes (PMP) and configuration management processes. However, a discussion about these steps is outside the scope of this article.

Because of the large number of steps in the mapped process, they have been summarized and their number reduced to allow for monitoring of the process, especially for imported items. Figure 2 presents the major milestones identified. The plan was that a date would be set for each milestone and its lead-times monitored. The process illustrated in Figure 1 was mapped in August 2006 and a weekly monitoring began in September 2006. A person was appointed to purchase every item required for the aerospace projects, and to monitor the status of each item. This employee was allocated to the project office shown in Figure 1.

One person was appointed to head each milestone and the monitoring process was discussed with him. These head people make weekly reports to the project management group about the schedule and status of each purchased item.

The last step to structure the monitoring process was to create performance indicators and a procedure for periodically monitoring and informing the status of the indicators. The indicators are monitored weekly and fixed on a monthly basis.

5 Findings

Figure 3 depicts the number of acquired items monitored, showing the imported and domestic items purchased per month. The data were systematized on February 15, 2007. This figure reveals that every domestic purchase process was concluded while the import processes were not. In fact, there are import processes dating back to July 2006 whose status is still open. Taking into account only purchases initiated after September 2006, one can see that almost 43% are from other countries. In the company's traditional projects, this number is less than 5%.

This analysis is complemented by Figure 4, which compares item lead-times. The materials are typologized according to their technological background, while equipments are classified as imobilized assets and software programs are listed explicitly. Note that the lead-time of imported mechanical and electronic items are 11 and 8 times longer than national lead-times.

