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ENSURING THE INTEGRATION OF PERFORMANCE AND QUALITY STANDARDS IN DESIGN PROCESS MANAGEMENT: CODESTEER METHODOLOGY

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ABSTRACT
The current competitive environment urges all companies to launch actions striving to improve their activities, in regards to products, processes, or organizational aspects. But how to intervene? What are the measures which will optimize in the best way the system performance? Parallels, with the aim of a better global efficiency, indicators and dashboard are fulfilled and monitored within robust Quality management system allowing a better steering of the companies' interests regarding strategic objectives. But are they well adapted and well integrated regarding the needs of the design activities? In order to set the basis of a framework, we present, in this paper a state of the art of what we call "performance" and "quality" in design. We look at the stakes of coupling the 2 concepts and the limits of the existing models. We therefore strive to present the CoDeSteer methodology (Collaborative Design Steering), describing a static model and a dynamic loop to implement it. The last section of our article depicts a software application of CoDeSteer and its roll out on academic design cases.

Keywords: Performance assessment, performance indicators, design management activity, best practices, Quality.

1 INTRODUCTION

1.1 Research context
Technological evolutions, concentration of actors, products more and more complex, new consumers, security, environmental protection… The improvement of the performance design is in the middle of the concerns of many R&D Departments today and is a source of numerous challenges to be found. From the research point of view, most of the work led in the field of design aims at improving the performance of the design process. Since the beginning of the 90s, numerous works has been perform in the domain [1]. In the specific case of routine product design, the implementation of a repository for performance management in the design activity can be a decisive advantage. However, a number of requirements from quality benchmarks or specific references in the company already exist. Our research work specifically focuses on this axis and aims at providing a reference frame combining the advantages of a quality system while incorporating a performance management system for the design activity. The present works have been realized within the framework of the CODEKF project [30] . This project has been labeled by the French automobile competitiveness cluster "Vehicle of the future" in *Alsace* and *Franche-Comté* areas in the east of France. This project is mainly focus on firms that are for the majority in the considered market area: rank 1, 2 or 3 subcontractors of the automotive industry but the results of the present article can be extended to every design situation.

1.2 Research methodology
We based or assumptions on industrial real cases studies, following the grounded theory methodology. We first of all lead an industrial survey among various companies working for the automotive industry in order to draw an inventory of fixtures in Engineering and Design Departments. We then confront our findings with the existing research works existing in the performance and quality field within design. We therefore reveal the lacks existing taken into account a view mixing performance and quality in design. As an answer, we propose CoDeSteer methodology, based on a static model and a dynamic loop named PoDCAS for implementing the methodology. We finally present the results of

the roll out of the CoDeSteer methodology and a software application embedding the concepts of the methodology in order to get more efficient results.

2 INDUSTRIAL SURVEY: ENGINEERING AND DESIGN DEPARTMENT ORGANISATION

2.1 Field study framework

This study was mainly rolled out during early months of 2009. We selected a sample of 40 firms and lead mainly phone call and email interviews. Most of the time, answers come from the head of the Engineering and Design departments (EDD) or project managers feedbacks. We initiate our interviews following the three directions:

- The management field;
- The Knowledge management and methodology management field;
- The training field.

We were mainly interested into the first two fields. The last field was more deeply investigated into [2].

2.2 Inventory of fixtures of the EDD regarding the management field

The notion of management gets in the EDD field in the operational direction only; the tactical and strategic levels being most of the time, not within the competence field of the project manager or the person in charge of EDD. We wanted here to know the ways of functioning and the underlying organization for the considered EDD.

Most of the interviewed companies acknowledge leading some competence evaluation inquiry (70%). Concerning the EDD personnel, the evaluation is steered by the Human Resources Department (40%) or by the project manager (25%). We can notice that only 15% o the interviewed service use poly-competences matrix to evaluate and follow the competences of the EDD members.

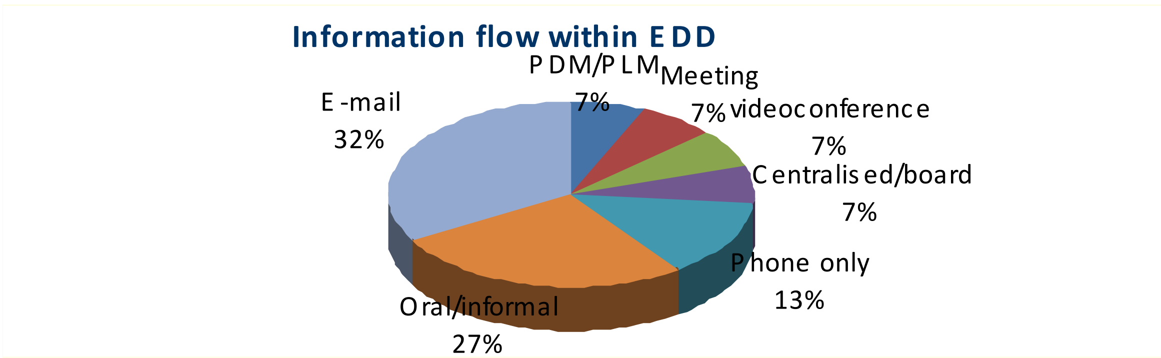

Figure 1. Support of information flow within the EDD

Concerning the way the information flow inside projects is managed, the email is mainly use (Figure 1). Informal talks are also usual. This kind of non-managed information can be also explained by the fact that the interviewed companies as well as their EDD were relatively small. Since the information flow is not really mastered, we will see in the next paragraph that the KM is also not really efficient.

