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TOWARDS PLM IMPLEMENTATION METHOD IN SME

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1 Introduction

Ensuring the co-ordination of the whole development of a new product is a challenge for managers at the different levels of such kind of projects, especially for SMEs (Small and Medium Enterprise) [1]. PLM (Product Life cycle Management) systems support product data management and for the company the main stake is the integration of such a system. In [2] a UML (Unified Modelling Language) based specification method has been proposed for implementing of product structure and workflow into such systems. The aim of this paper is to apply this UML based specification method into an SME and to assess the introduction of a project management point of view within a PLM system. The first section of the paper briefly presents the UML based specification method and the PLM system integration project in an SME. The second section deals with the description of the resulting specifications. The third section details the carried out implementation within Windchill™ PLM system from PTC (Parametric Technology Corporation). This section ends on a critical analysis of Windchill™ implementation regarding product data management and project data management.

2 Research and industrial context

Nowadays, companies are focused on continuous product innovation and process improvement in order to reduce the time to market and to decrease the development costs. Managers must take into account the mapping between industrial needs in product development process management and available functionalities of PLM systems. A PLM system manages and stores product data and related documents according to the design, manufacturing and support phases of the product development process. Many others functionalities are available in order to take into account specific needs or viewpoints from the whole company (e.g. classification, integrated views of the Bill of Material, etc.) or to integrate project management functionalities [3].

2.1 Overview of UML-based specification method

In [2] the added value of a UML approach is presented. First, it provides a modelling notation for specifying the product breakdown structure with related product data [4]. Second, it provides an efficient language for modelling generic workflow [5] with activities and transition criteria before their implementation in a workflow engine. Third, because it is object oriented, UML provides a set of diagrams which can associate objects which are not

usually linkable. These diagrams allow for the modelling of the entire system. The UML-based specification method is composed of the following steps:

- First step: Organisation and roles clarification

Basically, the tasks of each person involved in the product development process must be identified and the various kind of user needs have to be clarified. This work is carried out through several interviews of engineering design and production engineering team members: designers, production engineers, project leader, etc. The method used for this work is based on a classical BPR (Business Process Re-engineering) approach. At this stage use case diagrams are specified in order to formalise needs and to describe interactions with the future PDM system implementation and then to specify the required functionalities. These diagrams characterise each kind of user (i.e. each role) and the main tasks that they have to carry out during the product development process (i.e. the use cases).

- Second step: Product data modelling

Product data to be managed are described within class diagrams that allow for the characterisation of attributes, operations and links with other data. A class diagram of the product structure provides not only static information, but also evolution rules or methods and information about metadata. Product data change can be represented by state-transition diagrams which describe the data life cycle and main operations. For example the state-transition diagram of a document clearly shows the various levels and states of a document and its rules of evolution.

- Third step: Process data modelling

Product development processes are characterised by activity diagrams where dynamic and time criteria are handled. An activity diagram can also describe more clearly the process controlling the change of product data. As it does not represent the structure of the future system, an activity diagram is generic and describes at a global level the product development process as well as product data-oriented processes. This modelling concerns workflow characterisation. In this paper we extend this modelling to the project management modelling.

UML diagrams can be used as relevant tools for describing the link between the object of the system and the data of the company. It is useful for the specification and implementation steps and it avoids iterations with users. For many people, the UML structured notation is used as a common language providing a shared point of view between users and PDM implementers.

2.2 Business case study

We carried out a case study for an SME named Ederena which developed in the 90s an innovative manufacturing process concerning structures using honeycomb sub-assemblies. This new technology confers lightness and significant vibration absorption on products whilst maintaining the same rigidity as steel. The company reached new markets and has strongly grown during last years. So it is involved in an organisational change period in order to rationalise its information flows, which is the main objective of our study. Its main objective is to reorganise itself and to manage its growth by rationalising its product development process [1]. A workgroup composed of a researcher, the head manager, the quality manager, the technical department responsible, designers and manufacturers has led this study to define a new product development environment and to implement a PLM prototype. A first phase of business process re-engineering was composed of the following steps:

- Improvement of the organisational structure:

The organisational structure of the company is re-defined in order to support the further work on the project process and product data management. This definition, as illustrated in figure 1, is separated into three sub-steps: definition of the departments' function, identification of each actor's generic roles, and definition of desired project management context. The goal of this context is to identify the operational responsibilities and roles that will be used throughout the design project.

