Development of a Software Tool to Support System Lifecycle Management

V. ROBIN, S. BRUNEL, M. ZOLGHADRI, P. GIRARD

IMS Laboratory – LAPS department, UMR 5131 CNRS, University of Bordeaux,

351 cours de la Libération, 33405 Talence Cedex, France.

{vincent.robin ; stephane.brunel ; marc.zolghadri ; philippe.girard} @ims-bordeaux.fr

Abstract

In the extended enterprise context, many stakeholders act on the product during all its lifecycle. They influence the product development and managers have to be able to control all the activities and their interactions that are generating the different processes. They have also to manage each actor involved in the project during the product lifecycle. In this paper, propose an approach to identify, define and manage factors influencing product development. It is the System Lifecycle Management. PEGASE, a prototype of software to control design project, follow-up the system evolution and support decision-making, is also presented.

Keywords:

System Lifecycle Management, Strategic Design Process Management, Computer-Aided Engineering.

1 INTRODUCTION

In the extended enterprise context, many stakeholders act on the product during all its lifecycle. The notion of performance in product development not only concerns the product and the process but also the organization of actors and the system on the whole. Since the beginning of the development, managers have to encourage and favour collaboration between actors involved in the project. They have to manage design teams and existing networks but also to create new partnerships. These partnerships not only concern design process but also all the phases of the product lifecycle. In this paper, we focalised on the design phase management since it has many preponderant influences on the other phases of the product lifecycle. We are interested in the definition, the follow-up, the capitalization and the reuse of the performance inductors that could have an influence on the design performance. First, we study the PLM (Product Lifecycle Management) epicycle view to identify factors influencing product development and the information flows between them. Second, we propose a model to manage these factors and we focus on their description through out the system, from the actors to the enterprises network. Objective is to identify specific factors impacting the performance of each entity of the system. Finally, we present a prototype of software to control product development process and to support decision-making.

2 SYSTEM LIFECYCLE MANAGEMENT (SLM) IN THE EXTENDED ENTERPRISE CONTEXT

Co-ordination and control of design projects are part of a global approach for the new products/systems development that implies the need to identify the different situations occurring during the design process and the adequate resources to satisfy design objectives. The design situations are described by identifying components of the design activity and their relationships [1],[2]. In design project management, the control of the design process is defined as the understanding and the evaluation of these existing design situations to take decisions. These decisions will modify and improve the future process, according to design objectives given by customer specifications or the company strategy. In a nutshell, management of design projects is a decision-making problem to support designers in their activities and achieve an objective in a specific design context [3]. This context has an influence on the project and refers to the environment of the enterprise (society, subcontractors, market, supply chain, etc) and to its organization [4]. Influences of the context affect each entity of the organization. Sudarsan et al. [5] proposed a high level view of these influences in their adaptation of the epicycle diagram adapted from [6] (Figure 1). It explains the epicycle nature of PLM and characterizes the information flow pattern in any product lifecycle. The PLM epicycle current view emphasis that many kinds of information have to be considered and managed to ensure a coherent multi-level project management adapted to each decision-maker at each decision-level. In such a context, PLM support needs to connect the product design and analysis processes to the production and supply chain processes, including: product data management (PDM), component supplier management (CSM), enterprise resource planning (ERP), manufacturing execution systems (MES), customer relationship management (CRM), supply and planning management (SPM), and others that will undoubtedly follow [7]. Objective is to provide to each project manager a set of information representative of the real state of the system. All the data and the information have to be synchronized for each project in the organization to ensure coherence of the project management. Information has also to be continuously defined and characterized to permit an efficient decision-making during the progress of the project. It is possible only if all information flows, for each project are traced, analyzed and exploited to follow-up the design project. To identify and manage all these information flows, our approach was to developed a model centred on the design system (the system in which the product/system is designed) in order to analyse and describe them and to follow- up its evolution.
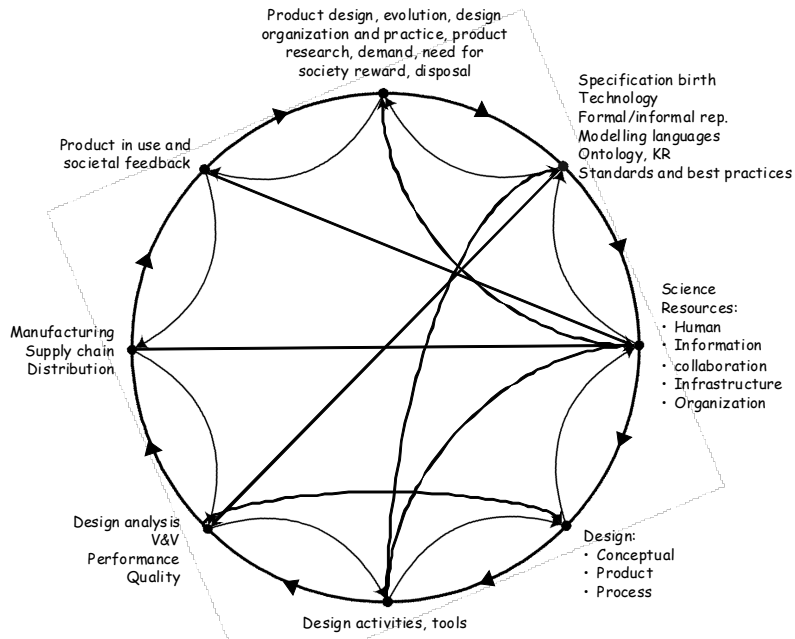
Figure 1: PLM epicycle current view

