A TOOL FOR ANALYSING COLLABORATIVE PRACTICES IN PROJECT DESIGN

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Abstract: The subject of this paper is the collaborative practices used in the product development process in SME's (Small and Medium Enterprise). The starting point is an empirical study, part of industry-based fieldwork on the introduction of a PDM system. Our results highlight the need for new approaches to take into account the socio-technical complexity of the collaborative processes. A new tool named CoCa is proposed to analyse collaborative practices *in situ*. This tool is designed to be used by researchers, consultants or, eventually, project managers in order to track all the collaborative events and the project context. The background and industrial case study, the theoretical basis and design of the tool are described and, finally, some indication is given of its potential use in gaining understanding of complex collaborative processes.

Keywords: Mechanical Engineering, Design, Co-ordination, Co-operation, Decision, Human factors, Process identification, Project management, Software tools.

1. INTRODUCTION

Many studies have tried to identify the best practices and strategies developed by enterprises (Balbontin, *et al.*, 2000) in order 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. Today design projects depend on the ability to co-ordinate and to control the collaboration between the numerous actors participating in such projects: e.g. designers, experts from different disciplines and with different experiences, external partners.

On the one hand (Coates, *et al.*, 2000) 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 co-design partners (Martinez, *et al.*, 2001, Giannini, *et al.*, 2002) and also with suppliers offers the possibility of gaining fast access to specialist knowledge and capabilities, of spreading and sharing costs and risks, and of better exploitation of the expertise of the partners. From the operational point of view of the project manager, such aspects are 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 and to reach project objectives.

In this paper co-ordination and collaboration are first studied as complementary aspects and we demonstrate that existing tools for coordination do not support collaboration (Legardeur 2004). The following section, an industrial case study in a SME, focuses on the needs for project managers to understand how actors collaborate before trying to improve this aspect. Finally, we describe a tool for capturing collaborative events that occur during a design project in order to allow its users to identify best practices thanks to their knowledge, experience and skills.

2. CO-ORDINATION AND COLLABORATION IN ENGINEERING DESIGN

2.1 Co-ordination of engineering design.

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 and adequate resources to satisfy the initial objectives.
In the "succession of hierarchical steps" model of design (Pahl and Beitz, 1996), the project manager acts upon traditional costs-quality-delays parameters. Other models define technical evaluation based on document deliverables or on resource management. The design coordination approach (Andreasen, 96) integrates several models in order to improve product design. In the GRAI engineering method (Girard and Merlo, 2003) guidelines are defined to improve performance in collaborative design by proposing a multi-level structure for design projects. This method intends to integrate traditional work on co-ordination such as (Mintzberg 1990) and new human based-approaches.
New parameters (Perrin, 1999) are now introduced, based on the level of collaboration and communication between actors in order to improve ideas, solutions, innovation and flexibility of the predefined scheduling or the actors' skills. These parameters are still fuzzy and difficult to characterise.
A project manager now has a wide range of criteria to take into account 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.

2.2 Collaboration in design between actors.

In this paper we address collaborative aspects in a pragmatic way based on empirical studies of industrial situations. Our goal is to go deeper in the understanding and in the characterisation of these complex processes. We have adopted a constructivist point of view based on the actor-network theory (ANT) in line with the works of Callon (1998). Therefore we consider that collaboration is a socio-technical process that entails the development of alliances among groups of actors, the evolution of practices and knowledge, the creation of specific mediating artefacts and finally organizational shifts.

2.3 Towards collaborative tools.

Much research has been aimed at developing tools to support collaboration such as CSCW (Computer Supported Cooperative Work) or PLM (Product Lifecycle Management) tools (Johansen, 1991), (Pol, 2005). Such tools support co-ordination between actors in projects by sharing a reference environment composed of the same language, objectives, methods and tools. However, the collaborative aspects of projects are not sufficiently taken into account by these tools. They act, for example, on *"what, when, who, for what"*, but they do not define how actors work: are they in synchronous or asynchronous mode, in the same place - or not, and with what degree of formality? In fact CSCW and PLM tools do not address the operational functionalities for project managers which would allow them to co-ordinate and control collaborative design processes. Before proposing such functionalities we must first analyse and understand collaboration in design and see how a project manager might integrate this dimension into the job of coordinating a project team.
After describing the industrial case study the issues of tools for analysing collaboration will be studied in order to support the project manager in gaining understanding of collaboration in design projects.