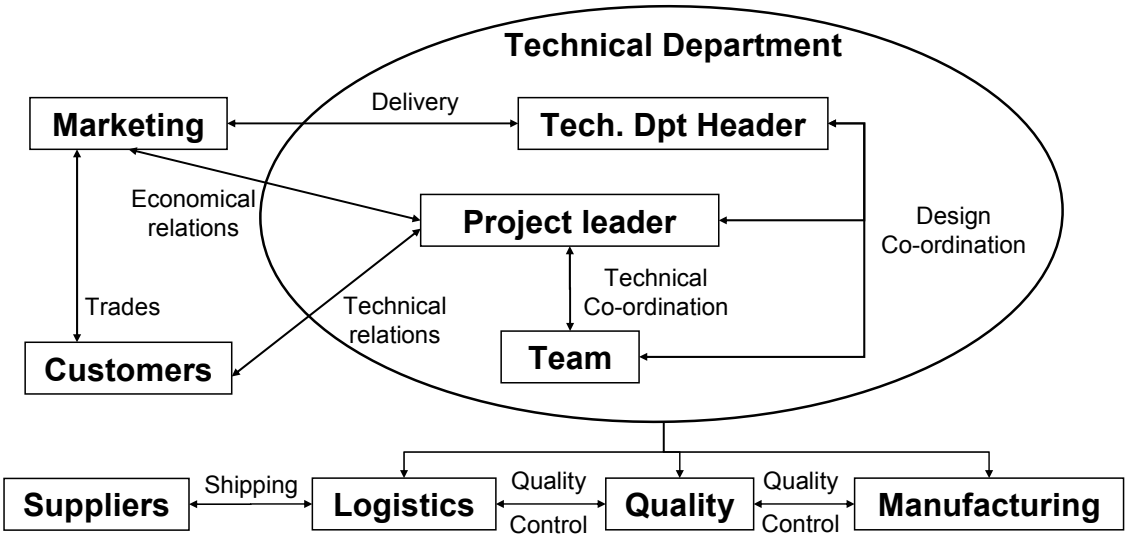

Figure 1. Organisational structure of the technical department

- Formalisation of new project process:

First the main phases of the project development process are defined based on the product life cycle phases: "feasibility", "design and manufacture definition", "prototype manufacturing", "production", and "obsolete", as shown in figure 2. Then for each phase are defined the sequence of the main tasks and milestones that control the progress of the whole product development. This representation is followed by the characterisation of each task and milestone to detail who is involved, which documents are used and produced, and what decisions are taken for milestones.

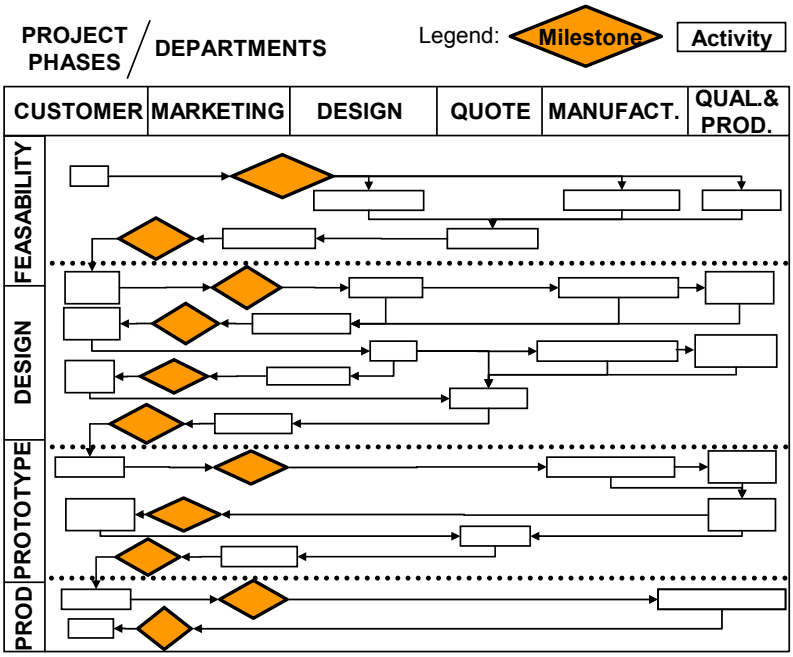

Figure 2. Overview of the product development process

- Identification of existing product data:

The management of information flow is necessary to manage the new structure of projects. We defined each task of the design process with incoming and outgoing information, the associated resources and the associated methods of control. We describe the physical or numerical supports and the transformation of each kind of information. The obtained results are analysed in order to propose some improvements concerning the consistency of product data and information chosen and to be implemented in the future information system.

The next section describes the UML-based specifications for the implementation of a PLM system resulting from this first analysis phase.

3 UML-based specifications of Ederena

Within the SME the integration of a PLM system follows the UML-based specifications [2] but requires some specific actions. As Windchill™ ProjectLink is document-oriented, we have to isolate each document, identify those that are necessary for the design process, and characterise all the users and activities that are linked to them. From previous work roles and users are defined as well as the necessary document life cycles and workflow are formalised. [2] already introduced these diagrams and their interest. As Ederena needs controlling its product development process at a global level we specify also the project management needs in order to evaluate the project functionalities of Windchill™ ProjectLink.

3.1 Organisation and role specification

For each department we define the main roles in order to carry out the different tasks and each role is linked to employees' names. We identify (figure 1) the "technical department" header, the project leader and the designers from the technical department, but also the marketing

role, the quality role, the manufacturing role and the logistics role. Use case diagrams are defined to characterise the tasks and access rights of each role. For example the marketing role is able: to have a read access on all product data from a project; to validate some documents at specified milestones, and to produce specific documents.

3.2 Product Data structuring

In the case of the considered SME the management of the design process is achieved through the control of clearly identified documents at several stages of the design process. As a consequence the modelling of product structure is not useful: this structure is already defined in the CAD system. CAD objects are then considered as documents. So the resulting class diagram models the document structure, i.e. each document template depending on their life cycle, and its respective location (figure 3). It represents also the links between the documents and the tasks in the product development process, the responsibility assigned to roles, and the manner of validation of each document through milestones through state-transition diagrams.

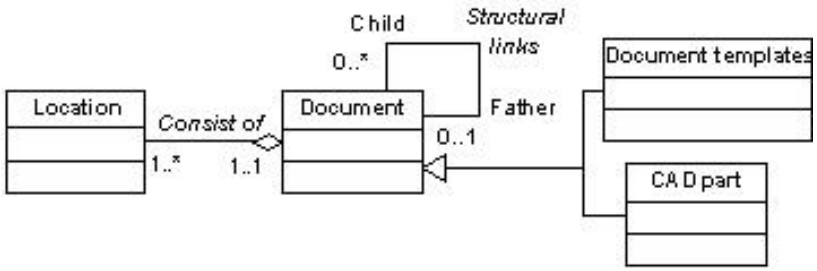

Figure 3. Overview of the product development process

3.3 Product development workflow specification

Class diagram and state-transition diagrams are compared to previous detailed design process to characterise the various tasks that manages each document template life cycle. Activity diagrams are then defined for each document template to specify workflow that will be implemented into the PLM system (see figure 7).

3.4 Project management specification

Previous activity diagrams represent document-oriented processes and do not allow the project manager to perform the management of the design process. They must be co-ordinated at the project level and we extend the study to the management of the project process at a global level. [6] suggest that task management, scheduling, and planning, together with resource management are the most important issues when it comes to operational co-ordination. We propose to formalise human-oriented processes using activity diagrams at a global level (as shown on figure 2) and sequence diagrams when detailed sub-processes are necessary. For example we formalise project manager tasks at several steps of the design process. Figure 4 represents project manager tasks when scheduling the design process for the CNI ("Customer Needs Identification") task then milestone which are the first tasks of the predefined product development process. It shows that a task is necessary linked to input and output information (product data or documents) and to a trigger (mainly project manager's action or specific information state). In the considered SME milestones are meeting reviews where a phase composed of several tasks is validated before starting a new phase. Generally

specific documents produced during the previous phase are analysed before project and/or technical decisions are made.