2.3 Inventory of fixtures of the EDD regarding the KM field

We questioned the companies about their habits regarding Knowledge Management and specifically CAD methodology used in their projects. 82% of the team leaders assumed using methodologies in CAD. When asking CAD users, only 51% acknowledged using them. 18% of CAD users know that a specific CAD methodology is existing for each CAD domain of expertise and only 12% assume having already capitalized their CAD knowledge. While investigating the way these methodologies have been setup, and where are they stored, a strange answer come from the fact that it was mainly informal or paper folder stored (55%). This means that they are must of the time not maintained.

When dealing with the way the methodologies are acquired, for half of the companies using them, they used specific training. For the others, it is just informal explanations or technical notes.

A second wave of face-to-face interviews led in the same industry field allows us to depict the way design project manager ware able to capitalize knowledge in a more general way. We first noticed that all the questioned firm were ISO 9001:2008 [3] or ISO/TS 16949:2009 certified [4]. The main way of capitalizing knowledge was: using the intranet (not well structured), using ISO documents (not well filled most of the time) or using Lesson Learned Boxes (good results if well broadcasted within the department). Questioning the project leader upon the way they were monitoring their projects, the only indicators were the classical triptych Quality, Cost and Delay.

Debriefing on this inventory of fixtures, we observed that the notion of performance evaluation, even if it is at cornerstone of each organization, was not so clear within the design activities (in term of process or organization concerns). The quality process, for the CAD application for example, but in an overall point of view was also not clearly set. We therefore decided to focus our research work on the way of coupling quality management and performance management in design process.

The next sections try to propose a quick state-of-the art of these concepts in the design field.

3 WHAT IS PERFORMANCE IN DESIGN?

In the field of performance assessment, looking at the design activity, the difficulty is to make the difference between the performance of the design activity and the performance of the design management activity (Figure 2). The purpose of the design is to answer the expressed needs and to optimize the artifact, whereas the purpose of the design management activity is to manage and improved the output of the activity itself [5]. They cannot be separate, but the way of managing them will not be the same one.

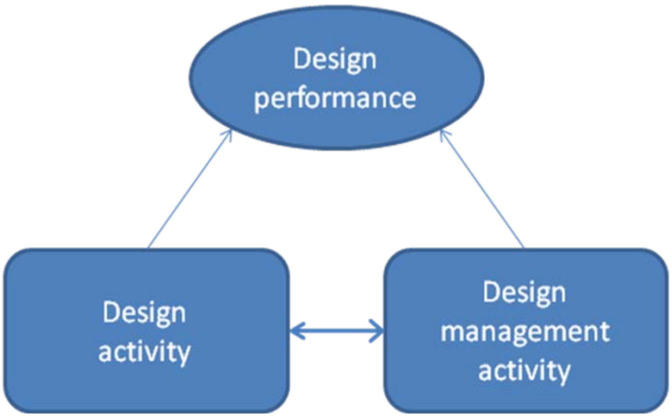

Figure 2. Performance relationship in design [5]

3.1 Why performance in design?

Design determines 75% of quality and costs from the choices which are carried out at this stage [6]. And in economic terms, one speaks about 90% of the costs engaged at the end of the design for only 10% of cumulated real expenditure [7].

The design activity has a strong evolution due to these reasons. And this evolution goes in the way of an optimization when it comes to the development of the design in its planning or in its management.

If we take into account the fact that the main part of the defects are made at the design stage, it is obvious that the design management activity is a mean of reducing these defects.

3.2 Design management activity performance and Knowledge Management

The performance management is the logical following of management by objective. It is an iterative process. It rises legitimately from the systems of continuous improvement like Deming wheel. But because of the increasing complexity of the projects and their management, it is not any more possible to identify the measurement of the performance as being an only "economic" performance. It is necessary to take into account a plurality of performances which will allow the achievement of the fixed objectives. The performance management requires a more precise and sharp implementation in regards of its objectives. It is thus imperative to fix clear objectives. To identify clearly this vision, it is of primary importance that the problems are seen in explicit ways and that experience feedback is made of rigorous manner, to be able to serve as new resources.

Design can be seen as the fulfillment of the implemented knowledge [5]. The knowledge is in perpetual evolution within the specific processes of design, between the reality of the project and the theory where the project started. Knowledge and its management inside the design process is one of the most important point. O'donnel and Duffy show us a design model based on knowledge management, that has four types of knowledge that circulates around a project:

- The input knowledge: which is the knowledge that is present before the beginning of the activity.
- The output knowledge: which is the knowledge which that is generated during the activity. Best practices can be found within this knowledge.
- The knowledge of purpose: it is about knowledge which steers and forces the activity.
- The resources knowledge: this is the knowledge that is going to act with the input knowledge to produce the output knowledge.

