INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07
28 - 31 AUGUST 2007, CITE DES SCIENCES ET DE L'INDUSTRIE, PARIS, FRANCE

FROM COLLABORATIVE PRACTICES ANALYSIS TO IMPROVEMENTS IN THE DEFINITION OF PDM WORKFLOWS

Christophe Merlo[1,2], Guillaume Pol[1,3], Graham Jared[3] and Jérémy Legardeur[1,2]
[1]ESTIA / LIPSI, France
[2]Bordeaux 1 University / IMS - LAPS/GRAI, France
[3]Cranfield University / SIMS, UK

ABSTRACT
Design co-ordination implies task management, scheduling, planning, and resource management. Human factors have a major influence on these points. Thus analysing collaborative practices used in the product development process can bring useful improvements in co-ordinating the design process. Our final research goal is to help project managers in their co-ordination tasks by taking into account the impact of collaboration on the design process. The scope of this paper is restricted to the improvements in design processes implemented through PDM (Product Data Management) workflows. We first propose an integrated method based on the use of a tool called CoCa which enables tracking of collaborative events in design projects. This method includes the analysis of the events recorded and the identification of detailed design sub-processes that specify flexible workflows for PDM systems. A case study carried out in a SME illustrates the method.

Keywords: Collaboration, design process management, PLM systems, workflows

1 INTRODUCTION
In the worldwide competition between companies, the development of new products has become a challenge where innovation and coordination of design processes are two main keys for success, especially in SMEs [1]. Design projects depend on the ability to co-ordinate the design process and to control the collaboration between the numerous actors participating in such projects: e.g. designers, experts from different disciplines and with different experiences or external partners. Co-ordination and control of engineering design are part of a global approach to the development of new products which implies the need to identify the different situations occurring during the design process.
Many studies have tried to identify the best practices and strategies developed by enterprises [2] [3] to improve the development of new products taking into account environmental challenges, market and customer characteristics, marketing process, product characteristics, new product development process, organizational characteristics and corporate culture, learning practices, and performance.
A project manager now has a wide range of criteria in order to control all aspects of a project such as the product development steps, objectives and results, tasks and scheduling, resources, expert skills, actors' network, levels of interest, collaborative guidelines, and heterogeneous collective and individual objectives. On the one hand [4] suggest that task management, scheduling, planning, and resource management are the most important issues when it comes to operational coordination. Clearly, a project manager intends to apply these aspects to control the design process. On the other hand, collaboration between designers [5] [6] offers the possibility of sharing specialist knowledge and capabilities. For the project manager, anticipating collaboration is difficult to take into account in the every day life of a project. The main problem is that of proposing to design actors the best context as possible (e.g. objectives, information, resources, tools, methods) in order to foster collaboration that will facilitate reaching project objectives. So analysing collaborative practices used in the product development process can bring useful improvements for co-ordinating the design process.
Our final research goal is to help project managers in their co-ordination tasks to take into account the impact of collaboration onto the design process. The scope of this paper is restricted to the improvements that collaboration analysis can bring to PDM workflow modelling in the context of an

SME flexible design process. In a first section co-ordination and collaboration are discussed and correlated to PDM systems implementation. Section two proposes a method then a tool for analysing collaboration and applying the results for PDM systems implementation. Finally in third section examples from an SME case study illustrate the proposal before a general discussion.

2 IMPROVING THE CONTROL OF DESIGN PROCESSES

2.1 Co-ordination and collaboration in SME

In design project management, progress control of the design process can be defined as the understanding of existing design situations in order to evaluate them and to take decisions that will modify and improve the future process, according to design objectives given by customer specifications or issued from the company strategy. The control problem here is a problem of decision-making to support designers in their activities [7] in order for them to achieve an objective in a specific context (Figure 1). Each design activity has "input" and "output" information. Actors use the "input" in order to produce the "output", to achieve their activity and have "supports" namely: human and material resources and knowledge to help them in their work.