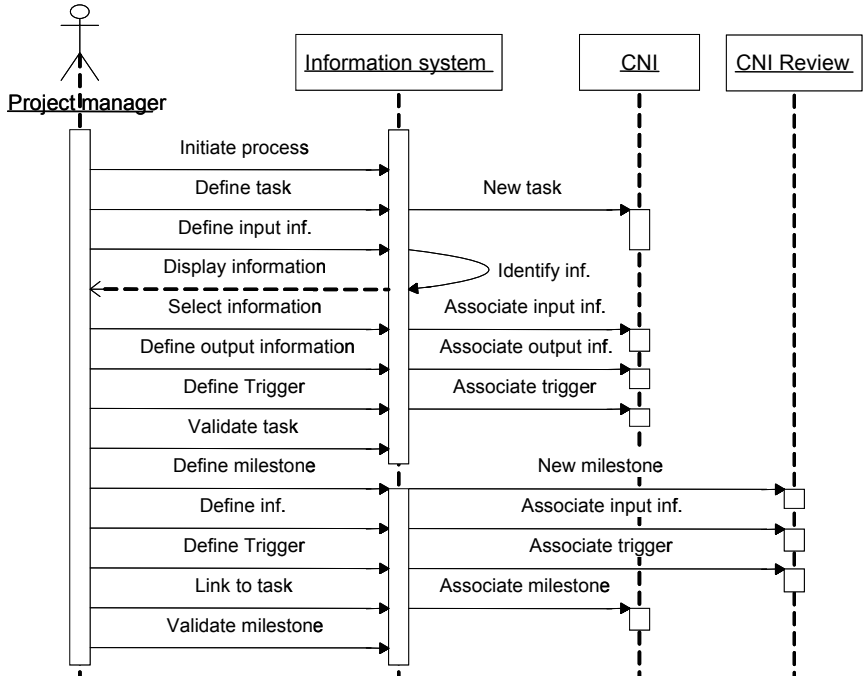

Figure 4. Process scheduling by project manager: sequence diagram

Such diagrams allow identifying the necessary concepts for the SME to manage its design projects. The most recent works demonstrate that it is necessary to integrate product, process and organisation points of view in order to control the performance of engineering design. [7], then [8] propose such an integrated model that we must fit with the SME company needs in order to allow project manager to control their design process. Figure 5 synthesises these concepts by extending the UML class diagram. The project manager is able to formalise the organisation of the design system of the company, characterised by departments, functions and actors (as human resources), represented in grey box. At that time human resources are characterised by a skill attribute before a real competencies management.

At the beginning of an Ederena project, the project manager uses the organisation in order to define the team (functions and selected human resources) of the project (design process). During the project he realises a schedule based on “process elements” sequences (tasks or milestones) allowing sub-sequences. For each process element, he/she has to select the right person according to the objectives, constraints, criteria and performance indicators that will be used later for controlling the project progress. For milestones he/she must keep a trace of taken decisions: he/she will be able first to improve the decisions he/she has to take, which are often based on informal information or experience. Second he/she will be able to introduce flexibility in the predefined global design process by formalising explicitly constraints, criteria and indicators. Finally he/she will be able to capitalise project information and decisions to improve his own skills as he/she is a recent recruited engineer.

