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TOWARDS AN INTEGRATED MANAGEMENT OF ENGINEERING DESIGN SYSTEM AND ENTERPRISE

Severine Sperandio, Vincent Robin and Philippe Girard
IMS, Université Bordeaux1, France

ABSTRACT
An enterprise is a complex system using human, technical and methodological competencies in order to improve its performances. Moreover, whatever its competencies, the enterprise must necessary plan, implement, measure its performances and improve these performances by setting new targets: it is the deployment (or industrial) strategy of the enterprise, consisting in the reengineering of whole or part of this enterprise. The *design system* can be defined as the environment where design projects take place. Such projects relate to the product or the system itself, i.e. relate to the reengineering of the product or whole or part of the enterprise. The aim of this paper is to optimise the synchronization and coordination of the development of several design projects in an environment with limited resources (material, human, know-how, etc.) and therefore satisfy the strategic performance objectives of enterprises (cost, quality, flexibility, lead time, etc.). With this intention, we propose to define the role of the (re)engineering in the industrial strategy of enterprises in order to explain how consider the *design system*, which is at the origin of this (re)engineering. Finally, we aim to provide a reference framework allowing to manage in an integrated way the evolution of design system and enterprise. This framework highlights a double modelling (enterprise – design system) allowing to identify the relations between the product / system design and the continual improvement process of an enterprise, in order to improve the global performance of this enterprise. An industrial case presents the use of the concepts by the mean of a software application.

Keywords: System Reengineering, Design System Management, Prototype of Software, Performances Improvement

1 INTRODUCTION

An enterprise is a complex system using human, technical and methodological competencies in order to improve its performances. PDCA cycle (Plan – Do – Check - Act) is an appropriate approach to define the decisional cycle in an enterprise [1], i.e. the continual improvement process. Indeed, it is necessary to plan, implement, measure the performances and improve these performances by setting new targets: it is the deployment (or industrial) strategy of the enterprise, consisting in the reengineering of whole or part of this enterprise. However, the design system itself, where the reengineering takes place, is generally poorly clarified, and "*none approach recognise the need to co-ordinate the resources necessary to realise objectives, or reflect the need to monitor and understand an activity's context or factors that can contribute to attainable performance*" [2]. Furthermore, many performance measurement systems exist to plan, implement, measure the performances of enterprises, but most of them are centred on the business performance [3] and few of them are dedicated to the evaluation of the design system.

We propose to define the role of the reengineering in the industrial strategy of enterprises in order to understand how consider the design system, which is at the origin of this reengineering. After presenting the concepts of deployment strategy of an enterprise, the model of engineering design system and enterprise is described: the GRAI decision-making breakdown criteria are used. Therefore, the structuring and identification of the interactions between decisions help engineers to coordinate and synchronize their design tasks with the continual improvement process of the enterprise. Influences of the design tasks on the improvement process are identified, and vice versa. Finally, an industrial case presents the use of the concepts by the mean of a software application.

2 THE DEPLOYMENT STRATEGY

The PCDA cycle [1] is a model providing a framework for the improvement of a system, complex, or not. It can be used to guide the entire improvement project, or to develop specific projects once target improvement areas have been identified. The PDCA cycle has to be used as a dynamic model. The completion of one turn of the cycle flows into the beginning of the next. Following in the spirit of continuous quality improvement, the system must always be reanalysed and a new test of change can begin. This continual cycle of change is represented in the ramp of improvement (Figure 1).

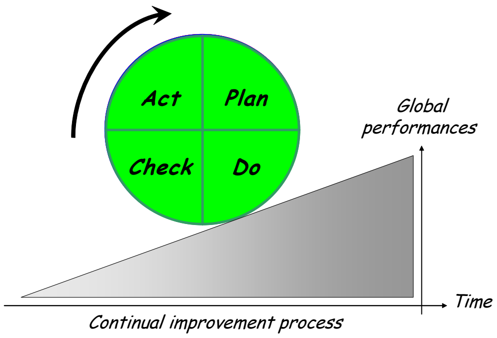

Figure 1. Ramp of improvement [1]

In order to know the level of improvement, we believe that it is necessary to refer to three points of view of the system [4]:

- A *functional point of view*, i.e. the description of system functionality and behaviour. System functionality concerns the purpose of the processes performed by the system, whereas system behaviour results from flow control within the system [5].
- An *organic* point of view, i.e. the description of resources used (human or technical), materials and information, and related control structures.
- A *genetic point of view*, which renders system evolutions and development.