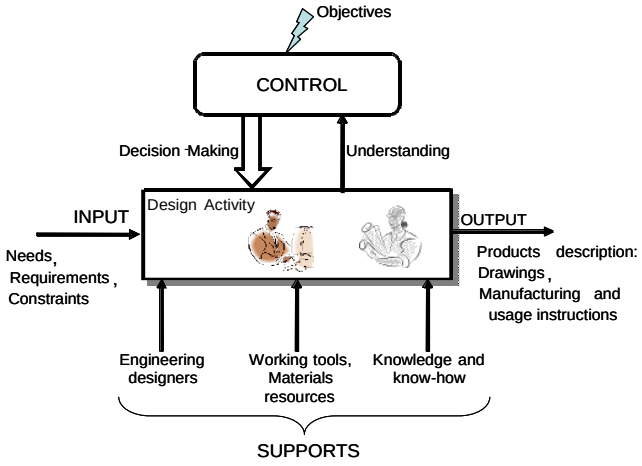

Figure 1. Control of design activities

For decision-making, project managers need to identify effective action levers which will influence collaboration thus increasing design performance. Moreover the situation in SMEs is very different to that in a large company, because in an SME each project is different and requires a specific study for each customer's specifications. Most of the time, the small structure of the SME does not ensure project management in a routine way and leads to combine various responsibilities. Indeed there are not enough actors to fulfil each design role, so most of them have various design roles in a project.
Consequently the role of informal relationships is very important in an SME in order that actors may help each other without rigid formalities. Thus, the combination of various responsibilities and the informal relationships lead to a high level of workload because informal tasks are added to the official ones. It is also a specific point into SMEs that their project structures have a rigid formalisation of their processes at a macro level and a very flexible non-formalisation of the detailed processes which allows informal relationships into the project.
In this context, the project manager coordinates (Figure 1) by formalising design decisions related to project management (translating customers requirements into a project team with its internal organisation [8], its schedule and deliverables, and its performance indicators) then by making a periodical control of the project progress before closing the loop by taking new decisions.

2.2 Design processes management through PDM systems implementation

PDM systems are intended to support the structuring and the management of product data and by extension the control of the product development process all along the product lifecycle. As they are now implemented in most of big companies and are actually introduced in SMEs, we consider that they are becoming a way of formalising standard design processes. Such formalisation is no more stored into a quality document but is really applied by designers through a generic tool.

PDM systems manage information through document management and especially product data evolution using predefined workflows [9]. As an extension, PLM (Product Lifecycle Management) systems introduce project management functionalities [10]. Workflow techniques are used for defining the 'ideal' process that will manage the life of a document or to define a project scheduling. It is generally said that workflow are predefined and offer no flexibility to the design process. This limitation is often dependant on the implementation of workflow techniques made by editors, as well as on the restriction to only one generic process made by the company business experts, and not on the workflow techniques by themselves.
In [11], a methodology for PDM implementation into SMEs was proposed and experimented. This method is composed of three main phases: an "Analysis" phase dedicated to the study of the existing product development process; a "Specification" phase dedicated to the definition of the future product development process; and finally the "Implementation" phase leading to the operational system.
The "Analysis" phase is composed of:

- Definition of the existing organisational structure (departments, roles, internal links).
- Definition of the existing design process including project management and design tasks.
- Identification and characterisation of the information flows.

After having applied the first phase, the different steps of the "Specification" phase can be described as:

- Definition of the future organisational structure of the company: departments, peoples' functional roles, and then the roles of future project members and their relationships for future collaboration.
- Definition of the new global product development process.
- Definition of the informational flow with all documents used.
- Definition of the product development process at a more detailed level with practical guidelines in order to fulfil each task. These guidelines are mainly defined by iterations.

The experience of PDM implementation into several companies shows that most of the time the studied design process is formalised at a global level on both "analysis" and "Specification" phases. "Global level" means that the structure of the project (phases and milestones) is defined and decomposed at each level of the organisational structures (departments, teams), but not inside teams at an individual level. Design actors have full autonomy to defined design tasks corresponding to the objectives that they have to reach at their level.
Another limitation identified through experience is that the management of documents is not really correlated to the project progress. This is due to PDM limitations: documents evolution is managed through specific workflows and project progress is managed through a tasks' scheduling. These two functionalities are not correlated and the project manager can only control 'a posteriori' that a deliverable is available or not.
So by analysing collaboration, the formalisation of detailed and flexible workflows into PDM systems should help in improving the co-ordination of design project by a project manager, i.e. the definition of tasks at an individual level as well as an improved control of documents life cycle. Next section will introduce both model and tool developed for analysing collaboration and show how the related method can be integrated with the PDM implementation methodology.

3 FROM COLLABORATION ANALYSIS TO PDM IMPLEMENTATION

One of the difficulties for the project manager is to take into account the collaboration into his project plan. In spite of various works on design collaboration, no generic rules and operational principles have been defined to help a project manager in his daily work. However it is essential to clearly understand what collaboration is, before defining devices to assist a project manager. The study and the characterisation of the types of collaboration used in companies is an important issue for project managers in anticipating design situations during projects and defining the best form of collaboration in accordance with the specific design context. However there is also a lack of devices to help the project manager to analyse the collaborative practices.

3.1 Collaboration analyses: a model for analysing collaborative events

In [12] a model and a software tool have been presented to track the collaboration between designers. The model deals with the identification of the main relevant elements for the characterisation of the

collaborative situations in design. Collaborative situations are defined from a co-ordination point of view, with scheduling, planning, formalisation, and the definition of milestones and activities. Alternatively, they are also defined from a human relationship point of view with the persons who are involved in the collaborative event, their skills, their motivation, and their form of communication. Both points of view are considered to characterise the factors of tracked collaborative events.