3. INDUSTRIAL CASE STUDY

A study in an SME supports our research work. This SME, 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. Our method of experimentation was based on a socio-technical approach (Boujut and Tiger, 2002). Our role was to participate in a company workgroup and thus introduce an external point of view. In this context, the objective of the company was to reorganise its structure to introduce the role of "project manager" for managing projects.

3.1 Context and objectives.

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 objective of the study was to help the company to reorganise and to manage further growth.

In this context, problems of organisation, project management and relationships with suppliers, customers, and subcontractors come into play. As a consequence, managers need to implement product data and process management tools which are well-adapted to the company setting. In a previous intervention in the company we had studied and analysed the company's design and industrialisation department: its re-organisation, the processes of development of new products, the management of technical information and of product data, as well as relationships between actors. So we have focused our work on the organisation, and on the design project co-ordination (Duffy *et al*., 1997).
The objective of the next study will be to orient their management of projects towards a new organisational structure. Project managers would be responsible for the whole design project progress, schedule project tasks and define resources in terms of persons and of material to allocate to a project. The objective of the associated research will be to test and validate a tool to help with the analysis of collaboration.

3.2 Defining project co-ordination tasks: Design process re-engineering

In order to create an environment for the management of projects by a "project manager", the design process has been re-engineered by focusing on project co-ordination tasks. The followed methodology is divided into 4 steps (Pol et al. 2005):
- Definition of the organisational structure including internal structure, external structure and definition of the project launch phase.
This first step defines the role of each actor and its implications in the global context of the company.
- Definition of the future global design process by describing the product development process and the project management process separately.
This second step defines the main tasks and milestones of design projects. For the case study company a "project manager oriented" organisation has been defined for managing design projects.
- Definition of the information flow by identifying pertinent information to be managed through the design process, and characterising the related lifecycles in order to specify responsibilities, resources, and validation processes.
This step focuses on data management and allows the creation of a shared environment to support information structuring and sharing between actors.
- Detailed definition of the product development process.
This model brings together information flow and human activities in order to specify detailed activities for team members upon identified sets of information. The aim is to specify the future roles of each team member that may be implemented through an information system. The final process is described through a phase / department table that characterises information links and dependencies between actors' tasks, in a similar way to Fagerstrom's (2001) use of a Design Structure Matrix.
This dedicated environment is enough to manage routine projects led by a "project manager" and to ensure, in this context, efficiency in progressing projects. Thus the proposed product development model for the company presents similarities with the third generation stage-gate model (Brown, 2006) in his description of Dynamic Product Development. However, we have also to take into account the character of collaboration between actors in order to foster flexibility within the design process (Vajna, 1997) and to bring the company closer to a dynamic model.

3.3 Example: a collaborative event.

Consider, for example, in our case study company the relationship from the marketing department which gives information to technical department which, in turn, have to estimate the cost to manufacture a product. This estimate is based on the information given by marketing. This activity is formalised and planned with tasks and milestones. But, the actors may use various forms of collaboration to achieve these tasks. For example, several scenarios were observed which represent different forms of collaboration in carrying out this collaborative activity: actors can collaborate in a synchronous or asynchronous way, in the same place or not, with or without guidelines to achieve their work and so on, with scheduled tasks, non-scheduled guidelines or only objectives, being autonomous … These alternatives depend on the situation and the collaborative practices used in the company.
This example shows that the same result can be achieved through several types of collaboration. Thus scheduling is not enough for the project manager to describe the conditions for achievement of a design situation. He can use several forms of collaboration in order to define the inter-actors exchanges.
We observe that in our case of an innovative project and non-routine activity the project leaders prefer to maintain flexibility by using "encouraged collaboration" in order to let actors be reactive. The collaborative dimension must be studied to help project managers to define not only scheduling but also prescribed interactions, methods and tools between actors, depending on each design situation.
In the next section we propose a tool to capture collaborative events. The main objective of this tool is to support the analysis of collaborative design situations, in order to help managers to identify "good practice" and to define flexible design steps in the product design process and the right type of collaboration between actors.

4. A TOOL TO ANALYSE DESIGN COLLABORATION: CoCa (Collaborative Capture)

In spite of various works on design collaboration, no generic rules and operational principles have been defined to help project managers in their daily work. As each company and each project is different, the assistance for the project manager must take into account the specificities of the local context of the project and the company. However it is essential to clearly understand what collaboration is, before defining devices to assist project managers. 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 a lack of devices to help the project manager to analyse the collaborative practices.
This section deals with the presentation of a tool to help the analysis of the collaborative practices in SMEs. First we describe the theoretical model underlying the tool implementation. The second section presents the tool in concrete terms with its GUI (Graphical User Interface) and finally we discuss some perspectives for the use of such a tool.

