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Analysing collaborative practices in design to support project managers

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The subject of the current paper is the collaborative practices used in the product development process in SMEs (small and medium enterprises). The starting point is an empirical study, part of industry-based fieldwork on the introduction of a product lifecycle management (PLM) 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 and in improving design coordination.

Keywords: Product design engineering; Design coordination; Collaboration in design; Project management; Human factors; Process identification

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 coordinate 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 possible (e.g. objectives, information, resources, tools, methods) in order to foster collaboration and to reach project objectives. This paper focuses on an initial research objective dealing with the analysis of existing collaborative practices and the identification of guidelines and tools for helping project managers to coordinate, i.e. prescribe adequate collaboration context to design actors.

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Coordination and collaboration are studied in section two as complementary aspects and we demonstrate that existing tools for coordination do not support collaboration (Legardeur *et al.* 2004). The third section describes the industrial case study in a small and medium-sized enterprise (SME) then focuses on the needs for project managers to understand how actors collaborate before trying to improve this aspect. For helping project managers we propose in section 4 a model of collaboration and a tool for capturing collaborative events that occur during a design project. Section 5 illustrates the use of the tool for capturing collaborative data and for analysing such data to identify best practices thanks to project managers' knowledge, experience and skills.

2. Coordination and collaboration in engineering design

2.1. *Coordination of engineering design*

Coordination 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 *et al.* 1996) is based on an architecture of 11 interlinked 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 coordination such as Mintzberg (1990) and new human-based approaches.

New parameters (Perrin 1999) are 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. However, these parameters are still fuzzy and difficult to characterize.

In design project management, the progress control of the design process can be defined as the understanding of existing design situations (in the real world) in order to evaluate them and take decisions that will modify and improve the future process, according to design objectives given by customer specifications or issued from the company strategy (Baumberger *et al.* 2003). The control problem here is a problem of decision-making to support designers in their activities (Girard and Doumeingts 2004) in order for them to achieve an objective in a specific context (figure 1).
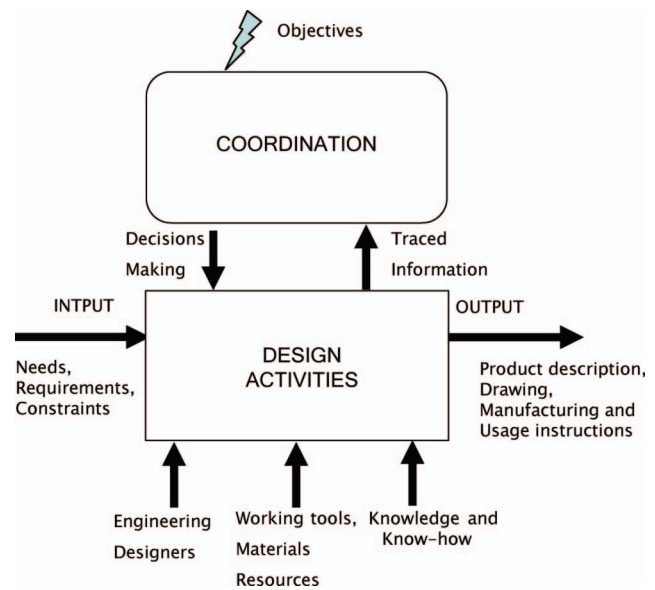

Figure 1.   Coordination of design activities.

For decision making, project managers need to identify effective action levers which will influence collaboration thus increasing design performance. 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*

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. Accordingly SMEs have to manage deadlines by setting an order of priorities on design tasks according to the objectives. Another point specific to SMEs is their project structures with a rigid formalization of their processes at a macro level and a very flexible non-formalization of the detailed processes which allows informal relationships into the project.

One of the difficulties for the project manager is to take collaboration into account in his project plan. In spite of various works on design collaboration (De Vreede and Briggs 2005), no generic rules and operational principles have been defined to help such 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 specific local context of the project and the

company. The study and the characterization of the types of collaboration (Hengst *et al.* 2006) 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. 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 *et al.* 2005b). Such tools support coordination 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, and with what degree of formalization? In fact CSCW and PLM tools do not address the operational functionalities for project managers which would allow them to coordinate 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.