2.1 Design system modelling

During the IPPOP project [8], a model integrating Product, Process and Organization models (PPO model) has been developed [9]. We placed this PPO model in a more global context to describe and analyze the design system. This approach puts in evidence the global and local performance inductors influencing the design system. They have to be considered to follow and manage suitably the design system and the design process co-evolution. Global performance inductors are [4]:

- The technological factor that concerns the techno-physical environment (scientific and technological knowledge).

- The context in which the design process takes place. It includes natural, socio-cultural and econo-organizational environments (external and internal environments).

- Human and his different activities during design process (actor).

These factors influence the design process and the design system. All of them and their interactions are integrated in a model composed with a technological axis, an environment axis and an actor one (Figure 2). Then specific objectives, action levers and performance indicators, dedicated to the design system, have to be identified according to these elements. Interactions between these objectives, action levers and performance indicators have to be considered to supply pertinent information to decision-makers. These interactions are a composition of each element of the model and of relationships between them. The product, process and organizational models allow us to put in evidence and manage relationships between factors influencing performance of the product development [4] (Figure 2). These models are local performance inductors for design system and interactions between them provide a dynamic vision of the design system evolution. In this model, the description of factors influencing the design system, at each decision-making level provides a global vision of the design context. Hence, thanks to such a representation of the design context, the decision-maker can analyse the design situation and identify particularities of each project. He is able to observe evolution of each component (environment, technological and actor one), interactions between them and consequently adapt his project management method. He could also study the impact of one of his decision by simulating the possible evolution of the system. To make it possible the model must be completed with a methodology to follow-up the design system evolution and to evaluate design process.
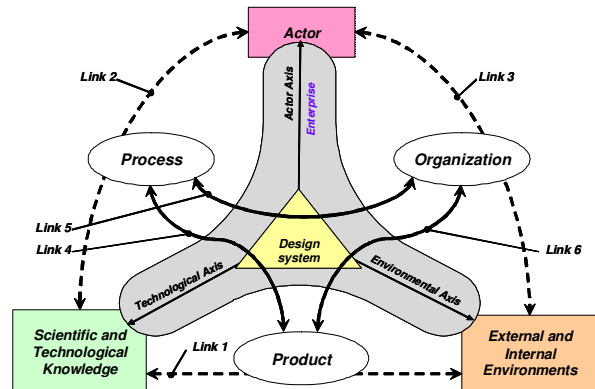

Figure 2: Design system modelling, factors influencing the design system [4]