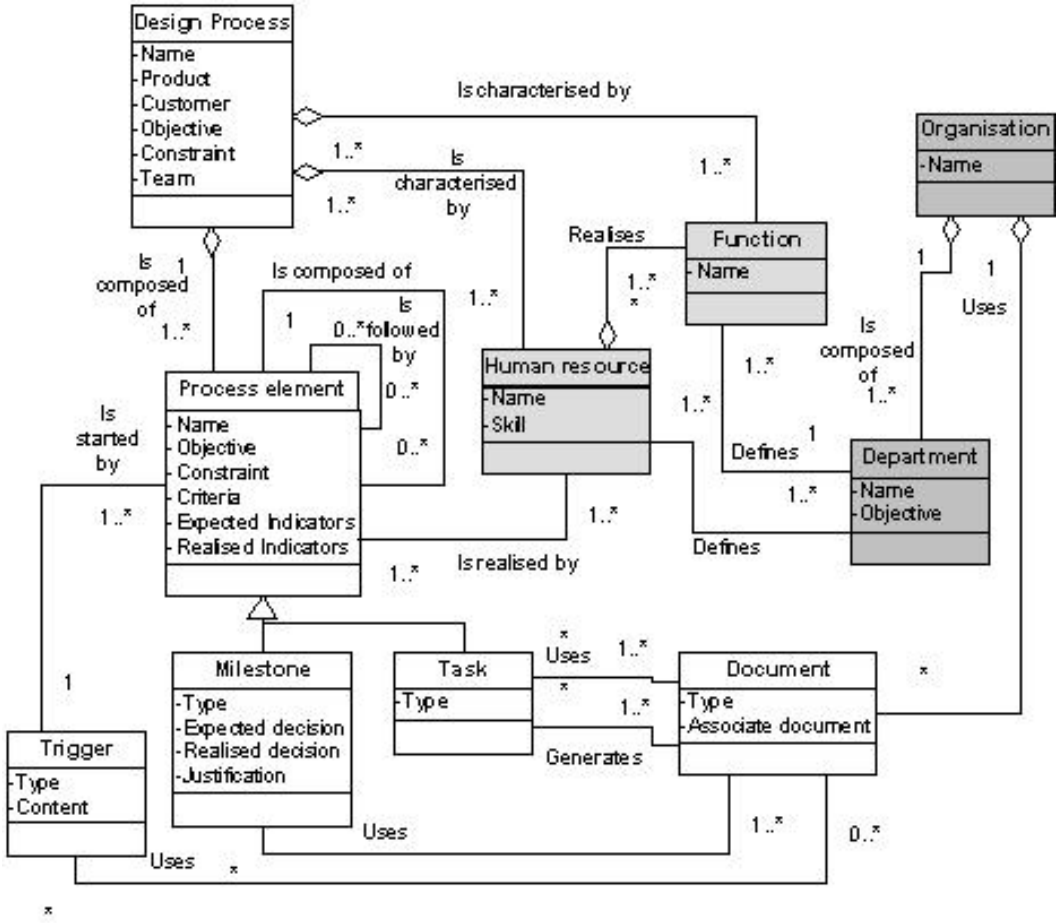

Figure 5. Conceptual model for project co-ordination

Such a model must be implemented and tested in order to validate its appropriateness with the SME way of product development process management. The next part details the implementation of the proposed model using ProjectLink.

4 PLM implementation

Previous specifications are introduced into Windchill™ ProjectLink. A "project" (i.e. design process) is a concept that allows managing documents and parts in a traditional way, by defining a team, i.e. "roles" and "users". So a project is created in order to define all required implementation. The specified roles, corresponding rights and users involved in the product development from all departments are implemented into the project team.

4.1 Product data management implementation

ProjectLink allows defining "document types" to manage standard workflow and life cycles, and also standard "document models". Necessary predefined documents are stored into a folder structure that is the main view of the future users (figure 6): "department" folders contain internal documents linked to the developed product and general folders describe the product data to be shared (document, CAD files and product configuration). The whole configuration is stored as a "product development model" in order to become a generic

configuration. By applying it, document types or models can be instantiated when required by actors such as the design report document.

Figure 6. Information structuring within Windchill™

Within this prototype product data and associated documents are structured and managed in order to control their evolution through versioning and their sharing. This is the main objective expressed by the company.

Life cycles and workflow are implemented for each "document type". As an example the following figure represents the validation process of the "design report" document which synthesises all technical studies of the product. First the author achieves the "wait for validation" task. Then is started the agreement of the "technical department" manager. This is followed by three validation tasks from the quality manager, the project leader and the manufacturing manager. Back loops are defined if validations are rejected. If all validations are accepted then notifications are sent to marketing department for the customer and to the "technical department" manager. Adequate change state tasks are introduced when required.