Consequently, we have developed a modelling approach which is in line with these concepts [6]. Its aim is to provide analysts with the appropriate view of a system, depending on the depth of reengineering to be performed, from initial design to structural evolutions or breakthroughs. The modelling methodology is based on a global representation of the system life-cycle (Figure 2), and its process is composed of five steps: (0) initialization, (1) *functional model*, (2) *organic model*, (3) *operating or operational model*, (4) *event management* procedure.

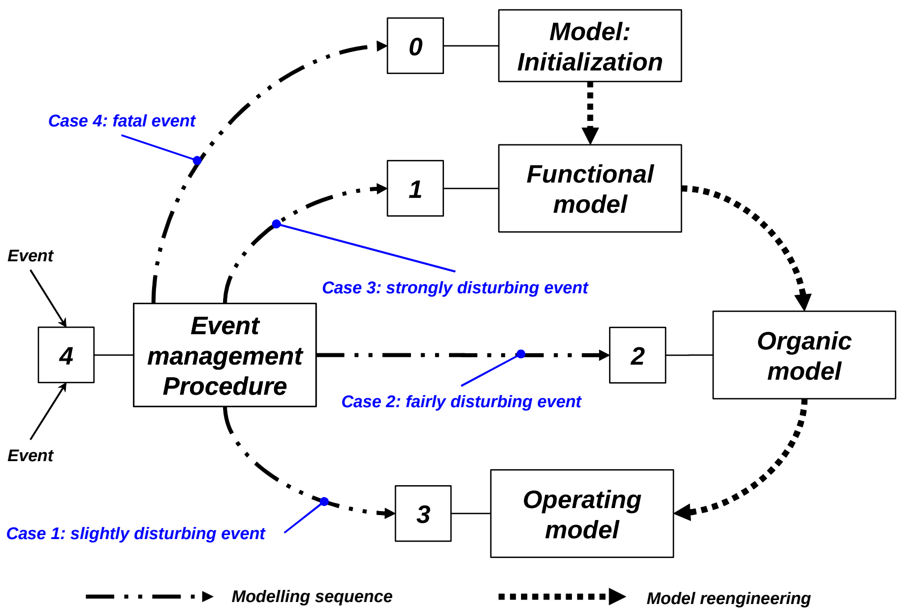

Figure 2. System life-cycle modelling [6]

Model initialization is the first construction of system's view, definitely assumed to be functional to make the role of processes ensured by the system explicit. Then, the aim of the functional model is to situate the enterprise (system) within its environment in order to understand the relations with its different partners such as identifying the constraints and degrees of freedom of decision making. Any strategic specificity should be captured. The organic view depicts the physical organization and resources which achieve the functions previously identified. Finally, the operational (operating) view stipulates the ways the organic system is exploited.

Along the system life-cycle, the appropriate models have to be used individually or sequentially to support reengineering analysis. The modelling trajectory is context-dependent and should be managed in accordance to the system evolution. An event management procedure is consequently necessary to take into account the various events being able to impact the system. Such events (eventually called disturbances) can be planned or unexpected, from external or internal origin, linked to market trends, eruption of new technologies, strategic or capitalistic decisions, etc. An event can be considered as:

- Slightly disturbing the current system if it has no impact on its structure (case 1, Figure 2). Such an event leads to a operational reengineering;
- Fairly disturbing if it acts upon the organic definition of the system, without modifying its functionality (case 2, Figure 2). Such an event leads to an organic reengineering;
- Strongly disturbing if it requires strategic system adjustments (case 3, Figure 2) impacting its functional characteristics. Such an event leads to a functional reengineering;
- Fatal if it makes the system obsolete (case 4, Figure 2) and leads to a dismantlement or full reengineering.