2.2 A PLM epicycle mediated-view to manage design system and design process co-evolution

The global and local performance inductors influencing the design system have to be considered to follow and manage suitably the design system and design process co-evolution. Dynamic of the design system is provided by the evolution of these factors but also by their interactions. PPO model is used to put in evidence and manage these relationships. Sudarsan et al. [5] have proposed a model for the mediation of information flow across the activities of PLM thanks to a common set of ontological structure and information models to represent product and process: the NIST information-modelling framework. The PPO model completes NIST framework by considering simultaneously three models that have an influence on the design system. We could propose the PLM epicycle mediated-view in Figure 3.
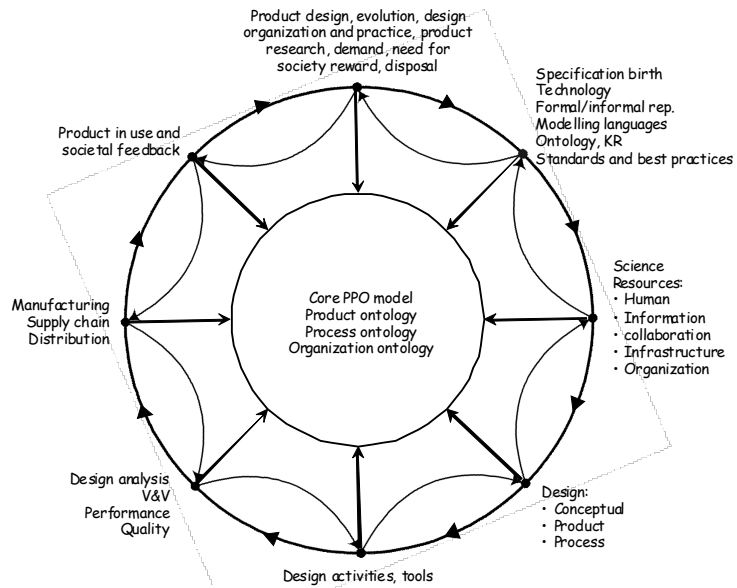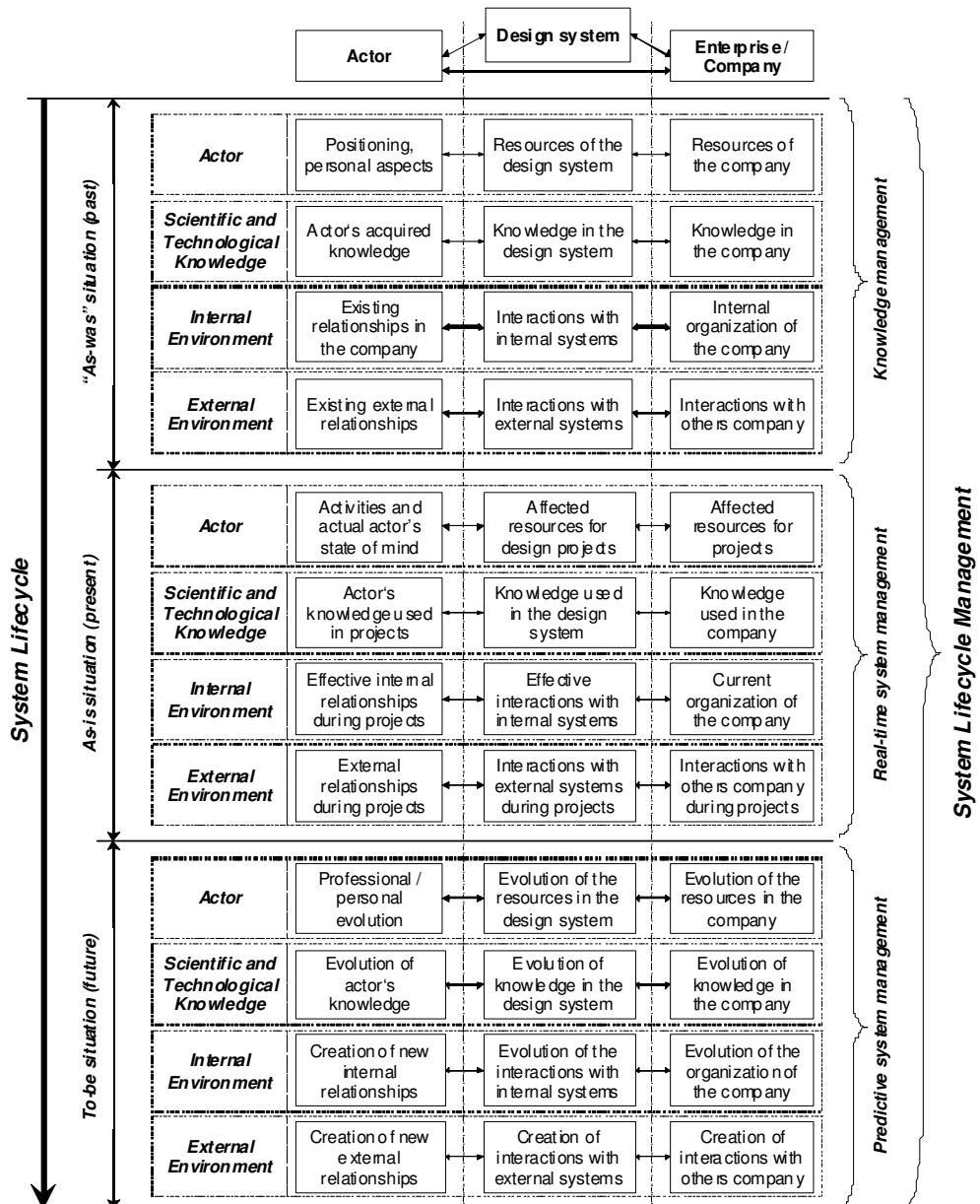
Figure 3: PLM epicycle-mediated view

Labels around Figure 3:
- Product design, evolution, design organization and practice, product research, demand, need for society reward, disposal
- Specification birth / Technology / Formal/informal rep. / Modelling languages / Ontology, KR / Standards and best practices
- Product in use and societal feedback
- Science / Resources: • Human • Information • collaboration • Infrastructure • Organization
- Core PPO model / Product ontology / Process ontology / Organization ontology
- Manufacturing / Supply chain / Distribution
- Design: • Conceptual • Product • Process
- Design analysis / V&V / Performance / Quality
- Design activities, tools