2.3. *Towards a better collaboration understanding*

In previous work, an integrated model for design coordination was proposed in order to support GRAI Engineering method (Girard and Merlo 2003, Noel *et al.* 2004, Nowak *et al.* 2004) and supporting tools for design project managers. However, a model of collaboration must be developed in order to manage the human aspects in design which were noticeably lacking in those models and thus improve project coordination.

Such a model of collaboration will lead to the analysis of the form of collaboration used between actors in order to evaluate collaborative situations and to allow then to anticipate future design situations and to coordinate new projects. The implementation of an IT tool (called CoCa for Collaborative Capture) based on this model will allow the collection of large amounts of data and its visualization in order to support the analysis of the collaboration by project managers. In this approach the analysis of collaboration would be used to define guidelines for the project manager in order to take decisions in his coordination management (figure 2).

Here we address collaborative aspects in a pragmatic way based on empirical studies of industrial situations. Our goal is to go deeper into the understanding and characterization of these complex processes. We thus 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. Therefore we propose a research methodology that is an extension of the socio-technical research method (Boujut and Tiger 2002). Our originality is to mix both human sciences approaches (participative observation, fieldwork analysis of industrial design situation) and engineering
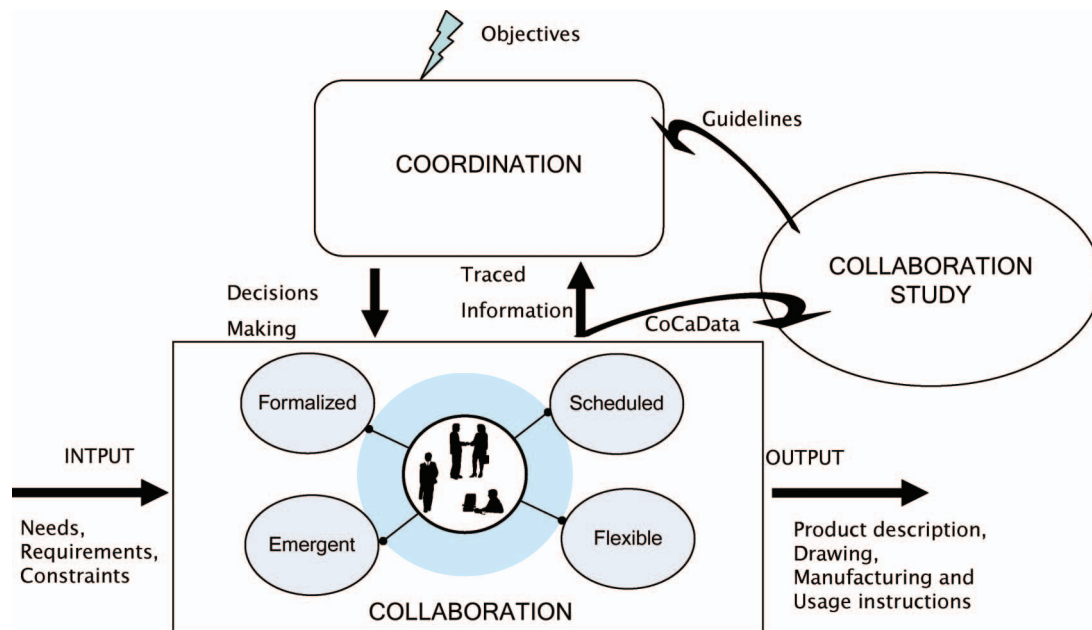

Figure 2.   Coordination and collaboration in project management.

approaches (Business Process Re-engineering, Software tools implementation methods, design sciences . . .).

Our approach (represented in figure 3) is based on the following steps:

1. Observation of industrial practices
2. Characterization of observed situation and processes based on fieldwork report, sociology and management theories, business process re-engineering tools . . .
3. Proposition of models based on social sciences and engineering design sciences,
4. Development of methods and tools.
5. Evaluation and tests in fieldwork industry in order to validate/improve the proposed tools and models.