3.3 Limits in design performance modeling

Many process models have been studied in the literature on product design [8, 9]. Nevertheless, a literature review laid on the specific field of performance in design showed us that there are only few models and formalism dedicated to performance in design. We pinpointed 3 main models able to answer to the design management performance evaluation: the O'donnel and Duffy methodology[5] for design performance modeling and analysis (PERFORM), the GRAI R&D methodology [10] and a proposal made by the PSI/produktiv + consortium [11]. These models are more deeply detailed regarding our concern in [12].
We can notice an overall lack of references in relation to the concept of performance itself. O'Donnell and Duffy [5] outline a few attempts that take into account different models of process developed in the 1990s. The elaborated models have however most of the time a border relatively badly defined between what is related to the performance of the design management activity in itself and what is related to the performance of the design activity and the artifact. Most of the time, the performance listed in the scientific works concerns the product performance and the artifact itself in specific areas [13]. The O'donnel and Duffy model, as well as the GRAI model, however take into account this essential differentiation, to consider the intrinsic performance of the organization and design teams, without mixing the characteristics of the product designed. The Girard and Robin model also allows this differentiation between local and global objectives [14].
However, the problem with these various models is their relatively non-experimental and non-use in a real industrial framework. Indeed, any research in the field of design aims at promulgating results, in other words approaches, methods, models and tools, which could improve the performance of the design activity. However, the relationship between the use of these methods, models and tools and the real improvement of design performance in their implementation in industry is rarely demonstrated.
The integration and the choice of parameters or indicators which were selected must be accurate to allow greater clarity in the design management. Therefore, standardization of the performance evaluation process might be the solution. Regarding the normative literature, this should be undertaken by following norms exigencies. In the next sections, we examine the quality systems for design management.

4 THE NOTION OF QUALITY IN DESIGN

4.1 Quality for R&D and EDD departments

Quality in Design project had been treated in various norms and in some research papers. We present here a synthesis of those works.
Regarding the standards, in concern of the product design, the usual requirements in term of quality management are in the norm ISO 9001, 2008 [3] chapter 7.3 The standard show us the important steps to follow, for designing and develop a product.

- Planning Design and Development
- Definition of input elements of the design and development
- Definition of output elements of the design and development
- Design review and development

- Verification of design and development
- Validation of design and development
- Control of design changes and development

However this standard does not define the explicit information that has to be in place at each step of the design project.

A French standard [15] named *process control design and development* specifies three particular steps of the design process.

The first one is the control design that includes guiding the process design and management of design projects. The second step is the design process development that can be divided into five phases (Specifications of the needs, Capability of the organization to perform the design, the choice of the solutions to be developed, detailed study of selected solutions, validation and acceptance of solutions). The third step is the modification of the design or Re-design : this step establishes that any change occurring in documents or databases must be analyzed to evaluate its justification and impact on product realization; specifying actors, documents, times and reasons for the changes. ISO 9001 version 2008 with its Chapter 7.3 and the standard FD X 50-127 are the two main standards at international and French level that apply specifically to the design activity and design process for its control. They are mainly related to aspects of planning the design activity. As a conclusion regarding the analysis of these standards, we can state that they are low detailed and do not refer to a system of performance evaluation in the specific field of the design activity. In the next paragraph, we have therefore strived to study the research works that have undertaken to bridge the concept of Performance and Quality in design.

4.2 Performance and quality in design

While studying performance and quality in the design field, we can notice various aspects. In this study we resumed the main themes. We will focus here only on two categories: “quality performance and knowledge management” and “the concept of quality and design management”:

- The quality system performance and knowledge management category describes how the system generates knowledge within the quality system [16, 17]. Furthermore it demonstrates the relevance of this approach for companies that primarily generates and manages this knowledge, knowing that the performance increasing is in the managing of this knowledge.
- “the concept of quality and design management”: this second category includes a large number of scientific papers on quality and design management. In [18] the author shows for example that the management of the design process allows higher quality performance whether internal or external. A structure for the synergy between these different methods of management which are very different depending on their strategic alignment within the company is also presented. In [19], in order to address the quality in terms of designing the quality system beforehand, the authors show its influence on quality performance.

The concept of quality in the design process is addressed in some research works. However, a number of questions remain suspended in this field. We show in the next paragraph some of the gaps existing while dealing with performance in design activities.