Figure 4: Global performance inductors influencing PD

		Actor	Design system	Enterprise/Company
"As-was" situation (past)	Actor	Positioning, personal aspects	Resources of the design system	Resources of the company
	Scientific and Technological Knowledge	Actor's acquired knowledge	Knowledge in the design system	Knowledge in the company
	Internal Environment	Existing relationships in the company	Interactions with internal systems	Internal organization of the company
	External Environment	Existing external relationships	Interactions with external systems	Interactions with others company
As-is situation (present)	Actor	Activities and actual actor's state of mind	Affected resources for design projects	Affected resources for projects
	Scientific and Technological Knowledge	Actor's knowledge used in projects	Knowledge used in the design system	Knowledge used in the company
	Internal Environment	Effective internal relationships during projects	Effective interactions with internal systems	Current organization of the company
	External Environment	External relationships during projects	Interactions with external systems during projects	Interactions with others company during projects
To-be situation (future)	Actor	Professional / personal evolution	Evolution of the resources in the design system	Evolution of the resources in the company
	Scientific and Technological Knowledge	Evolution of actor's knowledge	Evolution of knowledge in the design system	Evolution of knowledge in the company
	Internal Environment	Creation of new internal relationships	Evolution of the interactions with internal systems	Evolution of the organization of the company
	External Environment	Creation of new external relationships	Creation of interactions with external systems	Creation of interactions with others company

Left axis: System Lifecycle

Right-side labels (top to bottom): Knowledge management; Real-time system management; Predictive system management — System Lifecycle Management

The aim of our approach is to propose concepts, models and software tools to obtain an extended PLM support managing the global co-evolution of the product and the system. Our ambition is to work on the opportunity to make evolve models, approaches and tools from PLM to SLM (System Lifecycle Management). The SLM approach has to consider all the elements of the system influencing the product development (PD), their interactions and their co-evolution to establish the better context for decision-making. That obliges to have a modelling of the enterprise and of the network in which it has to evaluate. Objective is to capitalize and follow information about each entity of the system. This capitalization helps decision-makers to analyze and understand the as-is situation regarding to the capitalized information ("as-was" situation) and to evaluate the impact of its decisions by considering the possible evolution of the system (the to-be situation). The system could be described by defining the global and local performance inductors and their interactions. The description of the system according to different viewpoints allows obtaining a great number of information that has to be capitalized and dynamically managed [10]. Figure 4 presents a macroscopic description of the system regarding different viewpoints. This figure focuses on the global performance inductors and we have the same description for the local performance inductors [10]. Specification of all these elements permits the creation of a model of the system.

3 SOFTWARE TOOLS FOR SLM

According to the SLM concept and the PPO model, 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 [11], the design phase was based on concepts proposed by the creators of UML language [12]. This choice is justified by the fact that this method is very structured. Objective is to capitalize, manage and use information about the system and its evolution to support decision-making. PEGASE must answer is to ensure the connection between the structuring of the organization of the company relating to the creation and the control of a different kinds of projects. Information in the database has to be generic to offer the opportunity to help decision-makers in different situations. The detailed analysis of processes and of the mechanisms of decision-making throughout the product development allows identifying elements that have to be managed to control product development process (Figure 2). PEGASE has been developed to integrate and manage all these elements to ensure a coherent vision of the system (from a macroscopic vision (the network of enterprises) to a microscopic one (the actors of the projects)). The administrator of the system implements and configures the data base. The product development process has to be structured, planned and resources have to be allocated. This phase is realized by the projects managers. Finally, PEGASE controls project evolution by managing the realization of the designers' activities. It also helps managers to follow-up the project. In a nutshell, control of the product development

processes thanks to PEGASE results in several actions from the genesis of the projects to their closure:

- implementation and configuration of the data base,
- structuring and planning the projects and allocated resources:
  - o after a project was initialized and the objectives of the company were specified, the head of project structures his project to achieve his goals,
  - o he defines several sub-projects for which he specifies the objectives and the persons in charge (as local decision centres),
  - o he associates input technical data necessary to achieve the designers' goals, and output technical data corresponding to the achievement of these objectives,
  - o he defines a planning of the activities to be carried out and specifying their data and their objectives,
- realize the activities and follow-up the design projects:
  - o 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 PPO 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 and decisional flows and finally the follow-up of the projects are taken into account.