The use of such a system life-cycle modelling allows to identify the level of improvement in the PDCA framework, i.e. the different types of design (functional, organic or operational design tasks) susceptible to punctuate the improvement process of an enterprise. In order to highlight these different design tasks carried out in the continual improvement process, we point out below the V-model, often used for the development of automated production systems (Figure 3).

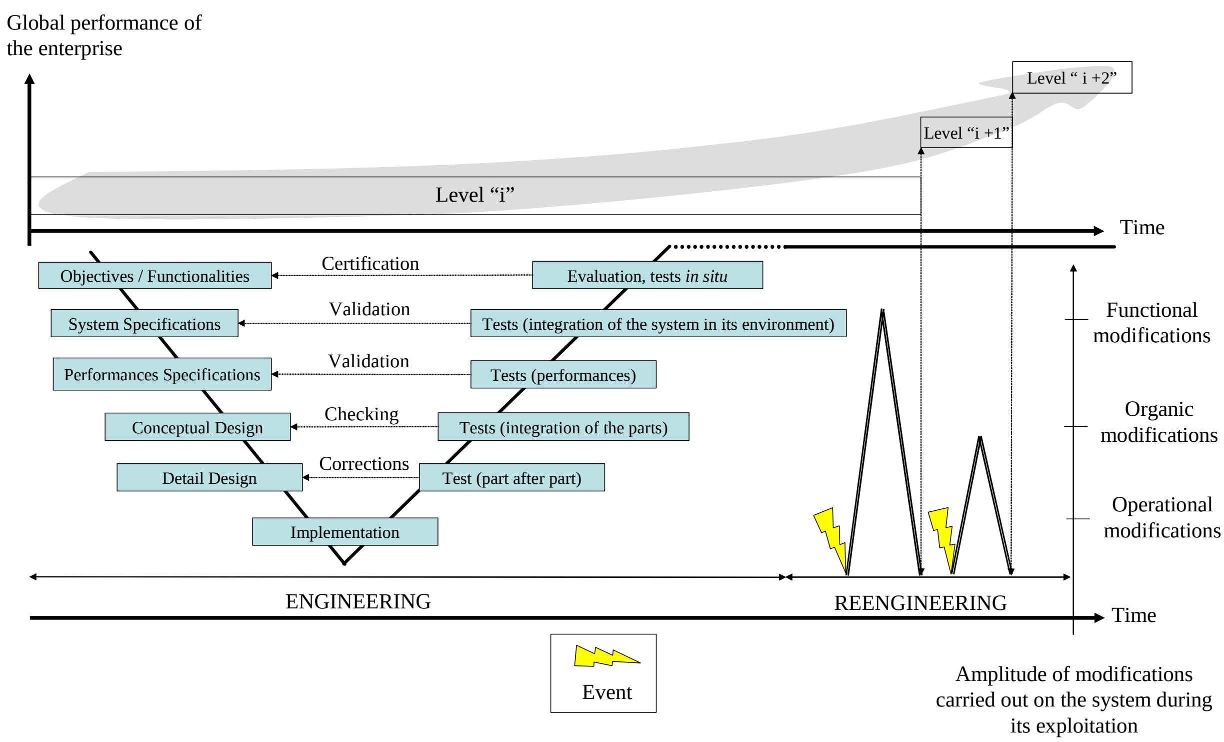

Figure 3. System life-cycle modelling [6]

This cycle reveals the succession of a long V and several short V, respectively symbolizing the genesis (engineering) and the iterative modifications of a system during its life (reengineering of whole or part of the system following the more or less significant disturbances). We detail the long V and position the level of performance that the enterprise reached thanks to the successive design tasks carried out. At each sufficiently significant environmental modification being able to impact the system, or at each internal dysfunction considered to be critical, there is disturbance and a reorganization of the system is essential. The deeper V of the exploitation part is, the more heavy the reengineering will be. It will be able to go from simple adjustments of the operational realisation of the system to significant modifications impacting its functions. The broader they are, the more the reengineering will take time. Hence, the whole of the modifications carried out on the system makes it possible to adapt the system to its environment and also increases its global performances.