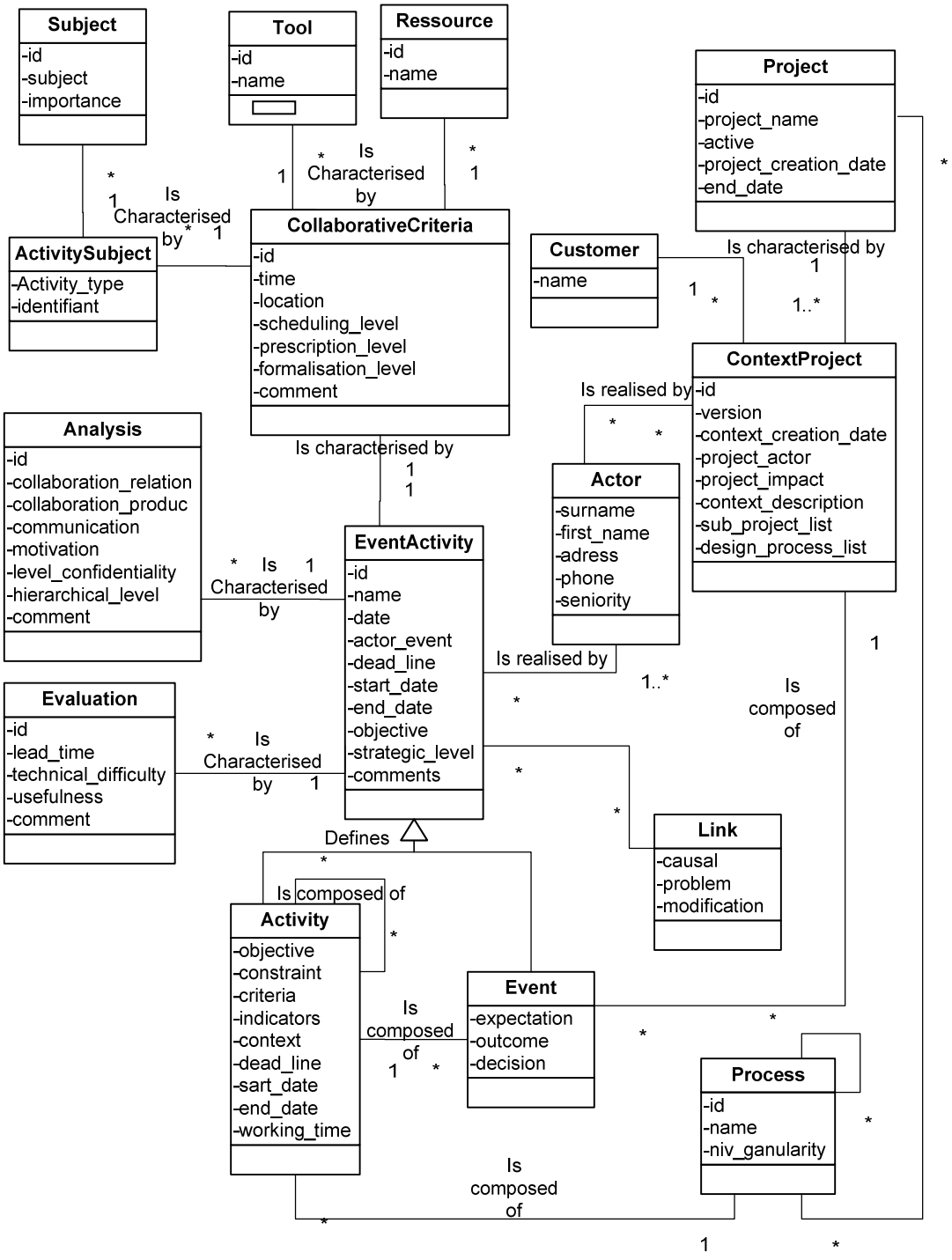

Figure 2. Class diagram of the model of collaboration

The theoretical concepts are shown in figure 2. The model is focused on the definition of collaborative events of the project. All events should be associated with contexts in order to understand and analyse the collaboration: both the global context of the project and the local context of a collaborative situation. Moreover, the model integrates different kind of parameters by capturing quantitative data such as time, activity type or problem solve as well as qualitative data such as quality of

communication or interests of actors. These different categories of information characterise the collaborative events of a design project:

- - The 'event' class (from the 'eventActivity' class) allows the capture of each collaborative event - whether formal or informal by storing the basic definition such as date, actor, expectations of the event, outcomes or taken decisions. The first level of description of an event is its activity type (such as report, scheduling, validation, milestone, co-design…) and its achievement form (such as meeting, discussion, videoconference, conflict resolution…) through the 'activitySubject' and 'subject' classes.
- - The 'context of the project' class, with the main information to situate the actor's tasks in the global project work of the company. This class is associated to 'customer' class and 'project' class.
- - The characterization of the nature of the collaboration through 'Collaborative criteria' class which details the different types of collaboration used by actors in the event e.g. location, time, schedule, methods...

Events stored may be scheduled tasks as well as un-scheduled events in order to identify formalised procedures but also real and flexible tasks sequences at a more detailed level. Events may not only be 'linked' in a temporal mode, but also with causal links or problem links. This information is generally useful to identify shortcuts or alternatives in the traditional process, then to analyse the parameters leading to these situations.

Results of the analysis of the collaborative events are stored through the 'analysis' and 'evaluation' classes and more subjective information can be added on communication between actors, motivation, and usefulness of the event… Sometimes it is useful for the analysis to group several events by creating a global activity (through the sub-class 'activity') in order to have an evaluation of their impact. By this way it is possible to rebuild a detailed 'process' from different but correlated events.