3.1 Implementation and configuration of the data base

Within the framework of GRAI R&D approach [13], 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 5). 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, services, stakeholders, etc.) and the corresponding decision centres and by connecting them between specifying information flows (Figure 5). The administrator configures information flows that will 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-making. Information and the information flows concern the data and links defined during the modelling of the system based on the macroscopic viewpoint on Figure 4.
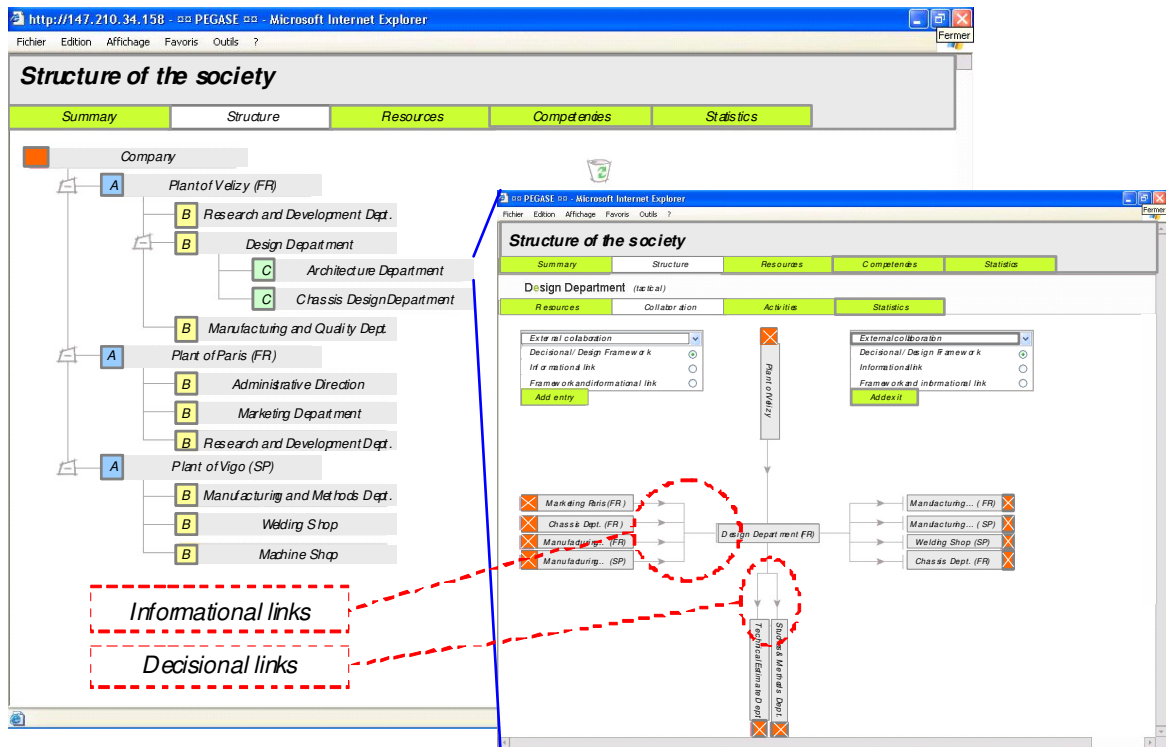
Figure 5: Graphical User Interface (GUI) defining functional structure and organization of the company
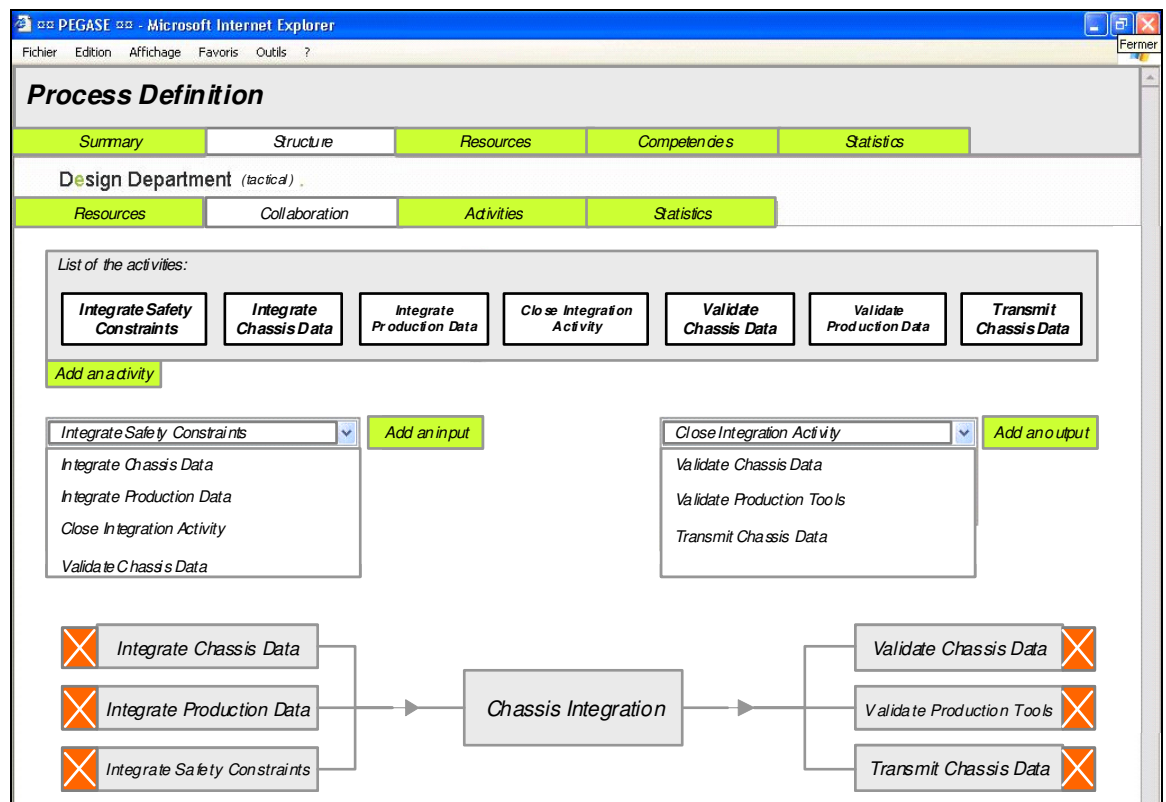