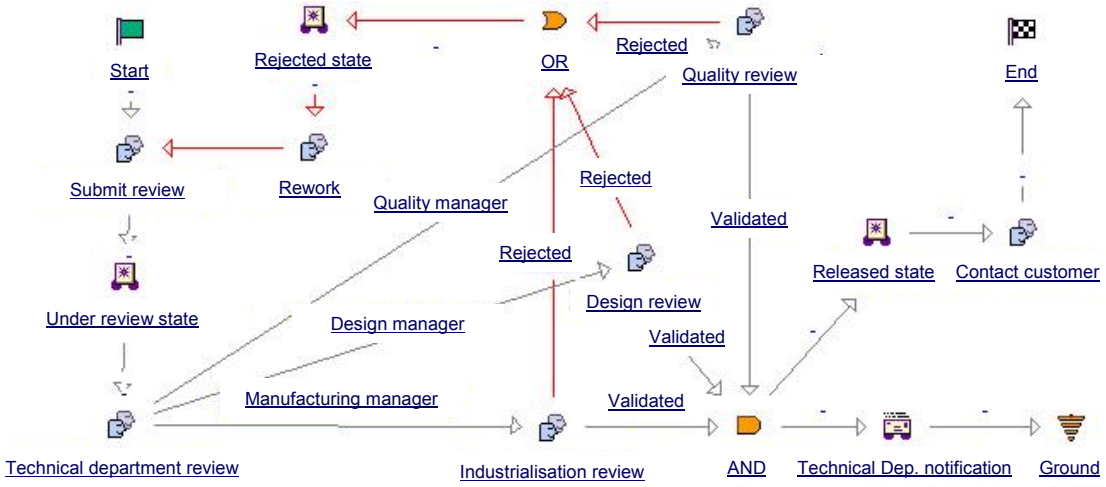

Figure 7. Workflow for "design report" document

4.2 Synthesis of product data management implementation

This configuration has been presented and evaluated with our industrial partner. The first result of this prototype is that the management of information is centralised and standardised according to well-defined quality procedures. The company is then able to control its information flow: important information is predefined and is completed during the process; product information is shared by the different stakeholders.

Nevertheless, within this prototype the control of the information flow still depends on human actions. For example even if each document evolution is managed, the project manager is not able to define through the PLM system when one document has to be generated. This means that he/she does not have a global and anticipated view of the project: product data are not correlated to a global design process, as defined in figure 2. We must consider in the next part this project dimension to improve the way that the company rationalises and controls its product development process.

4.3 Project management implementation

Within ProjectLink a "project planning" can be defined and is composed of "summary activities" i.e. activities containing other activities, "activities" i.e. basic activities and "milestones". The two types of activities can be correlated to our task concept, as defined into UML activity diagrams or sequence diagrams. An "activity" can be associated to a "deliverable" (i.e. an output methodological or information resource). A milestone can also be linked to a "deliverable". Considering these limitations we implement our model to manage a standard SME project.

The project planning (figure 8) is implemented to represent the product development process as introduced in figure 2: phases / "summary activities", tasks / "activities" and milestones. The divergent links between tasks are represented by using predecessor's concept, but convergent links cannot be defined.

Plan	Status	Done	Start	Dur.	Finish
Project Start			21 oct. 2004	0	21 oct. 2004
Feasability		91%	21 oct. 2004	264	25 oct. 2005
Customer Needs	✓	100%	21 oct. 2004	3	25 oct. 2004
CN Review	✓	100%	25 oct. 2005	1	25 oct. 2005
Feasability study		90%	26 oct. 2004	30	6 déc. 2004
Commercial offer	✓	100%	7 déc. 2004	4	10 déc. 2004
Design study	✓	100%	6 déc. 2004	20	7 janv. 2005
Prototype	✓	100%	7 janv. 2005	8	19 janv. 2005
Production		50%	20 janv. 2005	15	9 févr. 2005

Figure 8. Project planning within Windchill™

Deliverables are associated to each needed activity or milestone. It allows the project manager for controlling specific document-oriented workflows by defining deadlines for the corresponding deliverables: that means that the complete achievement of a document workflow is controlled by this deadline. To control the way that users work (before the deadline), he/she must define basic tasks with a detailed description of objectives, expected

actions and document production or modifications. By this way previous product data view is correlated to this project implementation by associating main documents as deliverables.