3.1 CoCa: a tool for analysing collaborative events

To support the traceability of the events, their characterisation and the context of the project, we have implemented a tool named CoCa (an acronym for Collaboration Capture) in order to implement the proposed model and to help managers to analyse collaborative situations occurring in projects.

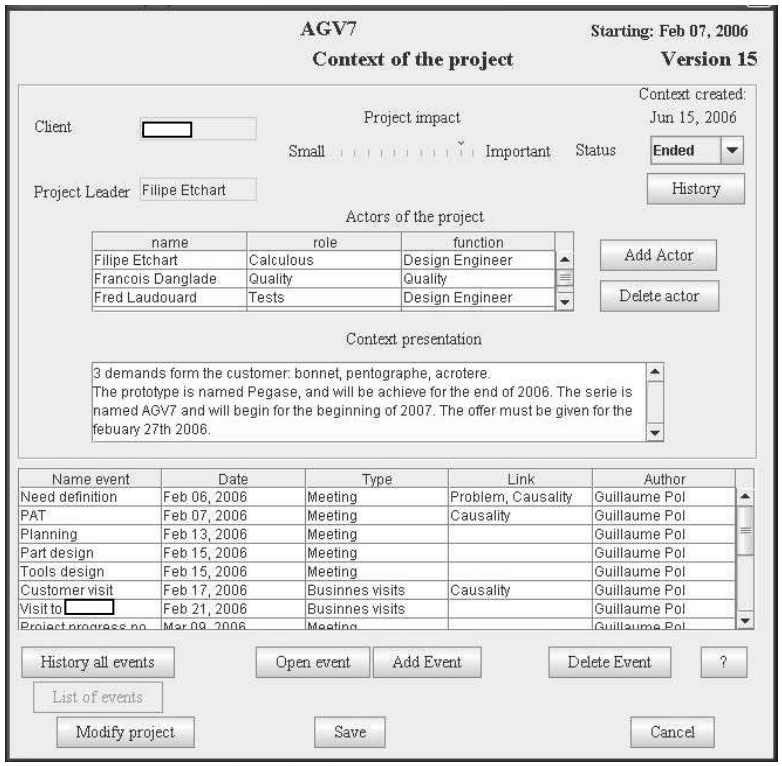

Figure 3. Project context form with the list of events

The CoCa tool has been developed to allow analysts of design process to apply the collaboration model. Analysts, either researchers or project manager or experts, are able to store information about collaborative events. Generally they begin with the definition of the project and its global context. This context ensures the capture of the main parameters of the project in order to facilitate the interpretation of the various collaborative practices occurring. Information about actors, customer, and any other data like the impact of the project in the strategy of the company, or any text field to refine the description of the context of the project are included.
Figure 3 shows the list of the events occurring in a project together with the links between them.

3.2 Integrating collaboration analyses and PDM implementation

The following method has been proposed to achieve collaboration analyses and to propose improvements for design co-ordination. It is composed of three steps:

- Capturing data about collaborative events and their evaluation using the CoCa tool. This step is managed by analysts that are involved in design projects in order to store each collaborative event. They have to characterise and evaluate it in order to facilitate future analyses.
- Analysing captured data to identify problems or possible improvements and to establish links between events. In this step analysts have to establish correlations between events in order to identify problems or good results. One of the expected result is the identification of task sequences corresponding to the resolution of a problem of an inadequate process for a given design situation, or to the formalisation of an adequate process for another given design situation.
- Identifying best practices through good activities' sequences for example.

Through the achieved experiments, we have defined three kinds of improvements for design co-ordination:

- Improvements on the processes, resulting from the identified best practices.
- Improvements on the human factor management such as detailing roles, modifying teams, managing skills with a long term vision…
- Improvements on the used tools, software as well as guidelines, procedures, or standard datasheets.

Such improvements can be correlated to previous PDM implementation methodology. Defining more detailed processes must be introduced when specifying new design processes and information flows. Human aspects influence the specifications of future organisational structure. Finally improving used tools has an impact on software to be integrated with PDM system and on documents management.
So we propose to capture data for collaboration analysis as a complementary work of the "analysis" phase, then to introduce the results of this method to help formalising the specifications of the PDM implementation methodology, as shown in figure 4.