After describing the industrial case study the development of an analysis tool to support the project manager in gaining understanding of collaboration in design projects will be examined.

3. Industrial case study

As already stated a case study in an SME has supported 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 main objective of the company was to reorganize its structure to introduce the role of 'project manager' for managing projects.
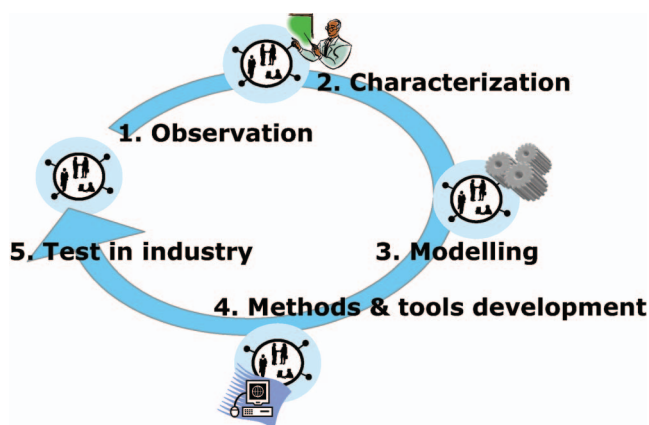

Figure 3.   The research methodology.

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 organizational structure and internal processes have not been formally revised. Thus one of the objectives of the study was to help the company to reorganize and to manage further growth.

In this context, problems of organization, 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 industrialization department: its re-organization, 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 organization, and on the design project coordination (Duffy *et al.* 1999).

As already stated, one objective of the study was to orient their management of projects towards a new organizational 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 was to test and validate a tool to support the analysis of collaboration.

3.2. Defining project coordination 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 coordination tasks. We applied the following methodology which is divided into four steps (Pol *et al.* 2005a):

(1) Definition of the organizational 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.
(2) 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' organization has been defined for managing design projects.
(3) Definition of the information flow by identifying pertinent information to be managed through the

design process, and characterizing the related life-cycles 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.

(4) 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 characterizes information links and dependencies between actors' tasks, in a similar way to Fagerstrom and Johannesson's (2001) use of a design structure matrix.

The resulting environment for design coordination 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 and Widell 2006) in the 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 *et al.* 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, has to estimate the cost to manufacture a product. This estimate is based on the information given by marketing. This activity is formalized 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 or different places, with or without guidelines to achieve their work and so on, with scheduled tasks, non-scheduled guidelines or only objectives, being autonomous ... The range of alternatives will depend on the situation and the collaborative practices used in the company. A same objective can be achieved through several types of collaboration. Thus scheduling alone is not enough for the project manager to describe the conditions for the 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. Towards design collaboration analysis

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 and third sections present respectively the tool with its GUI (graphical user interface) and its use through the storage of collaborative data from the case study.

4.1. A theoretical model of collaboration

The coordination of design deals with the identification of the main relevant elements for the characterization of the collaborative situations in design. Collaborative situations can be defined from a coordination point of view, with scheduling, planning, formalization, with the definition of milestones and activities. Alternatively, they can 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 defining several collaborative factors to categorize collaborative events such as: do the actors work in the same place? 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 the collaborative situations that occur in projects.

We propose a model of collaboration inspired by our literature review and industrial case study. The aim of such a model is to record information from collaborating actors' activities. Indeed, when applying coordination principles developed in section 2.1 and figure 1 within our SME partner, it has been noticed that the project managers often have difficulties in achieving the considered coordination tasks. On the basis of a little experience they know

how: to choose a team on scheduling criteria; to define the project structure with sub-projects, tasks and milestones; to characterize the responsibilities and objectives of main tasks; to schedule them until deadlines; and finally to analyse customer's needs. Nevertheless it is well known that inexperienced project managers and those involved in large and complex projects are commonly assisted by specialists. Some coordination tasks are still difficult for project managers:

(1) The definition of a project team based on the skills and roles needed in the project.
(2) The characterization of coordination rules: direct supervision, mutual agreement or normalization (Mintzberg 1990).
(3) The proposal of desired kind of communication between designers: diffusion, collection, circulation, exchange, meeting, knowledge sharing (Bareigts 2002).
(4) The definition of a preferred type of collaboration: free or forced, synchronous or asynchronous, in the same or different places, which level of communication, etc. (Johansen 1991).
(5) The identification and scheduling of the right design process.
(6) The definition and the evaluation of performance criteria based on product, process and organization points of view.