3 THE MODEL OF AN ENGINEERING DESIGN SYSTEM AND ENTERPRISE

We decide to use the basic concepts of the GRAI grid [7], which is a model allowing to decompose the decisional system of an enterprise in order to facilitate its management. The decisional system is regarded as a grid, where the columns represent the breakdown according to the type of decision (functional criterion), and the different levels represent the breakdown according to the temporal criterion. Two columns corresponding to external information and internal information for information-related interfaces with the environment of the decisional system and with the technological system are added. The GRAI grid was initially developed for manufacturing systems, which are generally well-structured and for which the transformation (route sheet) in the operating system is well-known. In this paper, the aim is to obtain a guide to manage the continual improvement process of an enterprise. However, such a management is not purely manufacturing and the GRAI grid has to be adapted accordingly. Hence, we are going to redefine the temporal decomposition, then the types of decision (functional criterion) essential for the management of the continual improvement process of an enterprise.

We consider the deployment strategy management of an enterprise according to three decisional levels (representative of the temporal decomposition):

- The industrial strategy, the highest level of the life-cycle management, which decides on the projects of reengineering, according to the environmental context. The industrial strategy throws back into question the functional point of view of the enterprise (functional reengineering);
- The structural strategy, which consists in implementing the engineering of the design system, and casts doubt over the organic point of view of the enterprise. The design system allows to guide design of new products or redesign of whole or part of the system (organic reengineering);
- The operational strategy, in charge of the exploitation of the system (process management and operational reengineering).

At each decisional level, the performance objective imposes to synchronise in time the product and resource availability to perform the activity with the higher level of performance. Thus, there are three basic types of functional activities: the product management activities, the planning activities and the resource management activities. Nevertheless, because of the different natures of the decisional levels, it is necessary to precise what we mean by product, resource and planning for each level (Table 1).

Table 1. Redefinition of the decision types (functional criterion) according to the temporal decomposition

Industrial strategy	
Products management	The product management activities are relative to the purpose of the function at the strategic decisional level, which is: to define and make evolve the role of the enterprise in the market. Here, the "product" is therefore this economic role, i.e. the most functional definition of the enterprise.
Resources management	The resource management activities are relative to the human and technical means which make evolve the role of the enterprise: analysts, leaders of the enterprise, external expertises, etc.
Planning	The planning activities realise the synchronization between the two precedent activities for an adequate industrial strategy of the enterprise. They have to analyse and audit the enterprise (identification of strengths and weaknesses, internal factors [8]) and its environment (identification of opportunities and threats, external factors). Used in a business context, such identifications help the enterprise find a sustainable niche in the market: they uncover opportunities that the enterprise is well placed to take advantage of, and by understanding its weaknesses, it is possible to manage and eliminate threats that would otherwise catch it unawares. It is also the first stage to help managers to focus on key issues and therefore define a new economic role for the enterprise.
Structural strategy	
Products management	The product management activities are relative to the purpose at the structural decisional level, which is: to propose a new structure – organisation, architecture – for the enterprise, then implement it. Here, the "product" is therefore the structure of the whole or part of the enterprise.
Resources management	The resource management activities are relative to the human and technical means which make evolve the reengineering: task forces, tools of project management, etc.
Planning	The planning activities realize the synchronization between the two precedent activities: a good management allows the structural level to launch reengineering projects taking into account all resources implicated in the projects. Moreover, such activities precise at which phase of the project these resources intervene. Each phase has to be the subject of deliverable, then has to be validated in order to check the conformity of the work carried out with the objective initially envisaged.
Operational strategy	
Products management	The product management activities are relative to the purpose of the function at the operational decisional level, which is: to transform raw materials and components into final products according to objectives, constraints, and criteria (optimisation of some features). We find in product management, the classical functions: to buy, to purchase, to store.
Resources management	The resource management activities are relative to the human and technical means which transform the material flow: operators, machines, tools, etc.
Planning	The planning activities realise the synchronization between the two precedent activities: a good management allows the operational level to synchronise the available means and the products to be transformed.