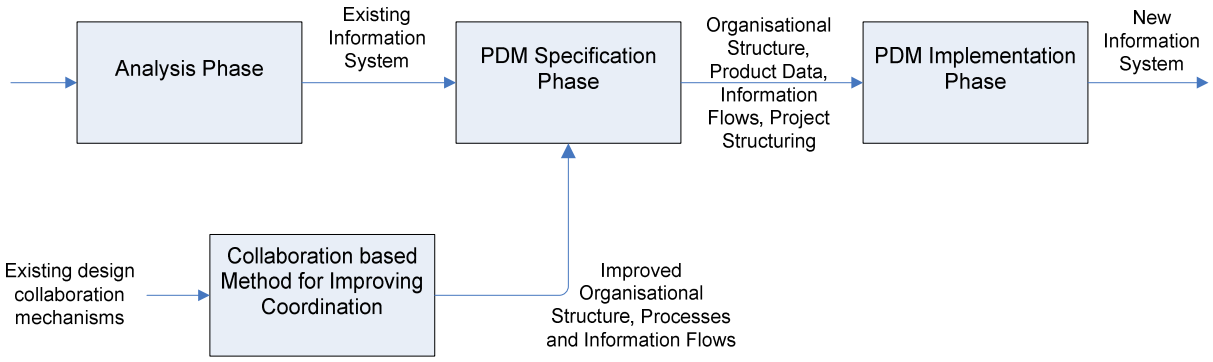

Figure 4. Method for improving PDM implementation through collaboration analysis

As a consequence, this integrated method allows the establishment of links between the analyses of collaborative practices and the formalisation of more complex and flexible workflows.
In the next section we introduce the industrial case study, before detailing an example of the use of the CoCa tool and the analysis that can be done with it for improving PDM implementation methodology.

4 CASE STUDY

4.1 Context of the case study

The industrial case study has been achieved in a SME which, some years ago, developed a new means of manufacturing structures using honeycomb sub-assemblies. This innovation confers lightness and significant vibration absorption on products whilst maintaining similar rigidity to steel. The company has captured several markets with products manufactured using its technology and consequently the number of employees grew from 4 to 40 over 10 years. Over this period the organisational structure and internal processes have not been formally revised. The study carried out was aimed at the improvement of design processes and then also to the prototyping of a PDM system in order to evaluate the interest for the company [13].

Our method of experimentation was based on a socio-technical approach [14]. Our role was to participate in a company workgroup and thus introduce an external point of view. In this context, problems of organisation, project management and relationships with suppliers, customers, and subcontractors come into play. We have first studied and analysed the company's design and industrialisation department. Then we have formalised: a new organisational structure, the processes of development of new products, and the management of technical information and of product data.

After this first phase we have focused our work on the study of collaboration and relationships between actors and on the design project co-ordination [15] [11]. This phase is the way to test and validate the proposed method. Some results of the analysed projects are now presented.

In the industrial case study, the CoCa tool was used to follow different projects. After six months, four different projects have been deeply analysed and more than one hundred collaborative events have been stored. The chosen examples come from the AGV7 project. The customer is Company A[1] (a global leader in power and rail infrastructure) who demands a quotation to manufacture structural elements of a railway transport engine. A prototype is needed in a first phase for the end of 2006 before starting mass production in 2007.

4.2 Storing and analysing collaborative events

After having stored the context of the project, CoCa ensures the capture of detailed information about the collaborative events and their context. For example in our case study, a specific collaborative situation has been studied: the CND (Customer's Need Definition) process which corresponds to the initial financial quotation of the design for the customer. This financial quotation has to be defined and proposed to the customer before the technical start of the design.

This situation is representative of the various forms of collaboration achieved for the same generic activity. By analysing this quotation activity through different projects we have found four different ways of collaborating between involved actors. In order to differentiate the corresponding collaborative events we have introduced several collaborative criteria into the CoCa tool [12].

These criteria are used to describe the form of collaboration used in the event, so we can, for example, know if actors work at the same time or not, in the same place, if the event was planned, prescribed or formalised, if actors used specific tools, or information resources to do their work. Other parameters are recorded concerning the collaborative event such as the type of activities done during the event, or the evaluation of the form of collaboration used or an ad-hoc analysis of the collaboration.

The evaluation of collaborative events by the analyst depends on the context of the project. For this reason, CoCa manages multiple versions of the project context in order to have a history of the modifications done to it and to the event list during the project. For each version of the project context a comment field allows the recording of an explanation as to why modifications have been made.

For the analyst the main issue is to find a good set of information in order to analyse the collaborative practices used in the company and to improve his forecasts. The aim is to take into account the character of collaboration between actors in order to foster flexibility within the design process [16] and to bring the company closer to a dynamic model.

Resulting from this analysis, several scenarios were observed which represent different forms of collaboration in carrying out this first activity:

- 1st scenario: free collaboration:

[1] The name of the companies is hidden for confidentiality reasons.

The marketing department was in charge of an activity for which it did not have adequate skills. Moreover the type of collaboration implemented during this scenario is called "free" because only the final objective was known: to carry out the technical quotation. The responsibilities and the interconnection between actors had not been formalized in advance. The principal problem of this scenario lies in the fact that the marketing department does not have sufficient technical skill to collect all the technical information. So, the technical department had to rebuild the customer's file and to contact them again in order to collect the correct information and to carry out the technical quotation.

- 2nd scenario: asynchronous collaboration "forced":

In order to force the collaboration between marketing and technical departments a document template was defined where all the technical information required to carry out the technical quotation was collected. The marketing person had to fill in the document template and transmit it to the technical department in order to make the quotation. In this case the main problem lies in filling in the document template, indeed the document was often left incomplete and thus some information was not processed. This was because the marketing person did not have the necessary skills to adapt to each new quotation that asked for technical and specific information about the product, or about the customer. The template is only a good response for a routine quotation where the information to be collected is always the same. This form of collaboration "forced" by standardization is more applicable to routine activities where information exchanged and the interconnections between actors are well established.