4.3 Questions and gaps regarding performance and quality in design

Performance management practices, such as performance appraisals, are often considered to be incompatible with the principles of quality management. But if designed appropriately, performance management systems could support rather than hinder quality. These past years, organizations view performance management as the successors of management by objectives. They see performance management as a key system that can promote and sustain good initiatives such as business renewal, and quality management. [20]

Deming [21] and others argued that performance system management is not compatible with the quality management. The main issue was that performance management was too focused on individual characteristics rather than on system factors. In the quality perspective questions, the emphasis is more on individuals rather than on aspects of systems as being relevant to work performance. In response to Deming's admonition, a number of researchers countered that traditional performance management practices could be customized to support quality. The debate resulted in several prescriptions for adapting performance management system components to the people requirements of quality. Whether or not this abundant advice resulted in new performance management configurations in quality-driven

organizations remains largely unknown as academic work was directed more at developing conceptually appealing alignments than at validating them.
In our literature review, we noticed that the subject of the performance of collaborative design and quality is not addressed from the perspective of performance management design in a quality system. The interest of studying quality in design is to establish a benchmark and standards for improved performance of the quality system [19] and performance of the overall company but results are mainly focuses on its production system [22]. The explicit use of the quality system as defined in [3] for managing the design project will affect the performance of the design.
The literature offered advices but failed to address the need for research findings that elucidate key alignments between quality and performance management. We therefore argue that this is problematic on both theoretical and practical grounds. First, a lack of empirical evidence casts doubts upon the validity of theorizing in the area of strategic human resource management. A demonstration that performance management systems correspond in hypothesized ways to a quality emphasis would provide suggestive evidence that organizations are indeed linking their performance management practices to broader environmental variables. Second, from a practical standpoint, empirical evidence of an alignment would suggest that performance management systems can be compatible with quality, a proposition that in itself remains widely disputed. Such evidence would further point to the strongest and weakest links between quality and performance management system design features [20].
So through a real alignment of the quality and the performance management system, we can produce a greater performance system. Then for managing design performance we know that we have to take a system or an organization in its global view, keeping in mind the triptych of management goals/results/resources. There are many tools and models in quality management and project management, but in general these tools are very general. In fact, these tools do not effectively measure the performance of design project. The view of the performance in the ISO 9001 was revisited in its 2008 version as shown in [23] but is still too broad for the context of management of the design process and does not accurately respond in terms of relevant parameters for these activities.
In the next section, we therefore propose the Codesteer model as a way of coupling performance evaluation and quality standards integration in collaborative design project.

5 OUR PROPOSAL: THE CODESTEER METHODOLOGY

5.1 Static point of view

Striving to handle the various problems pointed out in the previous section, we present here the CoDeSteer (Collaborative Design Steering methodology). This methodology is first of all based on a static model, depicted through an UML Class Diagram and enriched via a dynamic loop presented later. This model “CoDeSteer” (Collaborative Design Steering) incorporating both the concepts of quality and performance management for collaborative design of manufacturing products (Figure3).

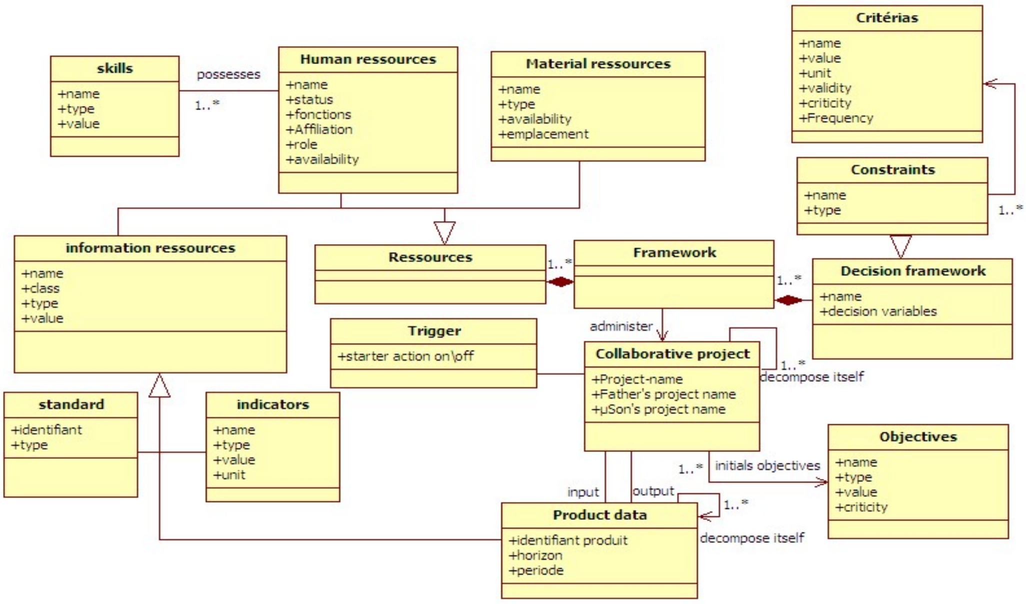

Figure 3. Class diagram of the CoDeSteer model for performance in the design process

Our class diagram incorporates the approach of modeling the project after IPPOP [24-26] by including an explicit reference to formalize the process under a quality approach. We chose UML because of its ability to be easily handled by developers. This language of technical communication allows us an easy translation in terms of computer specifications of our approach. Thus the model is a basis for a software application that we present in the next section. Here we explain the concepts presented in the UML class diagram in figure 3.