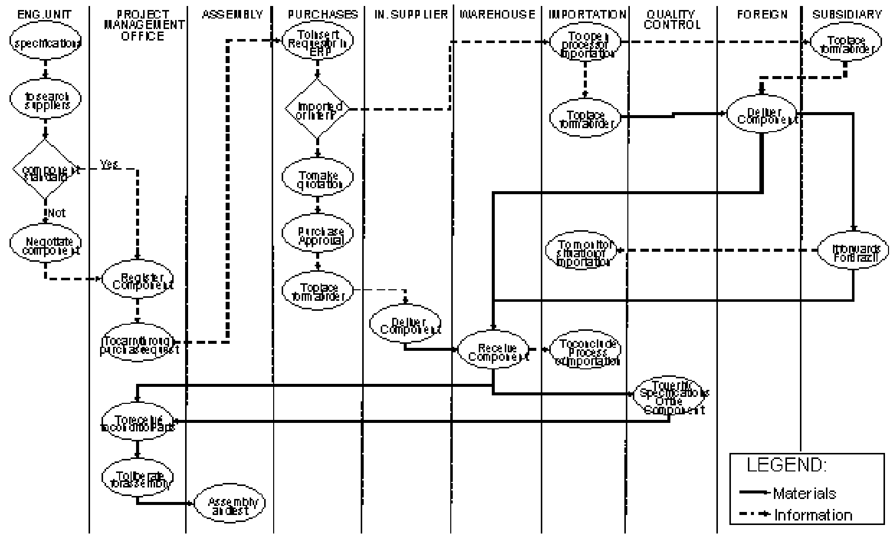

Figure 1. Flowchart of procurement process for prototype items

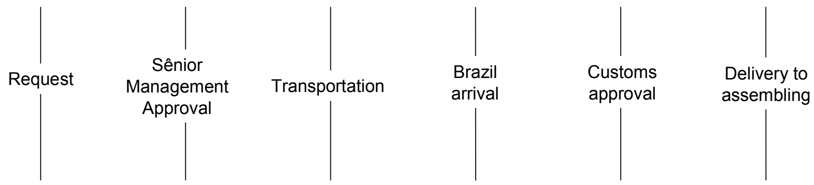

Figure 2. Main milestones of the procurement process of imported items

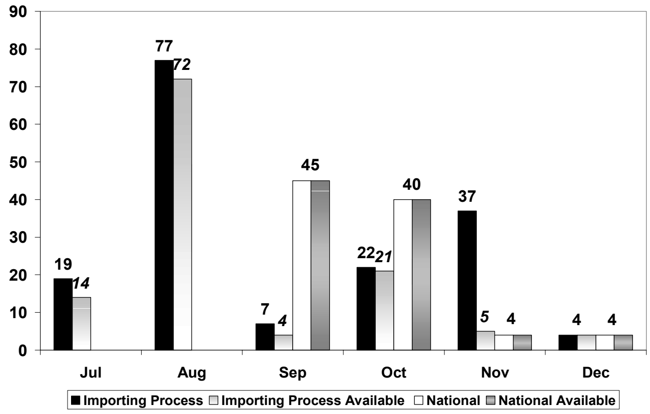

Figure 3. Purchase Process: Importing versus National Items

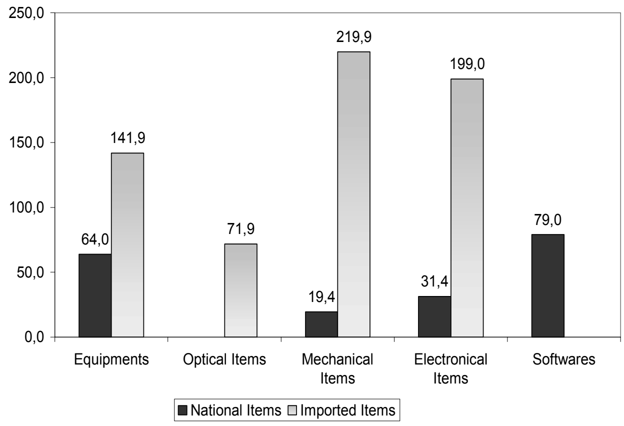

Figure 4. Lead-time by Item typologies

Figure 5 shows the percentage of the price of each item in the overall purchase cost of both national and imported items, revealing a very substantial difference. The price of imported items represents only 25% of the overall import process. National items rate up to 98% of total cost. This demonstrates how expensive the importation process in Brazil is.

From the number of national and imported items delivered, an average time can be established between the beginning (the order) and the end (the component's transfer to assembly) of the purchase process, or simply the lead-time of the process of acquiring new items. Figure 6 presents the lead-times of both national and imported items according to the month when they were ordered. A mean lead-time for each monthly average was calculated for national and imported items to analyze the trends.

The line of averages representing the import procedure is higher than the national one on scale of six (on average). The importation lead-time was reduced after the monitoring process started. The difference between national and imported item lead-times also decreased.

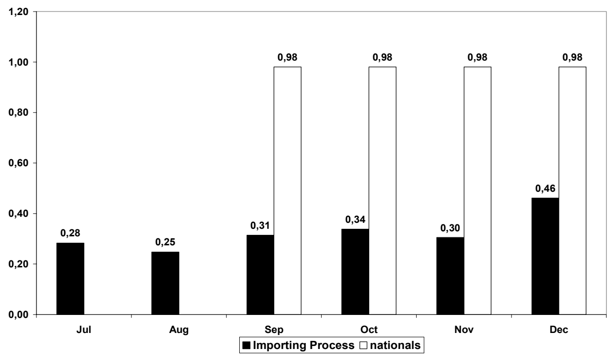

Figure 5. Average of item prices over the total cost of purchasing them.

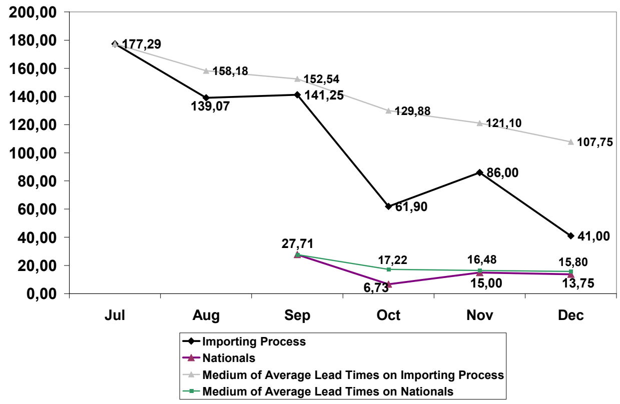

Figure 6. Lead Time for Month and Averages

Figure 7 illustrates the average time between the consecutive milestones illustrated in Figure 2. The graph serves to identify the critical steps in the lead-time of the procurement process. As can be seen, two months elapse between the commercial agreement represented by senior management approval and the beginning of the shipping process. This can be explained by the fact that almost all imported items are made-to-order. Moreover, the data indicate that the time elapsed between an item's arrival in Brazil and its release from customs is longer than the intercontinental transportation itself. It takes Brazilian customs agents more than a month to analyze an item and release it to the importer.