The proposed theoretical model (figure 4) is built to represent collaborative situations and to record previous elements. This model is based on the following main principle: from an external viewpoint the design process being implemented can be compared to a sequential list of discrete events. After having recorded these events, a project manager may characterize design activities to re-use them as a design process to be scheduled. We take into account all the characteristics identified from previous coordination tasks in order to define the collaborative events of a design 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 must be recorded. Moreover, the model should integrate different kinds of parameters by capturing quantitative data such as time, activity type or problems solved as well as qualitative data such as quality of communication or interests of actors.

These different categories of information characterize the collaborative events of a design project:
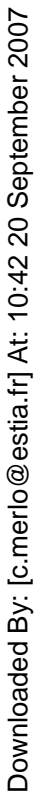
(1) The 'context of project' class, with the main information to situate the actor's tasks in the global project work of the company.

(2) The 'event' class that identifies any collaborative tasks and situations occurring in the project. An event defines a collaborative action which contributes to the progress of the project. As a consequence, tasks or milestones can be defined as events but the main interest of an event is to allow the definition of non scheduled actions such as a discussion during coffee break or an important phone call. 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 form of achievement (such as meeting, discussion, videoconference, conflict resolution...) through the 'activity subject' class.
(3) The 'collaborative criteria' class which characterizes 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...

After having characterized a collaborative event an 'evaluation' of the collaboration can be added and some analysis parameters and comments introduced to prepare future analysis through the 'analysis' class. Events may not only be 'linked' in a temporal mode, but also with causal links or problem links. For example, non-formalized 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 earlier event, this function is named 'link problem'. We can also make links between events in order to show that an event is the cause of the creation of another one.

The model of collaboration also takes into account the fact that tracked events can help to build processes composed of identified activities during evaluation and analyses phases. In this way several levels of granularity can be structured in order to describe more detailed processes. The classes 'activity' allows the management of an activity which is a sum of events like meetings, calls, mails, fulfilled to carry out the activity. This class 'activity' is linked with 'analysis', 'evaluation' and 'collaborative-criteria' classes in order to have information both on the activities and events. This requires the class 'eventActivity' to make an inheritance to the classes 'activity' and 'event'. Moreover, the granularity is managed through the links between the classes 'process', 'activity', and 'event' and by recording the complete structure of the project.

This model of collaboration categorizes and defines the different forms of collaboration used during project with

Figure 4. Design collaboration model.

the objective of re-using them in a future situation. This categorization is done by the recording of the context, objectives of the project and events; and by criteria to characterize the collaborative situation in design projects. This characterization leads to the analysis of the collaboration by the project manager.

Previous classes are dedicated to the storage and characterization of all collaborative events. Then the project manager needs to evaluate the situation and to introduce some analysis parameters and comments to prepare future analysis through the 'evaluation' and 'analyse' classes.

4.2. CoCa: a tool to support the model of collaboration

The CoCa tool has been developed in order to support the collaboration model presented in the previous paragraph. CoCa's architecture is a stand-alone client with a shared database.

The CoCa tool is intended for analysts of the design process. Owing to the numerous data to be recorded when recording all events in a design project, such analysts cannot be project managers nor designers but external persons such as PhD students. 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.

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 other data such as the impact of the project in the strategy of the company, together with text fields 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 contextualized for a specific project context.

4.3. Tracking collaborative events with CoCa tool

After four months, four different projects have been analysed in depth and more than one hundred collaborative events have been stored. Some results of the projects analysed are now presented.