In the GRAI grid, a decision centre is conceptually defined as the intersection between a function and a decision-making level. The concept of a decision framework is maintained in order to coordinate decision centres. The decision framework is defined by: objectives, decision variables that allow actions to be determined, constraint(s) in relation to decision variables, and criterion(a) allowing for a choice between decision variables.

Consequently, we propose a global representation model of the decision-making system to be used in the integrated management of engineering design system and enterprises (Figure 4). Such a representation leads to a multilevel management of the deployment strategy of an enterprise. The industrial strategy carries out a surveillance of the enterprise and its environment. At each significant environmental modification or at each internal dysfunction susceptible to impact the enterprise, the industrial strategy level decides on a reorganization of whole of part of the enterprise. Then, the structural strategy level, which brings into play the engineering of the design system (product, organisation, etc.), constitutes an action lever of the industrial strategy. The decision-making relative to this engineering uses the basic concepts of the GRAI R&D structure [9]. Finally, the operational level allows to manage the exploitation of the process.

Data exchanged between the industrial strategy and the structural strategy levels correspond to orders to carry out design (reengineering of whole or part of the enterprise) and evaluate the design results in order to help the people in decision centres to make their decision. Data exchanged between the structural strategy and the operational strategy levels correspond to orders to implement the new structure elaborated previously during the reengineering and evaluate the implementation results in order to help actors in decision centres to make their decision. Finally, data exchanged between the operational strategy level and the technological system correspond to orders to control the transformation of materiel flow, and evaluate the results in order to help the people in decision centres to make their decision.