- 3rd scenario: synchronous collaboration "forced":

The project leader proposed that the technical person responsible went to the customer with the marketing person to collect all information necessary to carry out the technical quotation. Thus it was decided that the type of collaboration should change, and we moved from asynchronous and "forced" collaboration by standardization to "forced" but synchronous collaboration. However, this form of collaboration was too constraining.

- Last scenario: encouraged collaboration:

This scenario is a compromise between free collaboration and forced collaboration. A first visit to the customer was made by the responsible marketing person alone in order to quotation the feasibility of the product on at the marketing level, and then, if it was necessary, the responsible technical person had a meeting with the customer to collect all the technical information necessary to carry out the technical quotation. The meeting could have been a physical one or by phone; with or without the marketing person according to the complexity of the case. In this scenario the technical department had the responsibility of finding the information necessary to carry out the quotation with a formal coordination by mutual agreement with the marketing department.

These four scenarios can be formalised and re-used to specify the detailed design process of the quotation phase.

4.3 PDM workflow improvements

Following example illustrates the consequences of previous analysis on the project management: the introduction of flexibility and detailed implementation of design processes.

Before applying the proposed methodology, the CND document was managed by the marketing person who builds the document in collaboration with the customer. Indeed this phase defines the product specifications from the need expressed by the customer. First activities of this phase were:

- The definition by the marketing person of the CND document with the customer.
- The validation of the document.
- The notification to the technical department that the document is complete and that a designer has to make the quotation.

A corresponding workflow for managing CND document life cycle was first proposed for PDM implementation (Figure 7).

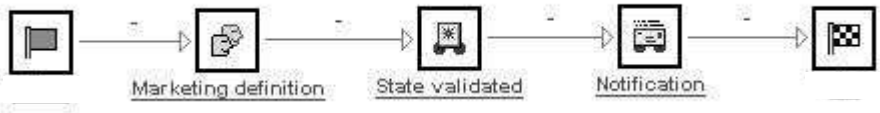

Figure 7. Initial CND process

The analysis of this initial situation through several projects allows identifying various problems:

- The description of the CND process is too global and do not incorporate details and flexibility.
- Only the marketing person is involved in the validation of the document.
- The marketing person does not have the necessary level of technical skill for all customers, and furthermore he does not have enough time to carry out all the CND process.
- Problem of customer data management appears between the technical and marketing department.

With the analysis of the collaboration with the CoCa tool, the analyst can define new guidelines and more detailed processes. As the 'good design processes' are defined through a deep study of real events occurring during a project, their level of granularity is more accurate than generic processes defined after the interviews of some experts and managers. By this way the added-value of the analyst is then to integrate the adequate 'good design processes' into the generic ones. To do so, he may define nodes of flexibility where the future context of the project will allow choosing between several possible sequences. Flexible workflow is here a workflow formalised as a graph with nodes, sub-processes and opened tasks allowing new tasks creation dynamically. In this way, the CND process is updated with an increased level of granularity based on the guidelines from the collaboration analysis. Consequently a new workflow is proposed to be implemented into the PDM system. In Figure 8 the marketing person evaluates the needs of the customer, he can:

- reject directly if the customer needs are not appropriated for the company,
- make a visit to the customer alone (task 'Customer visit Marketing') before sending the document to the designer or with a designer (task 'customer visit 2') in order to make a deeper evaluation of the need,
- directly define the document and send it to the designer.

Afterwards the CND document can be rejected at any time by a combined validation between the marketing person and designers. If not, the CND document transfers to the status of 'study' ready to be defined by a designer. The CND can be validated directly if the necessary information for the specifications is available or rejected directly with information to the marketing department and a notification to the customer, if the need of the customer is not in accordance with the company know-how. Nevertheless, an extra visit can be planned to finish the collect of information in order to finish the CND definition. After a combined study and validation (between the marketing and the technical department) the CND is validated.