The *Resources class* is composed of the three resources in a project design: information resources, human resources and material resources. In the different quality procedures that are used within the project management of design, resources must imperatively be present from the beginning of the project. As presented in[3, 15], information management is essential from the beginning of the project.

The *Framework class* represents the reference model of the standard. It is in this class that will formalize the project according to the quality standard used for managing the project design. It will also incorporate the performance indicators specifics for each hierarchical level of the project as well as the best practices of the past projects. These “process” best practices will be acknowledged manually, thank to an *a posteriori* performance debriefing of the project. These best practices, embedded within the framework class, will be therefore candidates for future alike design projects.

The *collaborative project* class gathers the specific information of the current project.

The *Data Product* class is the class for all the various information that will be generated during the project. It allows, according to the values of the different *performance indicators* and thanks to the information coming from the *framework* class, to steer the design activity.

To handle a performance evaluation thanks to this model, we need a strong referential, that is why ISO 9001[3] and the AFNOR FDX50 127 [15] design elements were embedded within the *standard* class. Those standards give us a guide for the process of design project. Every project subdivided itself in subprojects or activities. Each activity will have his pool of indicators, objectives, and constraints.

5.2 Dynamic point of view

Following the continuous improvement trend in quality, we could not avoid to take into account a dynamic point of view in order to handle the CodeSteer methodology.

Studying various cycle used in quality (namely PDCA, SDCA, DMAIC, DMAICS), we measured the pro and cons of these various quality cycle. The classical PDCA (Shewart cycle or Deming Wheel) [27] is not pertinent regarding the performance point of view. SDCA take into account the standardization phase that can be helpful regarding the way of integrating our best practices within the framework. Coming from the 6 Sigma methodology [28], DMAIC is not so different from PDCA in its philosophy: the process vision as well as the supplier/client point of view are present in these cycles [29]. Nevertheless, DMAIC let more place to the performance evaluation thank to the “Control” Step. DMAICS add the standardization phase. As far as the design process requires some incompressible stages, the mix of DMAIC and Kaizen Blitz approach proposed by [29] is not suitable for our purpose. Despite their advantages (they handle a measure and an analysis stage) , DMAIC and DMAICS do not allow in themselves to increase process performance as well as the capital of knowledge exchanged during the design activities. We therefore propose the PoDCAS (Plan, -organize, Do , Check, Act, Standardize) cycle in order to answer to the lacks of the preivous cycles regarding CoDeSteer methodology. This cycle is composed of 2 embedded loops as described in Figure 4. In order to promote an easy use of this cycle, we choose to depict it in a way that it can be easily understandable, like the Deming Wheel and we have therefore chosen to not use the UML representation.

Figure 4. PoDCAS cycle for dynamic implementation of CoDeSteer methodology

As in the PDCA cycle, the first stages are:

- Plan, Organize: Planning of the design activities and organizing of the project strategy thanks to the items gathered in the standards.
- Do: rolling out the elements and the design activities planned in the previous stage.
- Check : Checking and monitoring of the results thanks to the various indicators
- Act : analyzing the causes of the variations observed at the previous stage in a way of applying corrective actions.

  We therefore add a fifth stage:
- Standardize: Validating and promoting as best practices the best process activities in order to generate a more efficient planning in the next stage.

The next section proposes a roll out of our methodology on academic experiments.

6 TESTING THE CODESTEER METHODOLOGY

6.1 Manual use of the repository

We first of all tested the CodeSteer methodology in an academic experiment in order to check the validity of our methodology. The first roll out was done manually (using Excel tabs to gather the results) following the PoDCAS Cycle, on the subject of the reimplementation of a workplace. The performance indicators were the quality of the design handed out by the students (judged by a pool of teachers). This experiment was run 3 times over 4 to 6 student groups, with a standardization phase of the best practices at the end of each run. Thank to the use of the PoDCAS Cycle and the integration of best practices within the framework, the overall Quality of the results increased (Figure 5).