Figure 6: GUI for the processes definition (description of the sequences of activities)

The administrator deploys the processes modelled in the organization by associating to each decision centre the sequences of tasks (Figure 6). This process could be formalized according to the quality procedures of the company. When configuration is completed, PEGASE is operational. The administrator creates and initializes a project by sending the decision frame and associated design frameworks to the decision centres concerned in the organization. The administrator access also permits to define the whole of the resources: human, material and software. The knowledge and competencies of the actors are also managed. They could be specified according to competencies matrix of the company. Managing actors' competencies allows decision-makers to find and affected to specific tasks human resources during the design projects (Figure 7).
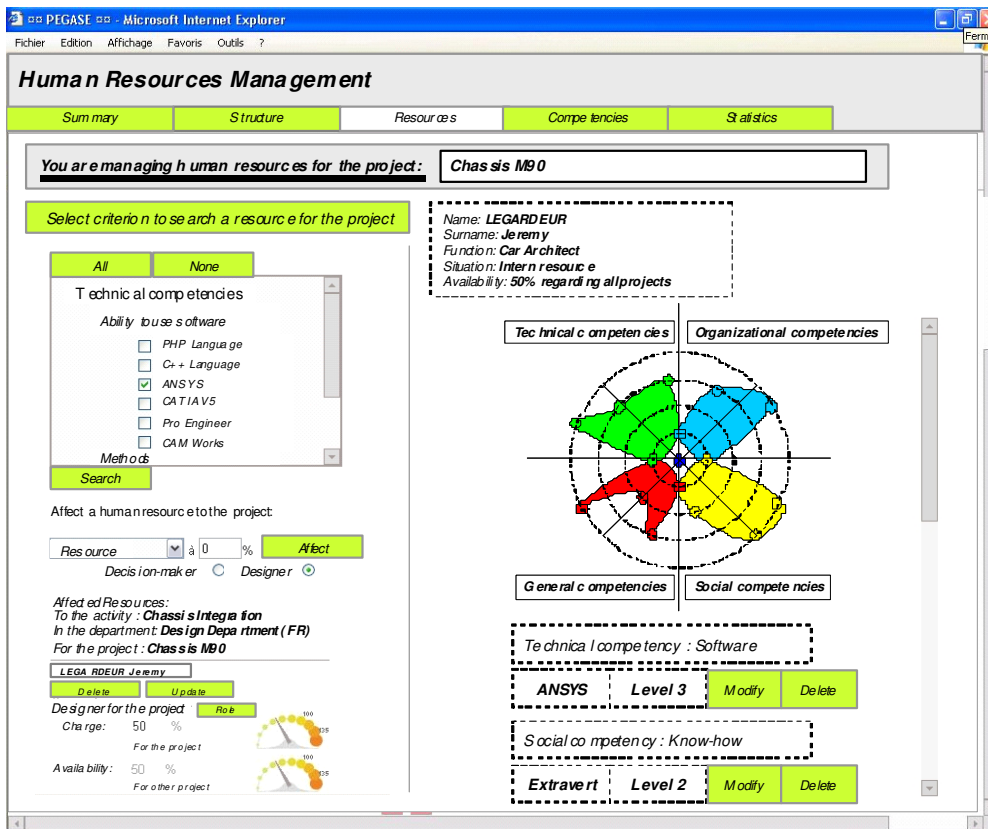
Figure 7: GUI presenting general information about an actor

3.2 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 or the design framework that is sent by the upper decisional level (Figure 8). 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 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. Project managers and the designers have the same GUI (Figure 8) to understand the context in which they must carry out their tasks. Difference is that project manager could create performance indicators and designer just could complete these indicators. They must, at the end of their task, indicate the values of the performance indicators.
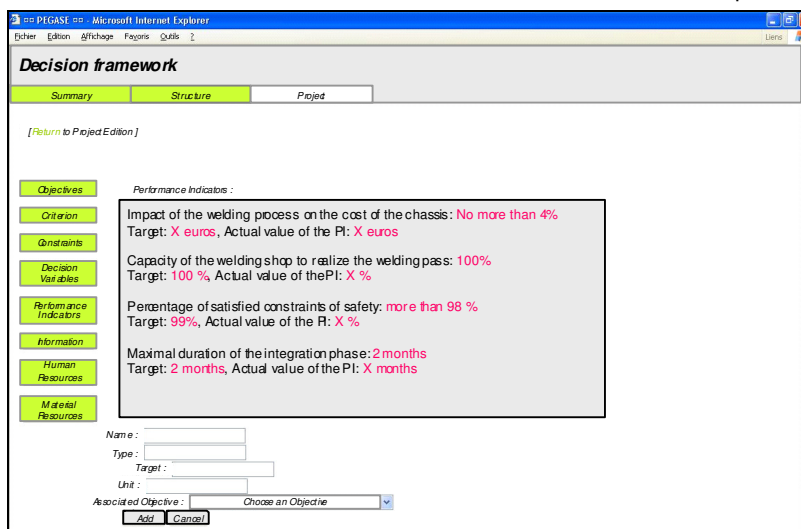

Figure 8: Dedicated actor's GUI to consult his decision frame

A PhD student is testing PEGASE in a real case study in the case of a partnership with LASCOM. LASCOM is a PLM / BPM solution developer. The company work on the validation of our approach by adapting some concepts developed in PEGASE in their PLM solution (named ADVITIUM).