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 provided for 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.* 2006). These criteria are used in the tool to describe the form of collaboration used in the event, so we can record whether or not the actors work synchronously, if they are co-located, if the event is planned, prescribed or formalized, if actors used specific tools, or information resources to do their work (figure 5).

Three other tabs record extra data on the collaborative event of the project such as the type of activities carried out

during the event, or evaluation of the form of collaboration used or the results of making 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 retain a history of the modifications made to the project context and on the event list during the project. For each version of the project context (figure 6) a comment field is

Figure 5.   Form of the tab 'Collaborative criteria'.

Figure 6.   Form of the 'project context'.

filled to give the user the opportunity to explain why modifications have been made.

For the analyst the main issue is to find a good enough body of information in order to analyse the collaborative practices used in the company and to thus improve his forecasts. The tool therefore needs first to provide a search by keyword and attribute to find main text data. Second a graphical visualization of the events with their links has been recently added in order to display the project process and the problem, causal and chronology links (figure 7). In the final version of the tool, a graphical visualization of information will be implemented to represent and compare various forms of collaboration with common criteria. Thus, various functionalities must be implemented in order to drive the analysis of the collaboration.

Finally, the tool will provide a specific form of output to visualize information from large databases (Jourdan and Mélançon 2004). The visualization 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.

5. From collaboration analyses to coordination proposals with CoCa tool

The following analyses take place in the 'AGV7' project. The customer is a global leader in power and rail infrastructure and asks for a quotation to manufacture equipments for a train engine. First a prototype has to be developed for the end of 2006 and this leads to the manufacturing of a generic product named 'AGV7' in 2007. A first analysis is made on a specific event then a second one on the whole events. In both cases the analysis is presented and possible improvements are proposed to the project manager for coordinating future projects.

5.1. Local analysis

In the AGV7 project, a problem of delay is identified during a meeting with the customer, at the end of the design phase of the project. The analyst must identify the origin of the problem by analysing the adequate event. Here in the event 'tools design' which precedes the late meeting, collaborative criteria give complementary information and characterize the event as an emergent, free and non-formalized event (figure 8). At this first step of analysis we notice that the event 'tools design' was not scheduled. Both project manager and technical team did not define the technical task 'tools design', and design process must be improved.

Possible improvements can be proposed. First new tasks such as 'tools design' can be introduced in the design process. Second project manager must characterize if this task is required for each design project or not, and if not what parameters should cause it to be scheduled. The project manager and the design team should evaluate these specific parameters at the beginning of and during the project. In this way 'nodes' of flexibility can be introduced in the new design process. They define alternative sub-processes in the main design process and may be implemented during the project depending on the specific situations during the progress of the project. Moreover, such flexible sub-processes can be managed automatically through a PLM tool for example.

5.2. Global analysis

After having analysed specific events and made local diagnostics and proposals, the analyst must detail these first results at a more global level by identifying links between events and correlate their different parameters to get more precise evaluations and new proposals. Links can be identified by comparing the first tabs 'context',
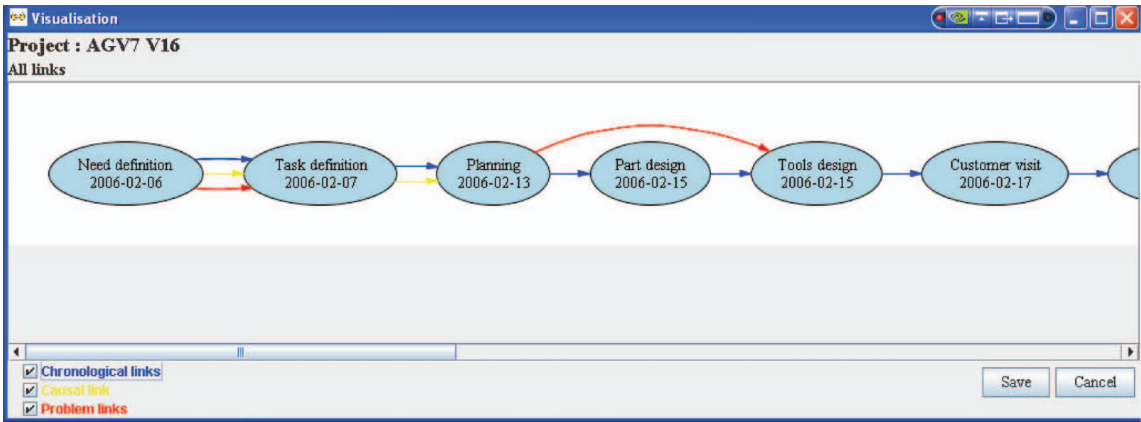

Figure 7. Visualization of the event sequence with the three links.