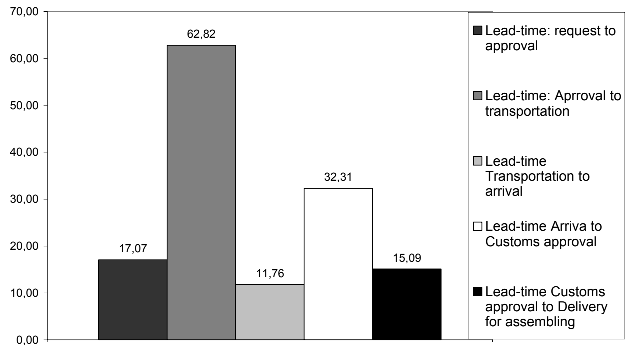

Figure 7. mean time between each procurement process milestone

6 Final considerations

The goal of the data presented in this paper is to help managers make decisions about purchasing and design strategies.

As reported in the literature, there are considerable delays and cost overruns involved in procurement. In November 2006, the three GSE models were to be delivered to the BAA. However, due to importation lead-times and costs, this delivery was postponed.

The company's management has opted to strictly monitor imported items, especially mechanical and electronic items, and attempts have been made to nationalize them. A team has been set up to study the composition of the period elapsed between an item's arrival in Brazil and its release from customs. This period represents one month of the total lead-time and almost all the cost overruns. The team is trying to apply a lean office program to the overall procurement process to decrease the other partial lead-times.

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Measuring the efficiency of outsourcing: an illustrative case study from the aerospace industry

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Abstract. Outsourcing is related to the action which an organization deals with its suppliers through a kind of business contract where a specific activity or service has been hired to be made. The outsourcing of some activities has become a common practice in the industry, nowadays. It reduces costs, significantly, in the production process and, at the same time, adds some values to the business organization. However it is necessary to measure the performance of these activities. Data Envelopment Analysis (DEA) is a non-parametric method useful to measure comparative performance. It has a wide range of applications measuring comparative efficiency. The Analytic Hierarchy Process (AHP) is a multiple criteria decision-making method that uses hierarchic structures to represent a decision problem and then develops priorities for the alternatives based on the decision-maker's judgments. This paper presents an integrated application based on DEA and AHP to evaluate the efficiency of subcontracted companies in a Brazilian aerospace factory.

Key-words. Aerospace Industry, Efficiency and Performance Analysis, Outsourcing, DEA, AHP.

1 Introduction

Outsourcing is an updating subject in many companies nowadays and it has become an option to reduce costs and to improve the productivity in the production process. The decision to outsource is often made in the interest of lowering firm costs, redirecting or conserving energy directed at the competencies of a particular business, or to make more efficient use of worldwide labour, capital, technology and resources.

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By this way it is necessary to develop a process to control the activities that will be outsourced. An evaluation of the productivity and efficiency of these companies becomes necessary to get the results reached by each company and with these data take some management decisions related to the outsourcing process and its costs. To evaluate this efficiency value some criteria need to be considered by the decision-maker once the objective of this study is to estimate the efficiency of outsourced companies based on the decision-maker's judgments and then develops priorities for the alternatives. In this paper an integrated application of DEA with AHP will be made to determine the efficiency of outsourced companies in the aerospace industry.

A comparative table with all outsourced companies (*Decision Making Unit or DMUs*) will be elaborated according to the inputs and outputs related to spare parts technical publication process. There are 8 outsourced companies to be evaluated. The input in this process is represented by the activities subcontracted or even the package that will be send to these subcontracted companies. This package comes from every modification that happens in the aircraft and that will represent an updating of spare parts technical publications. In this case the input means the quantity of technical documents that will be released by project department. A quantity of figures in the aircraft spare parts technical publications will be necessary to be revised or even created in function of those modifications released by the project and engineering departments. Beyond the elaboration of new or revised figures to be introduced in the spare parts technical publications, the updating of part list in the data bank becomes necessary once this information will be used to all operators to plan their spare parts logistic and aircraft maintenance to keep their fleet flying every time. The output of this process will be represented by the quantity of figures done and incorporated in the spare parts technical publications and at the same time if this activity will be delivered on time or not by each outsourced company.