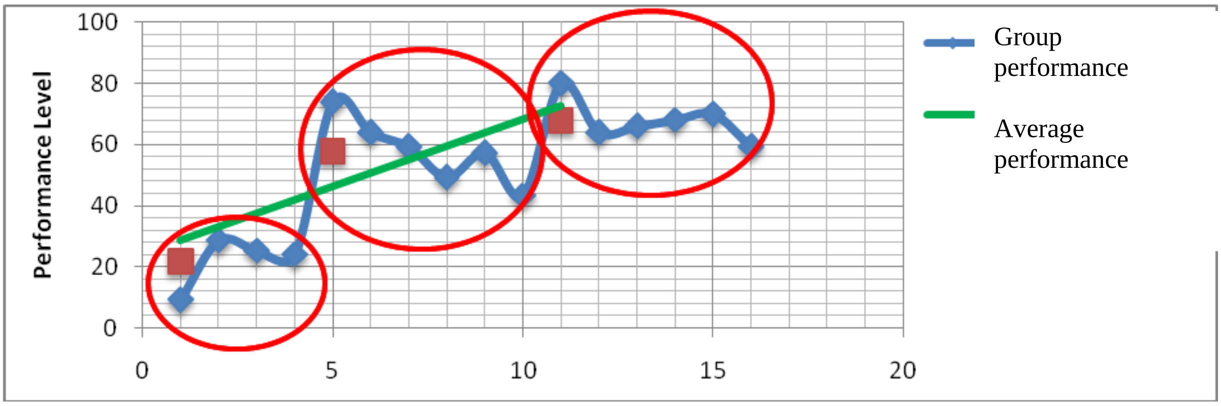

Figure 5. Monitoring Design performance with CoDeSteer

Nevertheless, the monitoring of the various results was really fastidious and not at all efficient.
We therefore decided to automate the CoDeSteer methodology and develop a software application allowing monitoring easily the management of design projects. The next section presents our software prototype.

6.2 CoDeSteer Software Prototype

We choose to develop our prototype following a web technology in order to dispose of open source tool and to have an easy-running solution. A classical 3/3 architecture based on a Cherokee Web server, a MySQL database and browsed via every internet navigator was adopted. We followed the standards of the W3C in order to meet these requirements. In order to have dynamic, functional and user-friendly web pages, we used was the PhP language as it is easily implementable and maintainable.
We presents the various functionalities of the software following a second academic experiment run with the help of the software, on the subject of defining a eco-friendly tractor toy for children, as proposed in Figure 6.

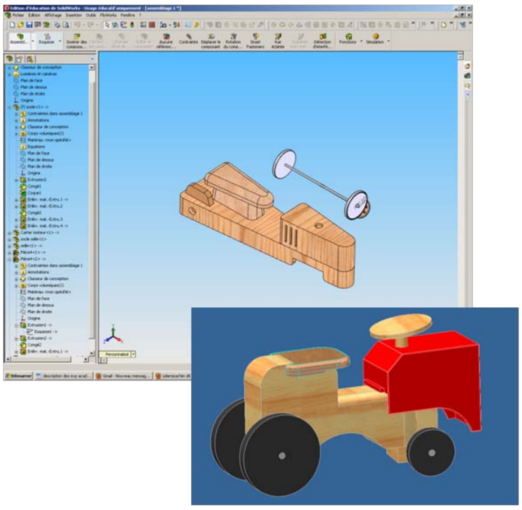

Figure 6. Academic assignment: designing an eco-friendly tractor toy

In the administration window, the project manager instantiates the resources to every activity and tasks as well as the indicators to be monitored during these activities. This corresponds to the "Po" phase of the PoDCAS cycle. Resources are the tasks to be handled, the material and informational resources as well as the affectation of the design actors to these activities.

The second stage is the "Do" phase. It is in this stage that the design actors run their activities and will enter the various commentaries regarding the running of their activities. During this stage, the level of the performance indicators is completed regarding the chosen indicators (Quality of the work hand out regarding the requirements and delay for our purpose in this example). The details of the activities are visualized while highlighting the activities (Figure 7).