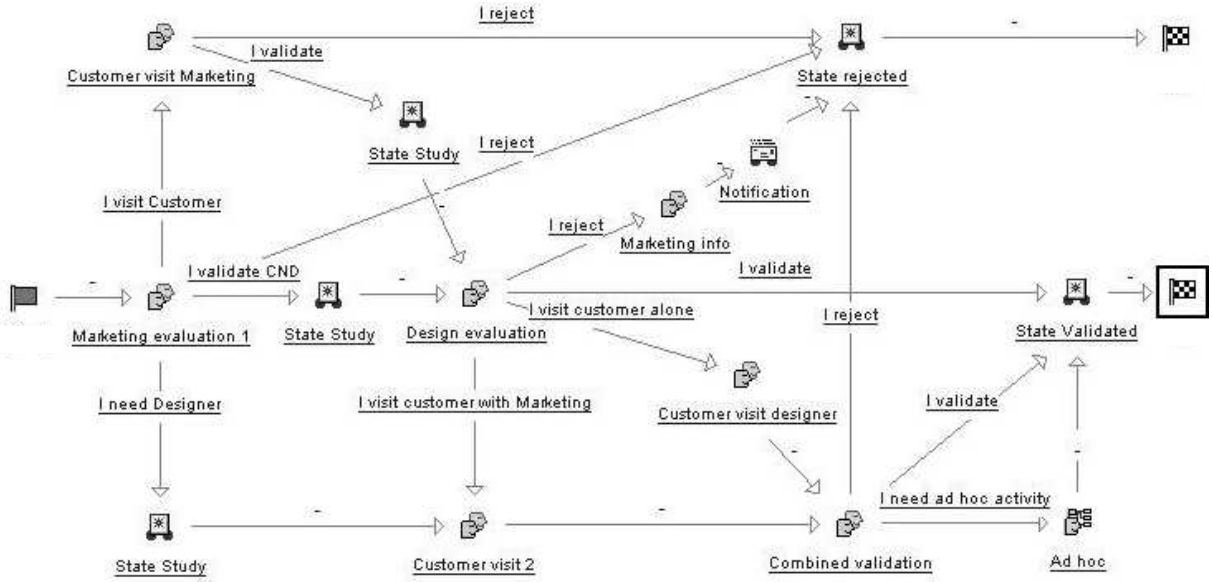

Figure 8. Final CND process

In this last case, an ad hoc activity is introduced in the process just after the node of decision 'combined validation' and the state 'validation'. The previous tasks are indispensable but not necessary sufficient, and then an ad hoc activity is added in this place to give the opportunity to add an

extra activity just before the validation. This ad hoc activity will be defined dynamically during the workflow execution and allows coordinating activities not already defined at the beginning of the project.
There are multiple benefits of this new CND process. Firstly the process becomes more detailed and flexible than the previous process: new tasks are created, some of them are nodes of flexibility by proposing the choice of the following sequence depending on the design situation, and ad hoc tasks can be added dynamically for non predefined situations. Then, the problem of technical skill of the marketing person is reduced thanks to the involvement of the technical department earlier in the process. And finally, the workload of the marketing person is improved with the non-systematic visit to the customer because it depends of the specific situation incoming.

5 SYNTHESIS AND DISCUSSION

The re-organisational structure and process re-engineering for design co-ordination demonstrates the importance to structure projects in processes and to manage the product data. In this situation the main issue is to retain enough flexibility in order to allow actors to keep the necessary amount of freedom to collaborate.

On the methodological aspect:
When a problem of collaboration between actors appears in a design event, the project manager is interested in analysing this event in order to understand what was wrong and what could be improved. This will orient the decision to take, improve or reject a collaborative practice that has occurred in projects.
The combination of different types of information allows identifying different kind of results by:

- establishing links between several events;
- establishing correlation between several parameters of different types between several events.

The resulting analyses have a great impact on the project manager co-ordination tasks, here are some examples:

- guidelines can be defined to help him when selecting designers with an approach based on skills, defining required tasks, scheduling tasks, etc;
- role of the project manager or company managers can be enforced or decreased depending on the context of a project to enhance prescriptive tasks or collaboration;
- formalisation of design process can be improved and more detailed by adding extra tasks, for example through the quality documents of the company;
- flexibility can be added in the process by introducing nodes for choosing best sequences of tasks.

The level of granularity of the events is also a methodological problem that we had to solve. We decided to track events at their more detailed level, i.e. basic events. But when analysing it can be more difficult to navigate between events and to have a global view of the different phases. The possibility of indicating the level of granularity and to group sequences of events in a higher level activity should help the analyst.

On the use of the CoCa tool:
For the moment, this tool is in an alpha version and has been experimented with during a study in our SME partner. The main difficulty is the acceptance of the analyst by designers. Here the fact that we know the people in the company as a consequence of earlier interventions is a key to success. Nevertheless designers have generally a large amount of work and their motivation depends strongly on the position of their hierarchy: sometimes we had to explain again and convince people because some messages from heads of departments were misunderstood.
Of course the work of the analyst is not easy: well-defined events such as meetings are much easier to track than emerging events during a coffee break. But this challenge brings the richest results.
The main limit of such a tool is the subjectivity of the observer. The actual architecture of the tool does not allow us to combine multiple points of view of the same event. Indeed two persons cannot collect information on the same event in the same database. However, the capture of different interpretations and analyses would be interesting for a future version of the CoCa tool.

These tests allow evaluating the level of assistance of the CoCa tool in the analysis of the collaborative practice of the company and what kind of impact it can have on the decisions of project managers.

On the evolution of the CoCa tool:
CoCa is limited to collaborative events, but for analysing problem origins or good practices, non-collaborative events can bring interesting information. So capturing all events of a project is a way to improve the methodology of analysing collaboration for coordination.
A graphical tool for analysing sequences of events and exploring links should be useful for the analyst. So the tool needs to provide a search by keywords and attributes to find main text data. A graphical visualisation of information will be implemented to represent and compare various forms of collaboration with common criteria.