This paper is organized in a review of theoretical considerations related to DEA and the efficiency concept and also a revision of AHP. In the next section the case study will be shown in details with a description of outsourcing process in the aerospace factory regarding to spare parts technical publications process and the application of DEA integrated with AHP. The results of this application will be shown with some comments and after this section a conclusion of these results will be made with possible future possibilities to continue this study.

2 Theoretical considerations

2.1 Data Envelopment Analysis

DEA is a methodology for measuring the relative efficiencies of a set of decision making units (DMUs) that use multiple inputs to produce multiple outputs [2]. DEA was initially developed by Charnes et al for a case of school evaluation [3]. DEA is also defined as a linear programming method to compute DMUs comparative efficiencies [5]. In this case the DMUs relative efficiency is defined as the ratio of the weighted sum of its outputs to the weighted sum of its inputs [6]. In DEA is possible to consider n DMUs each consuming m inputs and producing p outputs where **X** and **Y** are matrices, consisting of nonnegative elements, containing the observed input and output measures for the DMUs [6] . Usually there are multiples inputs and outputs, so it is necessary to form a unique virtual output and a unique virtual input, for the observed DMUp .By using linear programming (LP) [4], we can find the weights that maximize the ratio output per input through the model showed in Figure 1 [4]:

$$
\begin{aligned}
\text{Max} \quad & \omega_0 = \sum_{r=1}^{s} \mu_r y_{r0} \\
\text{s.t.} \quad & \sum_{i=1}^{m} v_i x_{i0} = 1, \\
& -\sum_{i=1}^{m} v_i x_{ij} + \sum_{r=1}^{s} \mu_r y_{rj} \leqslant 0, \quad j = 1, \ldots, n, \\
& v_i \geqslant 0, \quad i = 1, \ldots, m, \\
& \mu_r \geqslant 0, \quad r = 1, \ldots, s.
\end{aligned}
$$

Figure 1. Equation of CCR model [4]

The CCR model was chosen for this purpose once all outsourced companies have similar scales of operation [5]. In other words, the scale effects for each company are irrelevant. An important point to be mentioned is that it is necessary to choose the orientation of DEA model. In this case study the output oriented model was chosen once it attempts to maximize outputs while using no more than the observed amount of any input [3]. For this model it is necessary to exchange the numerator and the denominator and to minimize the objective function [3].

2.2 Analytic Hierarchy Process

The AHP is a multiple criteria decision-making method that uses hierarchic structures to represent a decision problem and then develops priorities for the alternatives based on the decision-maker’s judgments [8]. In general, the multiple criteria methods can be classified as weighting methods, outranking methods, goal and reference point methods and value function methods [7]. AHP uses redundant judgments for checking consistency, and this can exponentially increase the number of judgments [7]. Analytic focus of rating method enables decision-makers to evaluate a large number of alternatives easily. In this method an element is compared against an ideal property and generally, only the final alternatives of choice are absolutely measured [7]. It is used a linear scale from 1 to 9 (Fundamental Scale) in the judgements [8]. In this paper the AHP was applied to determine the weighted sums of scaled indicators. The weighted sums of scaled indicators reached with AHP will determine the criterion values which will be the input and output values for DEA application. This integration of both methodologies has been proposed trying to incorporate preference information of decision-maker in the final result of efficiency.

3 The application in the aerospace industry

The aerospace industry has some particular process that differs from other kind of industries and the process of spare parts technical publications is one of these particularities.