Figure 8.   Collaborative criteria of the project AGV7.

'type/subject' and 'criteria'. All these links show the design process with a specific viewpoint and allow rebuilding the sequence of the events of the project (figure 9).

The first event of the resulting sequence is 'needs definition'. In our SME partner the objective of this event is to define and validate the detailed needs of the customer in order to draw up the specifications of the product and to prepare the following event 'task definition. Inside CoCa tool, the corresponding 'analysis' tab of 'needs definition' event shows that the actors are fully involved (figure 10). This is indicated by a good evaluation of parameters 'consensus collaboration', 'high motivation' and 'constructive communication'. But the parameter 'unproductive collaboration' is set. Comments indicate that actors do not have enough free time, so they are not really concerned during this event: they seem to be involved but no detailed job is done. The analyst identifies here a possible problem and correlates it to the following event 'task definition'. He then formalizes its analysis in the 'links' tab (figure 11) of 'needs definition' through a problem named 'PAT'. The main problem occurring is due to a lack of time for the actors to carry out the task: for analysing the customer specifications designers had a too short deadline and this is the real cause of the problem.

In terms of diagnostics, there are problems in management of project teams that lead to this kind of behaviour. The project manager has to manage the workload of each actor in order to know exactly at any time who has enough time to do the work. Moreover the project manager has also to manage the 'skill pool' of the team, indeed to know with some accuracy what the skills of each actor are in order to associate the right task to the right actor. Consequently this problem is more a problem of the project management role as the project manager must be able to evaluate the tasks to do by himself and then to ensure these tasks are achieved.

A possible solution can be to negotiate more time with the customer; this is how the company manages delays in reality. However that can be difficult and another kind of solution is to manage the skills and the experience of the designers differently by, for example, choosing skilled designers when the delay has to be short. A third solution

Figure 9.   Context project of the AGV7 project.

can be to improve the way the project manager and the team manage designers' time and priorities between different projects in a multi-project environment. Both of the latter solutions are new to the company and its inexperienced project manager.

5.3.   *Synthesis: a method for analysing collaborative data*

In previous examples, a systematic and global method can be used to analyse the CoCa data. First, the entry point is generally a local analysis of an event where a problem or a really good result is identified. The analysis and the evaluation made during the data recording are essential and then the 'problem' links help the analyst to begin a more global analysis. These evaluations and analyses give a first overview of the situation and orientate the analysis towards other parameters or events in order to make correlations between them. Second, the global analysis of events is achieved with the local context and the collaborative criteria in order to have detailed information that will allow understanding the whole situation and its origin to finalize the analysis. Afterwards the same approach is repeated for each event linked with another one. And finally the global context of the project is studied to correlate all the information found from the beginning of

Figure 10.   Analysis of the event 'Need definition' of the project AGV7.

Figure 11. Links of the event 'Need definition' in the AGV7 project.

the analysis between them. At the end of the analysis the observer has identified situations where technical problems or problems of collaboration appear, or where the collaboration is useful and 'good practices' can be identified. This identification is made thanks to the analysis of the CoCa material. Based on this identification and on the complete analysis the analyst can propose 'guidelines' to improve the design coordination.

The analyst records, modifies and evaluates data; the project manager and designers control and validate recorded data. Analysts must work closely with project managers and designers in order to better understand events occurring and to propose pertinent improvements to the project manager. In previous case studies, such improvements concern several categories of actions: for example concerning design process such as tasks specification or nodes of flexibility; concerning product design such as characterization of technical parameters for flexibility nodes; concerning project manager skills and actions like long-term skills management or scheduling method; and also concerning communication such as relationships with team coordination.