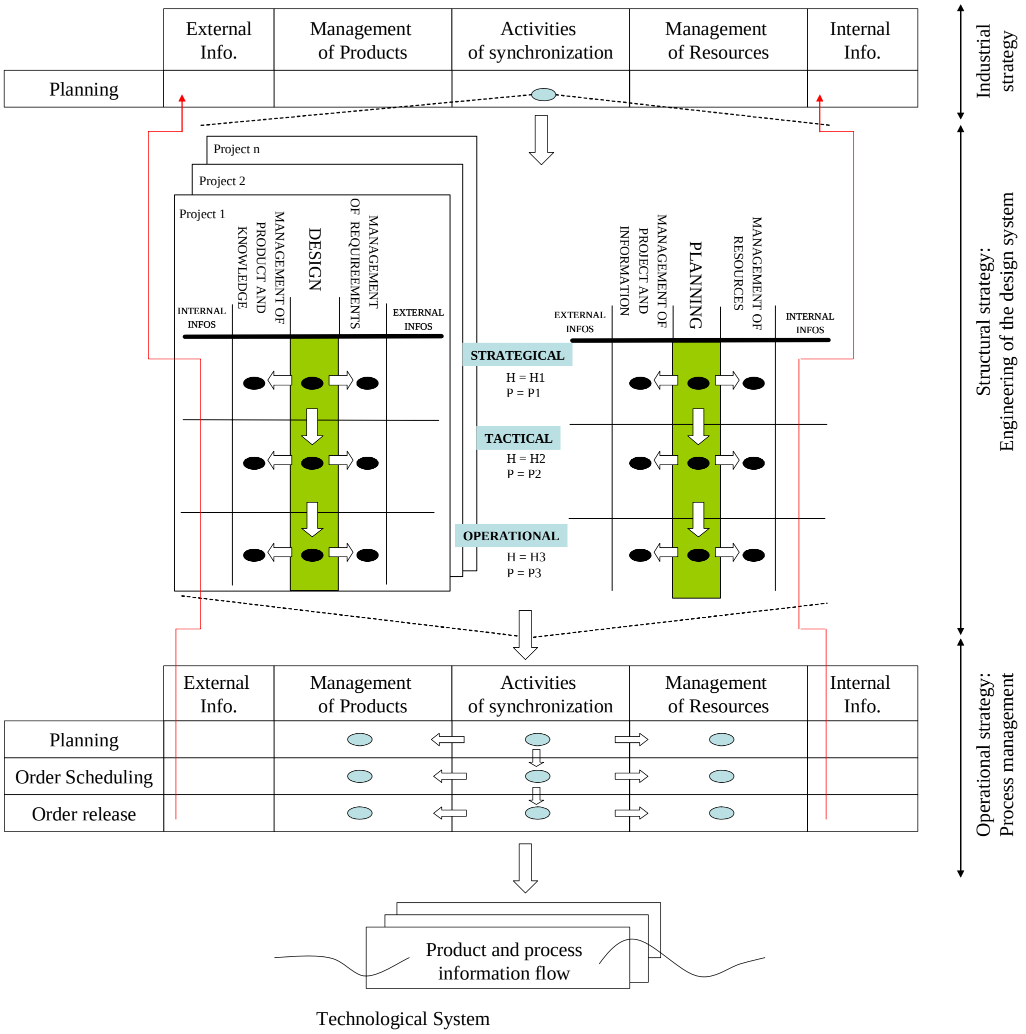

Figure 4. Model of an engineering design system and enterprise

4 PROTOTYPE OF SOFTWARE FOR AN INTEGRATED MANAGEMENT OF ENGINEERING DESIGN SYSTEM AND ENTERPRISE

To have an effective integrated management of engineering design system and enterprise we developed the PEGASE prototype of software. It integrates all the concepts described before. It permits the modelling of the system and the follow-up of the evolution of each element of the design system and of its context. To show how PEGASE could provide a relevant answer to the problem of design system and enterprise management, we present an industrial case study concerning the design phase of the reaction engine mast of the Airbus A380. The reaction engine mast is the interface between the reaction engine and the wing.

At an industrial strategic level, design departments which have to work together are identified in the structure of the enterprise. It is possible thanks to the experience of strategic project managers of Airbus which allows to define a global structure of the plane influencing design system organization. This identification depends on the decisional and organizational structures of the company. In the case of the mast, it is designed by the design department of an Airbus plant in Toulouse and has interactions with the wing (designed by Airbus Industry in England) and with the reaction engine (designed by a subcontractor in United States). Finally, this strategic level proposes a general design process to achieve properly design objectives. A global description of the company, of the design system and of the design process is provided. This description is exploited by the structural strategic level which has to integrate GRAI grids dedicated to each plant to build the decisional and organizational structures of the system. Decision frameworks are defined and objectives, action levers, resources and performance indicators for each plant, at each decisional level but also relationships and influences between each plant and each department of them are identified. All these elements appear in the GRAI grids and are modelled in the PEGASE software (Figure 5 and 6). The nature of the flow of information that will be exchanged during collaboration is also defined. PEGASE permits to model all these interactions and to define the nature of all the exchanges: decisional links (vertical links on Figure 5) and/or informational one (horizontal links, Figure 5). All the elements of the design system and its context are identified, defined and followed thanks to PEGASE. So a modification on an element causes the re-examination of the objectives, the action levers and the performance indicators to be always in adequacy with the object to be evaluated.