On PDM specification and implementation:
Improved workflow has been proposed with a certain level of flexibility. Nevertheless, the level of flexibility is still limited, because all added tasks and nodes of flexibility are themselves pre-defined. Thus, the process becomes more flexible but in the face of the important vagaries of design the process is not immediately reactive. Indeed the actors have to wait for a routing point (a node of flexibility) to have the advantage of this flexibility and to take a decision. The reaction cannot be taken instantly after the emergence of the vagary. The ad hoc activities are also defined in specific locations during the process and they can not be defined after or before each task or node: resulting workflow would be too heavy for designers.
This solution based on detailed processes with the introduction of some flexibility is a part of the solution. From the results of the case study, some further areas need to be addressed, for example: actors and skills management, triggering events, and also the ability to re-use and build on the planned/realised/modified process. The implementation of the task concept is not satisfactory: it is not clear how input and output information may be defined other than through deliverables and the decisional elements cannot easily be formalised. The proposed attributes of process elements, tasks or milestones do not exist given the inadequate status/level of the concept of implementation.
Thus the next objective will be to manage projects in real time with a flexibility which is continuous and evolves dynamically.

6 CONCLUSION

This paper deals with the results on the analysis of collaboration in order to improve the coordination of projects. The coordination is supported by the formalisation of organisational structure of the company and process re-engineering. Product data and process management tool are an extra support to design coordination. Collaboration inputs through the use of the CoCa tool allow the understanding of factors influencing co-ordination and, in particular, to characterise detailed and flexible PDM workflow. A method and a software tool for analysing collaboration and improving PDM specification have been proposed. The presented case study demonstrates the benefits of the analysis of the collaboration on design process formalisation and management through PDM implementation.
Nevertheless the use of the CoCa tool and the associated method is based on a six months study with one SME. Other projects with other companies are needed to validate the approach as a generic one. Moreover only document workflow has been studied and future work will also study how PDM project management can be improved and especially how project task sequences can be correlated to document workflow in order to have a multi-level control of design processes.

REFERENCES

[1] Fenves S.J., Sriram R.D., Choi Y., Elm J.P. and Robert J.E. Advanced Engineering Environments for Small Manufacturing Enterprises. *Technical report, NIST*, 2003, Vol.I, NISTIR 7055.

[2] Balbontin A., Yazdani B.B., Cooper R. and Souder W.E. New product development practices in American and British firms. *Technovation*, 2000, 20, pp.257-274.

[3] McMahon C.A., Liu Y., Crossland R., Brown D., Leal D. and Devlukia J, A. Best Practice Advice System to Support Automotive Engineering Analysis Processes. *Engineering with Computers*. 2004, 19(4), pp.271-283.

[4] Coates G., Whitfield R.I., Duffy A.H.B. and Hills B. Co-ordination approaches and systems,

Part II: An operational perspective. *Research in Engineering Design*. 2000, 12, pp.73-89.
[5] Martinez M.T., Fouletier P., Park K.H. and Favrel J. Virtual enterprise - organisation, evolution and control. *International Journal of Production Economics*, 2001, 74, pp.225-238.
[6] Giannini F., Monti M., Biondi D., Bonfatti F. and Moanari P.D. A modelling tool for the management of product data in a co-design environment. *Computer Aided Design*, 2002, 34, pp.1063-1073.
[7] Girard Ph. and Doumeingts G. Modelling of the engineering design system to improve performance. *Computers & Industrial Engineering*, 2004, Vol 46/1, pp.43-67.
[8] Mintzberg H. Le management. *Voyage au centre des organisations*, 1990 (Editions d'Organisation, Paris).
[9] Liu D.T. and Xu X.W. A review of web-based product data management systems. *Computers in Industry*, 2001, Vol. 44, pp.251-262.
[10] Saaksvuori A. and Immoen A. Product Lifecycle Management. 2004 (Springer-Verlag, Berlin).
[11] Pol G., Jared G., Merlo C. and Legardeur J. Prerequisites for the implementation of a product data and process management tool in SME. In *15th International Conference on Engineering Design*, ICED'05, Melbourne, 2005.
[12] Merlo C., Pol G., Legardeur J. and Jared G. A tool for analysing collaborative practices in design projects. In *12th IFAC Symposium on Information Control Problems in Manufacturing, INCOM'06*, Saint-Etienne, 2006.
[13] Pol G., Merlo C., Jared G. and Legardeur J. From PDM systems to integrated project management systems: a case study. In *international conference on Product Lifecycle Management*, PLM'05, Lyon, 2005.
[14] Boujut J.F. and Tiger H. A socio-technical research method for analyzing and instrumenting the design activity. *Journal of Design Research*, 2002, Vol. 2, Issue 2.
[15] Duffy A.H.B., Andreasen M.M., O'Donnell F.J. and Girod M. Design Coordination. In *International Conference on Engineering Design ICED'97*, Tampere, 1997.
[16] Vajna S., Freisleben D. and Scheibler M. Knowledge Based Engineering Process Model. In *11th International Conference on Engineering Design, ICED'97, Vol. 2*, Tampere, 1997, pp.181-184.

Contact: C. MERLO
ESTIA
LIPSI
Technopole Izarbel
64210, Bidart
France
33-559438400
33-559438401
c.merlo@estia.fr
http://www.estia.fr/