4.1 Theoretical model, a support for the tool.

We propose a model inspired by our literature review and industrial case study. It deals with the

identification of the main relevant elements for the characterisation of the collaborative situations in design. Collaborative situations could be defined from a co-ordination point of view, with scheduling, planning, formalisation, with the definition of milestones and activities. Alternatively, it could be defined from a human relationship point of view with the persons who are involved in the collaborative event, with their skills, their motivation, and their form of communication. In fact both these two points of view must be taken into account in several collaborative factors to define collaborative events such as: do actors work in the same place or not? in synchronous or asynchronous mode? do they use predefined tasks? and so on. All these factors must be included in a tool which helps managers to analyse collaborative situations that occur in projects. The theoretical concepts are shown in the following class diagram (see figure 1).

The theoretical model is built to represent collaborative situations which occur in companies. This model is based on the capture of information characterising collaborative events and their context:

- The 'context of the project' class, with the main information to situate the actor's tasks in the global project work of the company.
- The 'event' class that identifies any collaborative tasks and situations occurring in the project. This class allows the capture of each collaborative event - whether formal or informal. 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 "Activity/Achievement class.
- 'Collaborative criteria' class which details the form of collaboration used by actors in the event. This definition is focused on the collaboration definition in order to differentiate the various form of collaboration used in projects: e.g. location, time, schedule, methods...

The project manager can also evaluate the situation and introduce some analysis parameters and comments to prepare future analysis through the 'analyse' class. Events may not only be 'linked' in a temporal mode, but also with causal links or problem links. For example, non-formalised data could lead to losing time: in order to collect this information we can link two events to show that one event will have a problem which comes from the other event, this function is named "Link Problem" in our tool. We can also make links between events in order to show that an event is the cause of the creation of another one. 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. This information is generally useful to identify shortcuts or alternatives in the traditional process, then to analyse the parameters leading to these situations.

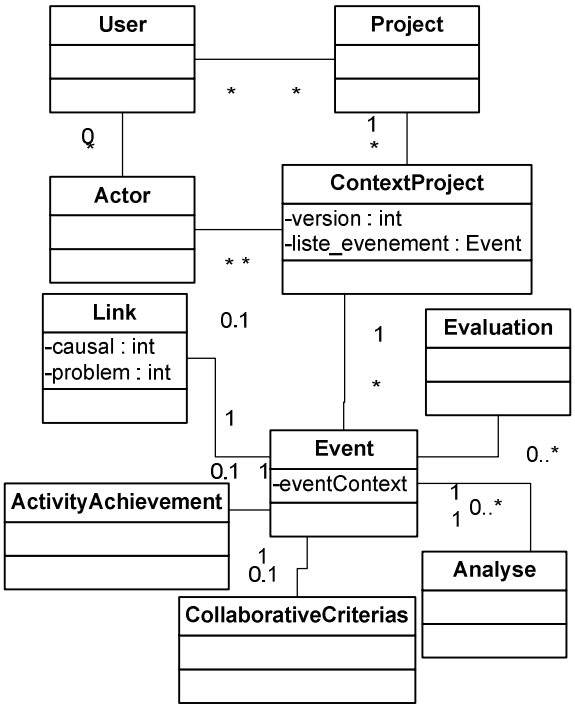

Fig. 1. Class diagram of the theoretical model

4.2 Tool with GUI

A tool has been developed named CoCa (for Collaborative Capture) in order to support the model presented in the previous paragraph. CoCa's architecture is a stand-alone client with a shared database.

Three kinds of users are defined: project managers, who have extended rights concerning their own projects; designers, with restricted rights to public elements of an event (i.e. no access to analysis elements); and finally analysts, with all rights on all projects.

Project managers or analysts generally begin with the definition of the context of the project. This context ensures the capture of the global view of the project in order to facilitate the interpretation of the various collaborative practices occurring. Information about actors, the 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. This context shows the list of the events occurring in a project together with the links between them. After the context of the project, CoCa ensures the capture of detailed information about the context of collaborative events included in the project. Events are so contextualised for a specific project context.