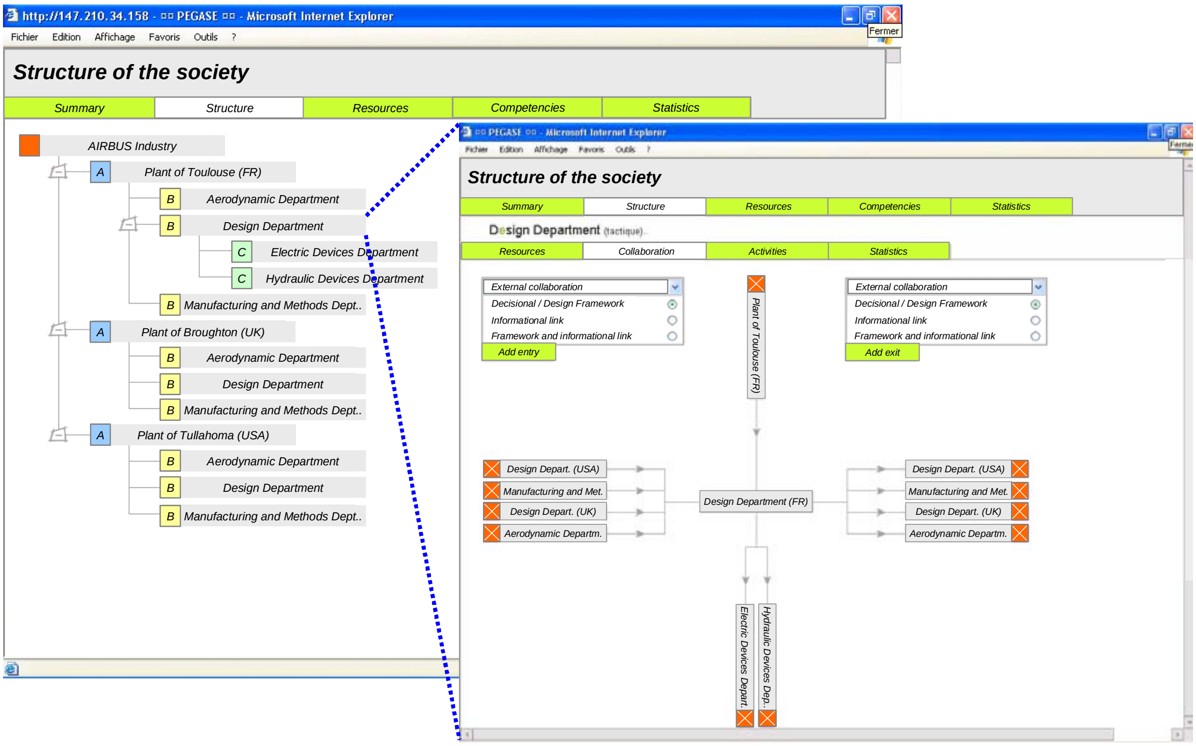

Figure 5. Modelling of the structure of the company and collaborations between each department

When all the elements and the interactions in the design system are identified and implemented in the PEGASE software, projects could be created and software will manage their evolution. This phase concerns the operational strategy level. At the beginning of the project, thanks to PEGASE software, project manager of each department know his partners and has to initialise internal or external collaboration identified by the upper decisional level. He has especially to create and control workgroups according to knowledge, distribution, culture, collaborative capacities, interoperability of each human and material resource and regarding to design objectives. PEGASE proposes to project manager a specific Graphical User Interface to control his activity and to create and follow-up workgroups by creating specific design framework (Figure 6).