5.4. Feedback for a coordination model

These short examples show that a lot of information about the collaboration occurring during design projects can be stored. Combining different items of information can lead

to detailed analysis of problems or good practices in order to define guidelines for project managers.

A first version of the model of coordination was developed in Merlo *et al.* (2005). We propose here a second version (figure 12) which includes improvements resulting from previous collaboration analyses. The main point deals with the problem of granularity concerning the management of events and their links with tasks scheduled by a project manager. In applying the first model a project manager describes the design process that he is expecting to be completed. With this second model, a project can be structured into several design processes which represent different levels of granularity. Each design process will then be composed of tasks or milestones. Moreover the management of the granularity level in projects is represented by the loops on the classes 'project' and 'designProcess' to represent the sub-projects and sub-processes and their links.

In this way the detailed description of a project will include the notion of projects, sub-projects, processes, sub-processes, activities and events.

The new version of the coordination model must also take into account the notion of flexibility in the design process. Indeed, links between process elements will represent more faithfully the various possible transitions during the progress of the project. These links are managed by a class 'transition' which can represent links types such as: 'and', 'or', 'if', 'else'... In this way the project manager can manage the design processes better by excluding sequences or creating new ones according to the design situation (customer, product, actors, suppliers...).

Such a model must be implemented in a global project management tool in order to propose an integrated environment to project managers, allowing them to make their coordination tasks, to track collaborative events, and define more detailed processes as a possible feedback. This feedback can take several aspects such as: detailed processes can also be implemented through PLM systems; good practices can be formularized as work procedures corresponding to specific design situations; or guidelines for the project managers (new parameters, new criteria, and new control tasks, to take into account before a decision).

5.5. 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 use, improve or reject a collaborative practice that has occurred in projects. This is one of the main ideas that guide this work. We proposed a model of collaboration and a tool to support the analysis of collaboration in order to
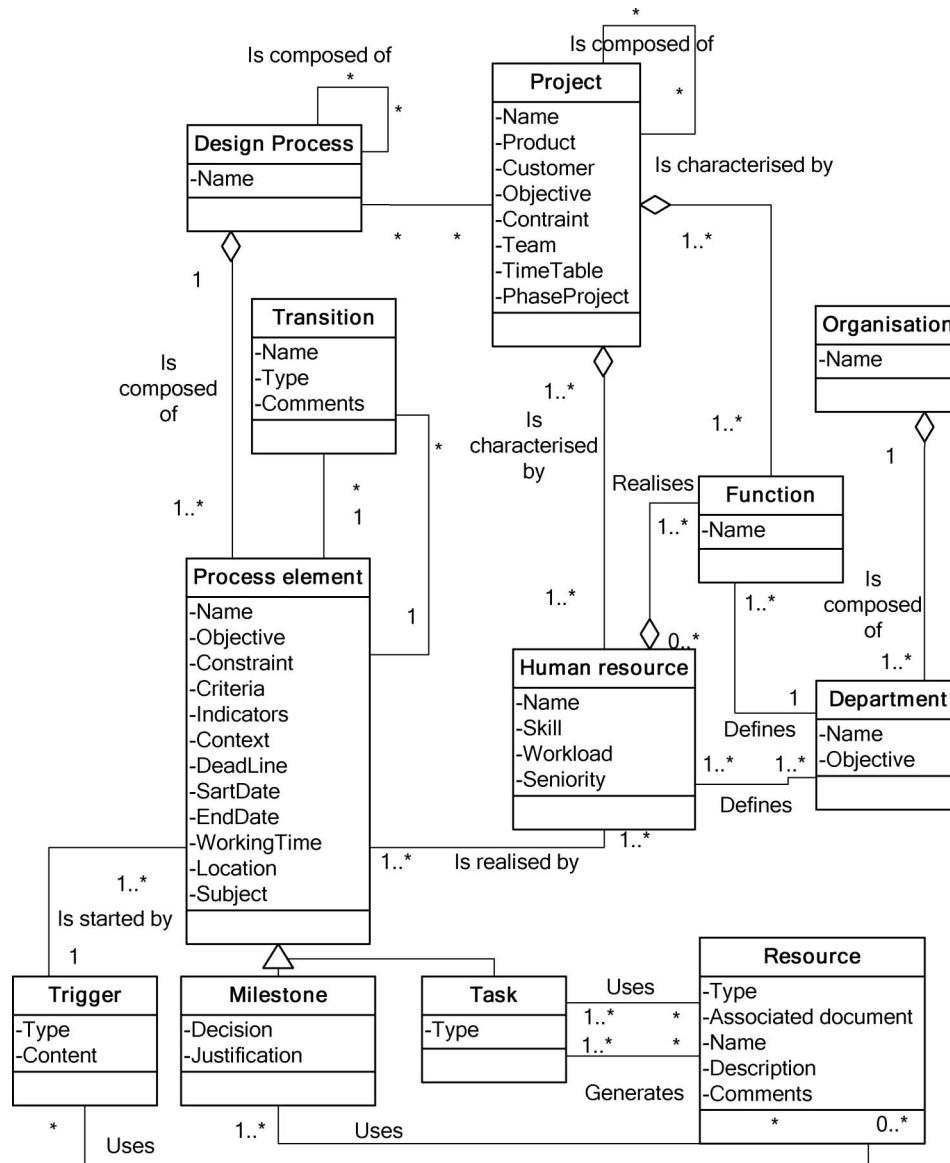
Figure 12.   Improved coordination model.