When controlling the project progress, the project manager may control tasks end date then task status and its level of realisation. Finally he may modify project plan.

Other optional functionalities of this PLM system are integrated to the prototype in order to facilitate actors' collaboration: for example a document viewer (CAD and office documents) allowing mark-up, document subscriptions that the project manager uses to control specific events, or technical forums to trace exchanges between actors.

4.4 Synthesis of project data management and discussion

First of all this prototype brings three important results to the company. First, people can view and handle the new structure of product development process in order to understand what is the interest of such an organisation, what role will have the project manager… Second, people can evaluate the level of interest of a PLM system to improve their information flow especially in the control of their design projects. At a global level the prototype seems to answer to the needs of the company and especially for information structuring and management. It materialises shared concepts such as roles or formalised process through a single environment useable by everyone. Third this implementation allows validating previous formalised models by main company stakeholders. Experiments based on product data creation, corresponding life cycle operations and project tasks management lead to a practical feedback of the SME ideal design process achievement. As a consequence improvements are brought to the models then to their implementation.

Nevertheless the project implementation reveals strong limitations if correlated in detail with the proposed model. Obvious limitations concern: actors and skills management, triggering events but also capitalisation of the planned/performed/modified process. Task concept implementation is too limitative: defining input and output information is impossible, except with deliverables; the decisional elements cannot be formalised. The proposed attributes of a process element, task or milestone, do not exist and the proposed status and level of achievement attributes are a restrictive concept to represent performance indicators. At the whole project level, its structure is too sequential. Convergent links between tasks are not possible. Moreover alternative tasks sequences do not exist while it is possible in a workflow.

This last point highlights the necessary flexibility of a design process into an SME, especially in this case study where innovation is a constant concern. In an SME the formalisation of the organisation is a critical point for the optimal management of resources. If the process is predefined at a global level, actors from all departments work daily in a context of "mutual fit" and this organisational aspect is rather incompatible with PLM capacities. When establishing specifications in an SME it is an important issue to identify what must be really controlled and so predefined through a workflow, and what must be encouraged and not detailed. For example collaboration between actors cannot really be defined through existing project plan or workflow concepts. The co-operation processes are quite unstructured and the confrontation of the various project teams' points of view leads to informal and unofficial information exchanges [9]. The management of the product development processes requires greater flexibility in the activities [10] and the project-oriented approach must be improved for a stronger link with document-oriented flexibilities and for a more complete implementation of the proposed model for project co-ordination. So we focus now our work

on flexible workflows linked together to structure the whole design process. We intend to extend existing concepts by customising Windchill™ database in order to implement directly our proposed model.

Considering the UML-based specification, its use into a SEM company shows that product structure may not always be an important issue. In this case a document structure fits better to the company working procedures. A second significant issue concerns the process modelling using activity diagrams and sequence diagrams. Such diagrams can be used to describe both the global project process and detailed document-oriented workflows.

5 Conclusion

A PLM system is a complex system and its implementation can be modelled and specified based on a structured notation such as the Unified Modelling Language. PLM systems provide a single and secured storage for documents (CAD or MS-Office, etc.) linked with product structure and workflow. The analysis of the product development process has highlighted the need for more global flexible tools for the project process modelling and instantiation. This study is achieved with an SME developing products based on innovative materials and processes. Using Windchill™ ProjectLink for prototyping we first demonstrate the interest of such a point of view for managing product data and co-ordinating document-oriented flows. To improve design coordination at a global level, we propose an integrated model that takes into account organisation, process and product information dimensions for an SME context. We then demonstrate that Windchill™ ProjectLink is not able to implement this model adequately even if most concepts are shared at a global level. This point leads us to define future work concerning deeper PLM customisation and the study of multi-level flexible workflow in order to control the whole design process.

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