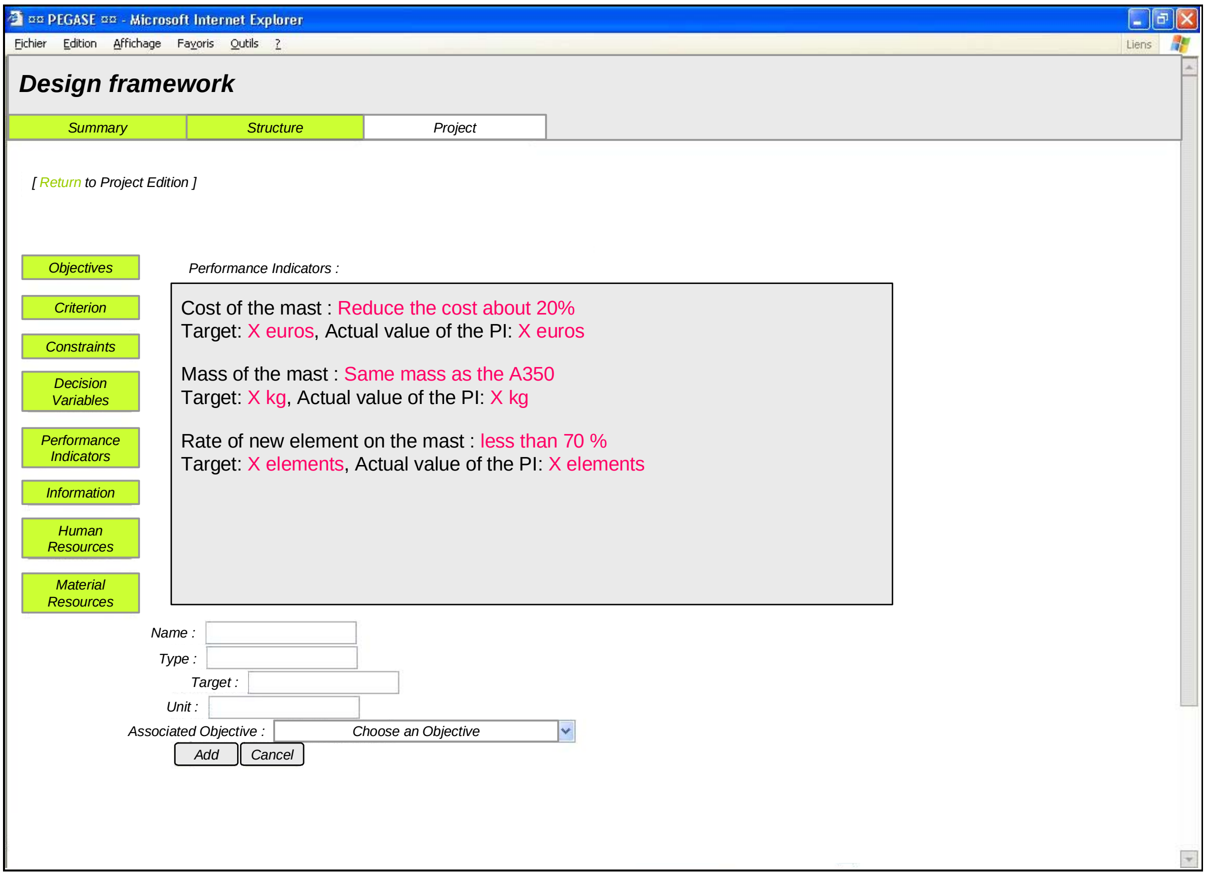

Figure 6. Example of Graphical User Interface dedicated to a project manager

The operational strategic level also concerns achievement of collaborative design activities between actors distributed in each plant. Each actor's task is defined and PEGASE provides to each one a set of contextualized information on a specific GUI about his context of work (human and material resources, distribution of these resources, objectives, constraints, influence of the others actors…). This decisional level provides tangible results on the product and information about collaboration that are capitalised and send to upper decisional levels by PEGASE. PEGASE permits to control collaborative activities by the mean of an integrated product-process-organization model, completed with a specific PMS to obtain a dynamic system for an effective integrated management of engineering design system and enterprise.

5 CONCLUSION

In this paper, we analyse the deployment strategy of an enterprise, and characterize this deployment according to the more or less significant changes implied by functional, organic and operational modifications. Then, we propose a global representation model of the decision-making system, which provides a framework to consider simultaneously the engineering of design system and enterprise. Such a representation allows to identify, on the one hand, the influence of the design system in the deployment strategy of the enterprise (PDCA cycle), and vice versa, and, on the other hand, the impact of the design system on the processes of the enterprise, and vice versa. An industrial case presents the use of the concepts by the mean of PEGASE, a prototype of software application.

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Contact: S. Sperandio
Université Bordeaux 1
Laboratoire IMS UMR CNRS 5218, département LAPS
351, cours de la libération
33405 TALENCE cedex
France
Phone: + 33 (0) 540 006 532
Fax: +33 (0) 540 006 644
E-mail: severine.sperandio@laps.ims-bordeaux.fr
URL: http://www.laps.u-bordeaux1.fr