Generally an aircraft manufacturer used to produce different models of aircraft and for each of these models it is necessary to support all these aircrafts during a long period. The aerospace industry follows the procedures and standards from IATA (*International Air Transport Association*) which elaborated important international standards such as ATA 100 , ATA 200, SPEC 2000 and SPEC 2200. All those standards were elaborated by operators, regulatory agencies, manufacturers, and others important government authorities around the world. By this way there is a great importance regarding to safety and quality in the aerospace industry. As many others industries the resource of outsourcing was adopted by many of manufactures around the world although always following the roles and standards based on ATA 100 and SPECs 2000/2200.As a result of this development the resource of outsorcing has started to be applied in the spare parts technical publications because it was necessary to increase productivity and at the same time to improve the efficiency in all the technical team of spare parts engineering in function of the increasing in modifications related to new models of aircrafts that were being developed. So it was necessary to elaborate a process to control the activities of outsourced companies. As consequence it was proposed the employment of DEA integrated with AHP once it can result in a good tool to control and to take some efficiency values of these subcontracted companies with the possibility to incorporate the decision-maker preferences according to the criteria adopted to this case study.

It is necessary to define a set of criteria, which are sufficient to characterize the process of outsourcing of spare parts technical publications. The criteria should be relevant to the decision-maker once he/she should emphasize different aspects of outsourced companies performance. Also it is important to use multiple criteria in the evaluation, because it is extremely difficult if not impossible to find a way to aggregate the criteria into one criterion [6]. These criteria were defined by a group of specialists of spare parts technical publications team that used their experience and monthly reports related to all technical documents worked by these subcontracted companies. According to this group of specialists and their carefully analysis to define a set of criteria which are sufficient enough to characterize the process of outsourcing of spare parts technical publications the above criteria were defined:

- Quality (C1)
- Time (C2)
- Cost (C3)
- Quantity of technical documents released by project (C4)

For these criteria it is necessary to introduce some indicators which can be employed to make the criteria suitable for evaluation. These indicators are concrete in the sense that we can somehow more or less objectively measure alternatives with them [6].It is also interesting to create some indicators to some criteria once they contain enough information about the values of the criteria. The indicators were proposed below to all criteria except for the fourth criterion.

(a) Criterion: Quality (C_1)

- Illustration,
- Part List and
- Number of Questions

(b) Criterion: Time (C_2)

- Delivered,
- New and
- Assembly

(C) Criterion: Cost (C_3)

- Internal,
- External and
- Tools

Carrying out a systematic and quantitative evaluation of these companies, it is important to introduce the scales for the criteria according to the indicators allocated to each criterion [6]. In order to aggregate values to the indicators it is necessary to quantify them with appropriate tool and for this case study the AHP was chosen once it will be used to determine the weighted sums for each indicator. The results which will be obtained with AHP for each criterion will be applied to determine the efficiency of production process with DEA. These values will be the inputs and outputs to determine the efficiency of these companies with DEA.

5 Results and Comments

The first step in this analysis was to determine the weighted sums for scaled indicators [6]. The values for these judgements were obtained with a group of specialists that attributed values to indicators for each criterion. For this purpose it was used the AHP and Table 1 presents the judgements according to explanation in section 2.2.

Criteria C_1 is the quality of spare parts technical publications. This quality can be measured by illustrations created or revised for each outsourced company, or even by the quantity of questions received per month by operators and also by the revision of parts list which needs to show exactly all the parts numbers and the relation of intechangeability between parts. The other criteria C_2 is represented for the time that these companies used to deliver the package of activities send to them. The indicators in this case mean the time spend for each company to deliver a package of activities to a new aircraft (in this case a program that it is still being developed), to a delivered aircraft or to an assemmbly aircraft. The cost of each outsourced company is represented by criteria C_3 which indicators are the external costs, internal costs and the costs with specific tools as softwares and systems. Criteria C_4 is the input of the process. This input was measured by the quantity of technical documents released by project and engineering departments which reflects modifications in the aircrafts. The other step for this evaluation was to determine the values for the criteria. A group of five specialists were asked to scale all indicators in a range where the lower value is zero and the higher value is one. The weighted sums for each indicators was used to determine the final value for each criterion [6] and Table 2 gives the result of this analysis.