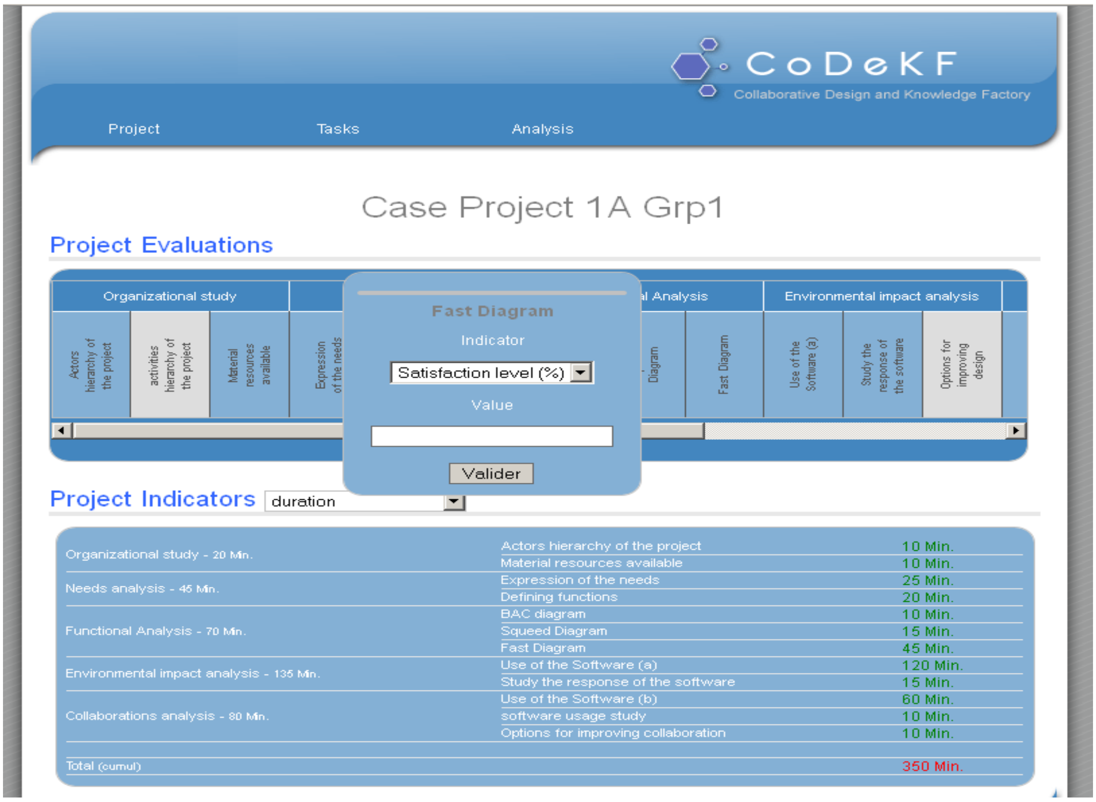

Figure 7. CoDeSteer Graphical User Interface for performance recording - "Do" phase

The "Check" stage: in this stage, we verify the level of performance. The graphical interface differs depending of the type of the chosen indicator. This is done with the aim of targeting easily the activity that get the best results and the one that are the worst marked.

The” Act” stage is fulfilled while analyzing and comparing the various activities as proposed in Figure 8. This is done via the selection of activity that man wants to compare. At this stage, the validation of the various knowledge created during the project is effective. The best practices are therefore decided here, according to the level of the performance indicator acquired. For our purpose, regarding the customer satisfaction indicator, the best practices will be when the students will have the best marks upon this criterion. The capitalization of knowledge is done in the software database.

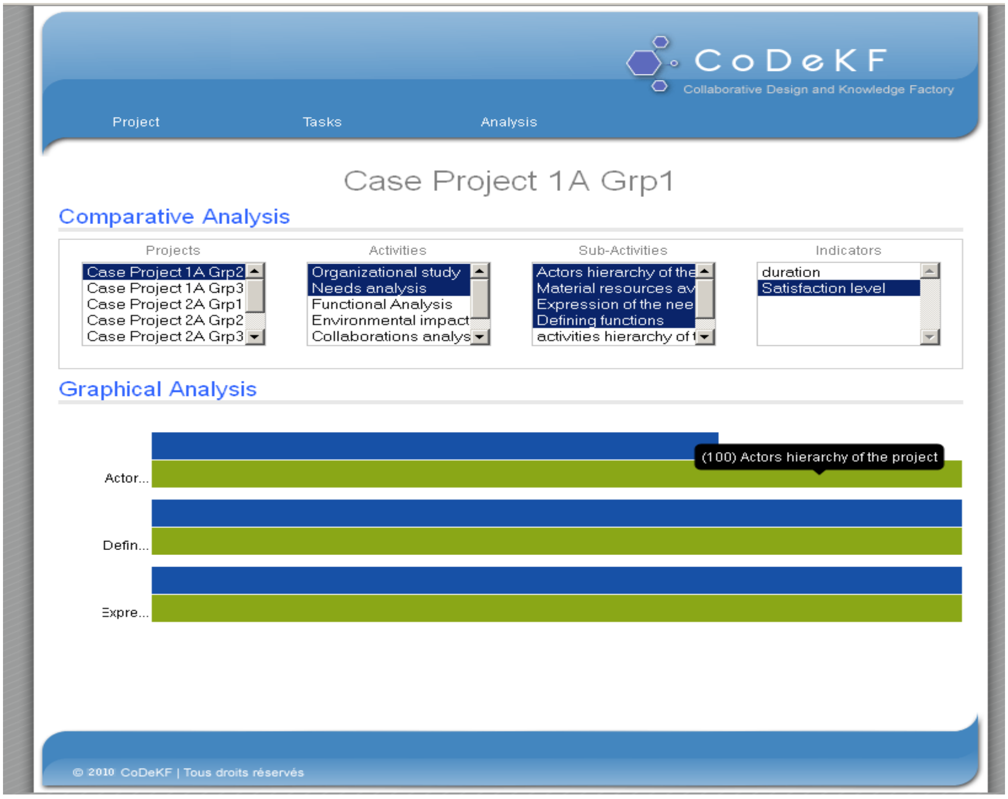

Figure 8. Comparing and Analyzing best activities in order to promote them as best practices

The “Standardize” stage is based on the results from the previous comparison. We take the results coming from the previous stage and create a standard process based on the best practices elicited previously. This standard process could be re-instantiated as the project manager will find a similar routine design process.

The best practices therefore appear as the goal to be reach on the diagram of the software prototype, allowing an easy monitoring for the project manager in a new similar project. This was done on our academic example, taking into account the results of a first bench of students and fostering the best practices in the software in order to have a goal to reach for a second session of students working on this exercise (Figure 9). Compared with the first academic experiment, this automation through the CoDeSteer software prototype allow a significant gain in term of data collection, analysis and best practices knowledge promotion for further project.