For example in our case study, a specific collaborative situation has been studied. The situation occurs at the beginning of the design process, when a financial estimate has to be defined to the customer before the real start of the project. This situation is representative of the various forms of collaboration achieved for the same activity defined initially in detail. In this situation we have

found four different practices of collaboration. In order to differentiate these collaborative practices we have introduced collaborative criteria (Merlo et al., 2005). These criteria are used in the tool to describe the form of collaboration used in the event, so we can know if actors work in the same time or not, in the same place or not, if the event is planed, prescribed or formalised, if actors used specific tools, or information resources to do their work (figure 2).
Three other tabs record extra data on the collaborative event of the project like the type of activities done during the event, or like evaluation of the form of collaboration used or to make 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, this tool manages the versions of the project context in order to have a history of the modifications done on the project context and on the event list during the project. For each version of the project context (figure 3) a comment field is filled to give to the user the opportunity to explain 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. Thus the tool needs firstly to provide a search by keywords and attributes to find main text data. Secondly in the final version of the tool, a graphical visualisation of information will be implemented to represent and compare various forms of collaboration with common criteria.

Finally, the tool will provide a specific form of output to visualise information from large databases (Jourdan and Mélançon, 2004). The visualisation of data recorded supports the analysis of collaboration and allows the establishment of a memory of design projects and best practices from the perspective of collaboration.

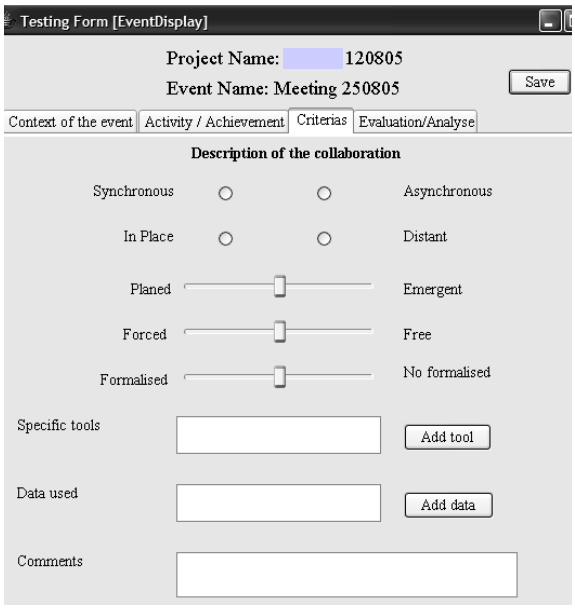

Fig. 2. Form of the tab “Collaborative criteria”

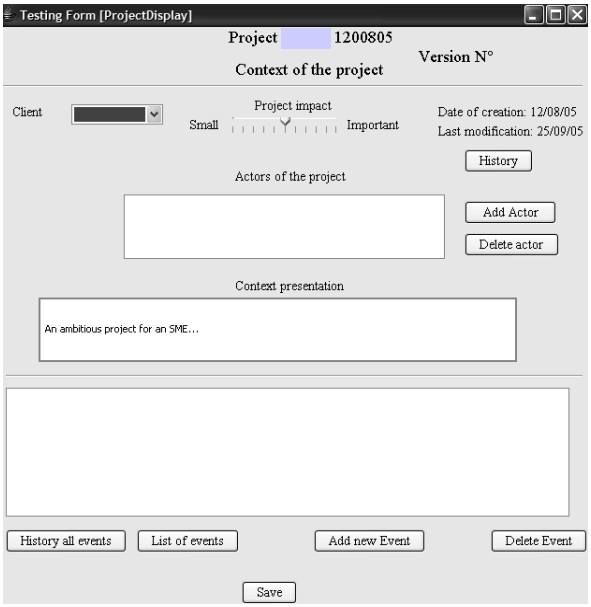

Fig. 3. Form of the “project context”

4.3 Discussion and Perspectives.

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 main limit of such a tool is the subjectivity of the observer. The actual architecture of the tool does not allow us to have a 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.
For the moment, this tool is in an alpha version and it is being tested during a new study in our SME partner. The main difficulty is the acceptance of the observer by designers. Here the fact that we know people in the company well 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. These tests will allow evaluation of the level of assistance of the 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. This will ensure the improvement of the tool toward a version that is usable in company. These tests will also allow better characterising the results that can help project managers.

5. CONCLUSION

Co-ordination in design is essential to reduce cost, improve product quality and to meet deadlines. But

collaboration between actors is important to federate actors and make co-ordination effective. Choosing a good form of collaboration between actors is necessary and requires analysis of the collaborative practice of the company. We have noticed in our research field a lack of tools to help the analysis of the collaboration. Thus, we are implementing such an analysis tool, CoCa: it does not help with co-ordination (decision taking) but helps to understand design activities and collaborative practices of the company. CoCa allows the establishment of a record of design projects from the point of view of collaboration and might be used to identify best practices and improve managers' decisions.

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