Table 1. Weighted sums of scaled indicators

Criterion C_1				
	Illustration	Part List	Questions	Weight
Illustration	1.0	0.33	0.2	0.10
Part List	3.0	1	0.33	0.26
Questions	5.0	3.0	1.0	0.64
Criterion C_2				
	Delivered	New	Assembly	Weight
Delivered	1.0	3.0	3.0	0.59
New	0.33	1.0	3.0	0.28
Assembly	0.33	0.33	1.0	0.13
Criterion C_3				
	Internal	External	Tools	Weight
Internal	1.0	3.0	2.0	0.54
External	0.33	1.0	3.0	0.30
Tools	0.5	0.33	1.0	0.16

Table 2. Criterion values as the weighted sums of scaled indicators

	OUTPUTS												INPUT
	Illustration	Part List	Questions	C_1	delivered	new	assembly	C_2	Internal	External	Tools	C_3	C_4
Weights	0.10	0.26	0.64		0.59	0.28	0.13		0.54	0.30	0.16		
A	0.60	0.80	0.70	72	0.60	0.90	0.90	72	0.60	0.40	0.40	51	90
B	0.70	0.80	0.60	66	0.70	0.50	0.80	66	0.50	0.30	0.30	50	85
C	0.90	0.70	0.80	78	0.90	0.80	0.70	85	0.90	1.00	0.80	73	75
D	1.00	0.90	0.80	85	0.70	0.90	1.00	80	1.00	0.90	0.80	94	60
E	0.70	0.70	0.70	70	1.00	0.80	0.90	93	0.50	0.40	0.40	78	72
F	0.80	0.90	0.70	76	0.80	0.70	0.70	76	0.60	0.30	0.30	44	80
G	1.00	0.80	0.90	88	0.80	0.70	0.70	76	0.80	0.70	0.90	71	70
H	0.70	1.00	1.00	97	1.00	0.80	0.80	92	0.80	0.90	1.00	91	65

The criterion values for each alternative will be used to evaluate the production efficiency for these outsourced companies with DEA and in this application of DEA the outputs are represented by criteria C_1, C_2 and C_3 while the input is represented by criteria C_4.The results for efficiency evaluation with DEA can be viewed in the Table 3.

Table 3.Efficiency scores of DEA

DMU	Efficiency
A	0.57
B	0.55
C	0.80
D	1.00
E	0.91
F	0.67
G	0.84
H	1.00

The results of DEA evaluation were elaborated with the software FSDA – Free Software for Decision Analysis [1].Observing the results of Table 4 is possible to note that the DMUs D and H are efficient with standard efficiency while the others are not so efficient as DMUs D and H. In this paper an efficiency analysis of 8 outsourced companies was performed considering the values obtained with AHP analysis to indicators chosen according to decision-maker's preference. Other possibilities to develop this study case can be performed applying other decision making tools although the results obtained here tried to approach the preference of the decision-maker to establish the efficiency of these outsourced companies.

6 Conclusion

In this paper an integrated application of DEA and AHP in the aerospace industry was showed. This application was done with outsourcing process of aircrafts spare parts technical publications and how this application could help the decision-maker to evaluate the efficiency of the outsourced companies considering criteria and alternatives related to this outsourcing process. Those criteria and indicators were chosen by a group of specialist that deal with the spare parts technical publications process which were considered relevant to affect the final results of this production process and also its efficiency and productivity.

Through the application of AHP was possible to scale these indicators in weigthed sums and define which one was considered the most important to the process according to the range of values that were attributed to each indicator by the decision-maker. An other evaluation was done to determine the criteria values of alternatives in each criterion. These results were used to determine the efficiency of each alternative related to criteria that were scaled by the decision-maker applying DEA. For this application the criteria of quality, time (deadline) and cost were considered the outputs for DEA while the quantity of technical documents released by project department related to modifications in the product was considered the input for DEA evaluation.

As a result for DEA evaluation DMUs D and H were considered efficient for output orientation model what means these DMUs used to maximize outputs while using no more than the observed amount of any input. According to this result a proposal to improve the efficiency of others outsourced companies will be elaborated considering the criteria defined by the decision-maker. The results of efficiency for DMUs D and H will be used as a benchmarking for others DMUs and at the same time all the values reached with measured parametrs will be considered to improve the performance of these outsourced companies.

7 References

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