7 CONCLUSION AND FUTURE WORKS

Taking into account the requirements as well as providing a framework for the performance evaluation of the design activity is a vital asset to the design project managers today, but this must be done regarding Quality requirements existing in the various international norms and standards. Following an industrial survey, we synthesized the existing models seen in the literature and gaps corresponding to the particular situation of the design activity regarding performance and Quality stakes. Then we presented the CoDeSteer methodology based on a static model and a PoDCAS cycle for implementation. We then proposed of a software prototype based on CoDeSteer specification and a roll out of the methodology on two academic experiments in order to show how the validation by the performance of the best practices in design process and their reuse can significantly increase the

performance level of the design projects. Future works on the subject could be done around the integration of this methodology within a framework of Lean Product Development Management.
A second research perspective is the application of these results to allow performance improvement on all aspects of design (view Product / Process / Product / Usage). In this work we were focused on Process and Organization aspects. However, the CoDeSteer methodology can be easily adapted for a product point of view. To do so, adding Product/ usage ontologies would be a necessary step in order to categorize the "best practices" validated by all stakeholders in a given context. Thus, this methodology is totally adapted to eco-design, the concept of Best Practices taking in the context of sustainable development an even larger scale.

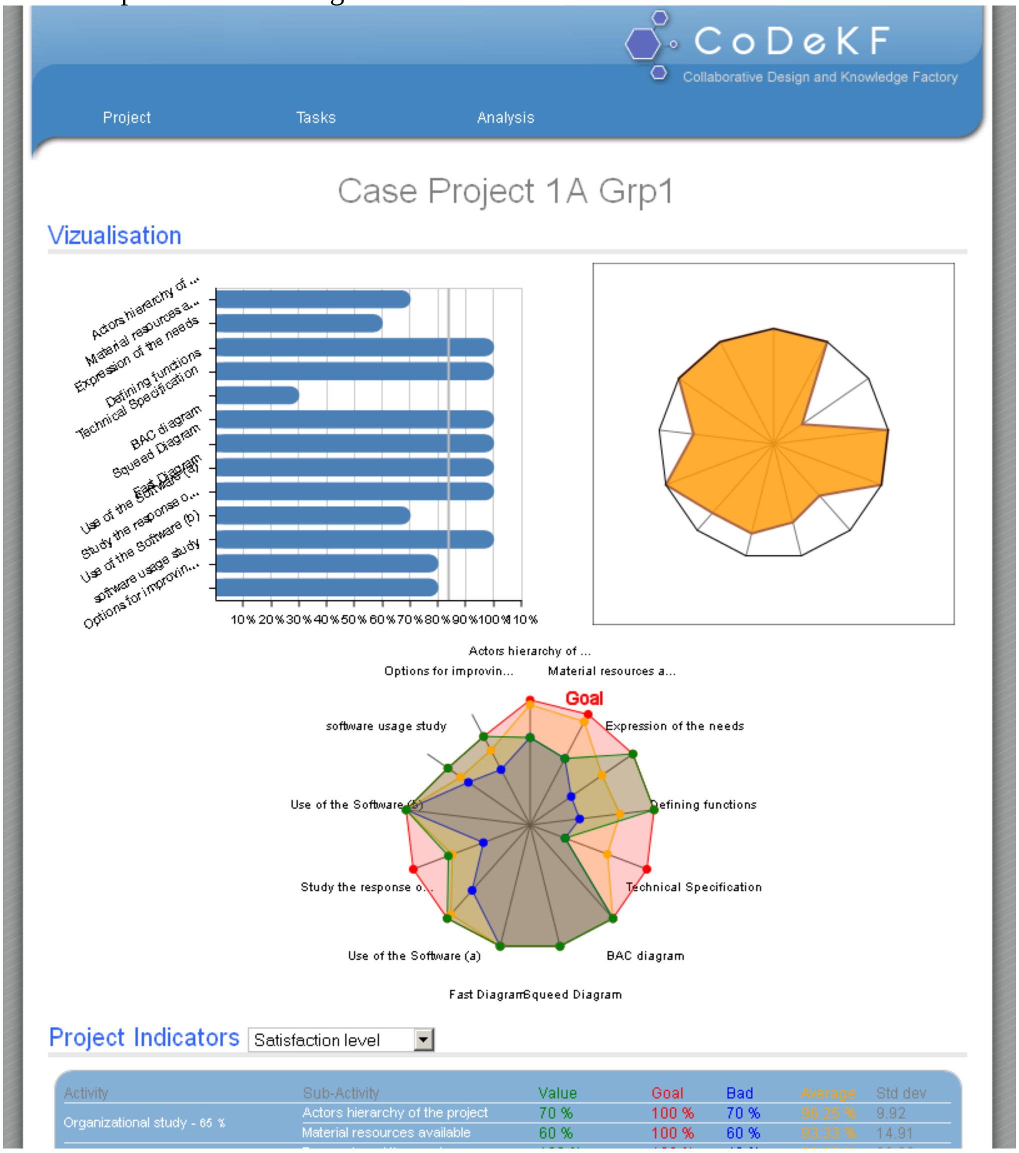

Figure 9.Visualizing the final performance of a project regarding a goal coming from Best practices

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