3.3 Use of the data base to support decision-making

To offer new functionalities to decision-makers we are working on new concepts to make evolve PEGASE. Our objective is to combine information in the data base to allow decision-makers to obtain a particular representation of the system, the process or the actors. We have to treat and organize capitalized information of the data base of PEGASE to provide to decision-makers a set of information describing an element of the data base or a specific viewpoint about the system. This set of information could concern the product, the process or the organization (data of the PPO model), or elements of the system (data describing actor, environments or knowledge). According to this information, we propose to decision-makers scorecards describing the resources of the company, the tools used during the different activities and the knowledge. For the moment, this scorecard is a comparative scale (Figure 9).
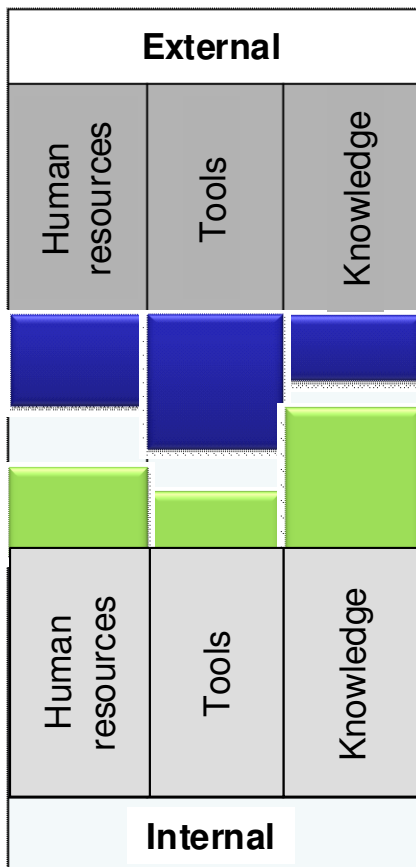

Figure 9: Comparative scale

Such a comparative scale provides to decision-makers information about the positioning of the company, the design system or the actor (depending on the adopted degree of analysis) and contributes to:

- Know "what my company / design system or an actor is able to do (internal point of view)": "I know what I know and what I am able to do".

- Identify "what I can not do even though other company can do it (external point of view)": "I know what I can not do and I know who can do that".

- Put in evidence the possible difficulties by defining "what I cannot do and to find solutions to provide me information about this lack of knowledge": "I know what I cannot do but I don't know who is able to do that".

- Help decision-maker by providing information about possible solutions to solve a problem (internal or external solution, tools, and resources).

The gap between the internal and external viewpoints in the representation (white part in figure 9) corresponds to the position "I don't know that I don't know". The gap emphasis that this scale is opened and could always evolves.

From now on, to create this comparative scale we correlate information about:

- The actor: who possesses information or data about the element and what is the state of his relationship in its environment? We are able to identify if an actor (internal or external actor, department of the company, etc) possesses the information and what he is doing in the system.

- The supports of the information: what are the objects that permit to "make it real" and to "use" and "reuse" it? To create interactions or collaborations between actors, we have to specify the objects and supports that favour exchanges and the share of information. That could make appear interoperability problems.

- The knowledge: what are the theories that fund existence of the information about the element? Objective is to precisely define the information.

Far from the comparative scale, we are also able to make appear organization of the data and of the information. It possible because we capitalize the way the information is used during an activity, a "map" of the knowledge in the company and of the actors' abilities. This capitalization allows us to obtain a set of information about the different entities describing actors, knowledge and support of the information. Product, process and organizational models are aggregation of some of these entities.