help project managers to coordinate design. A coordination model has been improved to allow implementing good practices issued from previous analyses. Nevertheless this approach has just been evaluated through one case study and needs other studies and more improvements to be validated at a generic level. We need more practice in other industrial case studies in order to identify:

(a) more collaborative criteria;
(b) new factors influencing the collaboration and the coordination;
(c) the best practices according to the design situations;
(d) the guidelines resulting from the analysis to improve the coordination of design projects.

The main limitation of CoCa tool is the subjectivity of the observer. The actual architecture of the tool does not allow us to have multiple points of view of the same event. Indeed two persons cannot collect information on the same event in the same database. However, the tracking of different interpretations and analyses would be interesting for a future version of the CoCa tool.

Another point 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.

From the experimentation various propositions can be made to improve the analysis of the collaboration.

The first main improvement concerns the automation of the analysis thanks to statistical studies. More studies must be done to validate this idea: can good practices be correlated to specific values of adequate criteria? So several pre-requisites are needed:

(a) to validate that the characterization of the collaboration introduced in the automatic analysis is useful;

(b) to record enough data to make the statistics relevant;

(c) to find the adequate statistical tools to manage the data.

In this way, new GUI forms that support semi-automated and statistical treatments for analysis, will improve the analysis process. These statistical treatments will be able to show critical recurring situations by charts, curves and graphs.

The second improvement concerns the method to analyse the collaboration. For the moment the method begins by the study of the 'analysis' and 'evaluation' tabs made 'on the spot', but the improved method must be based also on a detailed statistical analysis of the criteria. This statistical analysis will be able to provide a 'check list' of critical information recorded with CoCa in order to drive the analysis progress. An extra module to help the implementation of this method is under construction. This module will allow the representation of graphs and queries on the events in accordance to the type of links, and it will notify the analyst if the event has an evaluation or analysis 'on the spot' recorded.

In the discussion we have explained the importance of the level of granularity management in the analysis. As a consequence, tracked events can be seen by people as scheduled tasks or as un-scheduled events in order to identify formalized procedures but also real and flexible tasks sequences at a more detailed level. This can be used to extract from lists of events formalized 'processes' composed of 'activities' which are events or sets of events. This information is generally useful to identify shortcuts or alternatives in the traditional process, then to analyse the parameters leading to these situations.

6. Conclusion

Coordination in design is essential to reduce cost, to improve product quality and to meet deadlines. But collaboration between actors is important to federate actors and make coordination 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 have implemented such an analysis tool, CoCa: it does not help with coordination (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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