For instance, Figure 10 presents a partial view of the entities and of their organization that have been capitalized during the design process of a bike. The box on the left of the figure is an aggregated vision of the product model of the bike. It is composed with some ball bearings and we have theoretical elements in relation with theses elements. We have also a box to identify the resource which is able to design the product or a part of the product. Specific knowledge, exchanges and collaborations between actors, and actors' abilities or capabilities could be also put in evidence, All these information are capitalized during the system evolution. This example shows that such a representation could provide information about each entity of a product. The entity could be decomposed, linked with other ones and resources which are able to work on the product or share information about it are identified too.
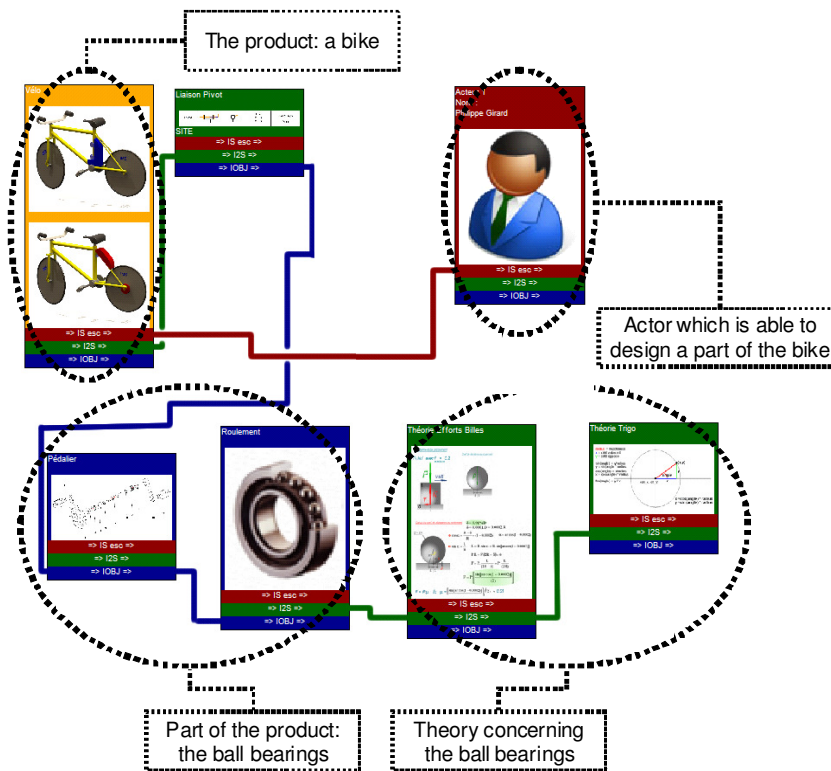
Figure 10: Partial representation of information about a bike

4 CONCLUSION

During the product lifecycle a great number of information concerning the product, the process and the organization is created and evolves. Furthermore, the system and its environment also evolve and information about it too. Our objective is to catch information about these evolutions and to capitalize them if it necessary. From now on, much information is capitalized thanks to PEGASE but many evolutions are not considered and the database has to be frequently manually updated. Procedures to automatically capitalize some evolutions are not well established for the moment and have to be studied and integrated in our software. Despite the fact the database does not evolve quickly, it could be used by decision-maker to analyse the situation of the system. Our propositions permit an analysis of this situation by capitalizing information about the company, the design system and the actor and their context of evolution. The comparative scale provides a vision of what the company is able to do or not. Our approach and our prototype of software help decision-makers to analyse the as-is situation and formalize their strategies.

5 REFERENCES

[1] O'Donnell F.J.O., Duffy A.H.B., 1999, Modelling product development performance, International Conference on Engineering Design, ICED 99, Munich, Germany.

[2] Chen H.H, Kang H.Y., Xing X., Lee A.H.I. and Tong Y., 2008, Developing new products with knowledge management methods and process development management in a network, Computers in Industry, vol.59, pp.242–253.

[3] Girard, Ph., Doumeingts, G., 2004, Modelling of the engineering design system to improve performance, Computers & Industrial Engineering, vol.46, n°.1, pp.43-67.

[4] Robin V., Rose B. and Girard P., 2007, Modelling collaborative knowledge to support engineering design project manager, Computers in Industry, vol. 58-2, pp 188-198.

[5] Sudarsan R., Fenves S. J., Sriram R.D., Wang F., 2005, A product information modelling framework for product life cycle management, Computer-Aided Design, vol. 37, n°13, pp. 1399-1411.

[6] Lederberg J., 1990, The excitement and fascination of science: reflections by eminent scientists, vol. 3, Part 1: Annual Reviews, Inc.

[7] Sudarsan R., Subrahmanian E., Bouras A., Fenves S.J., Foufou S. and Sriram R.D., 2007, Information sharing and exchange in the context of product lifecycle management: Role of standards, Computer Aided Design, doi:10.1016/j.cad.2007.06.012.

[8] IPPOP (Integration of Product, Process and Organisation for engineering Performance Improvement) is a french RNTL network project labelled by the French Ministry of Economy, Finances and Industry More information on http://ippop.laps.u-bordeaux1.fr/

[9] Robin V., Girard Ph., 2008, An integrated product-process-organization model to manage design system, International Journal of Product Development, accepted, to be published.

[10] Robin V., Sperandio S., Topliceanu G. and Girard P., 2008, Managing product design by considering evolution of design context: from Product Lifecycle Management (PLM) to System Lifecycle Management (SLM), Proceedings of the 5th International Conference on Product Lifecycle Management, Seoul, Republic of Korea.

[11] Morlay C., 2001, Gestion d'un projet système d'information – Principes techniques mise en œuvre et outils. Edn Dunod.

[12] Quatrani T., 2000, Modélisation UML sous Rational Rose, Edn Eyrolles.

[13] Girard P., Merlo C., 2003, GRAI-engineering methodology for design performance improvement, Proceedings of the International Conference on Engineering Design, Stockholm, Sweden.