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A FRAMEWORK TO CLASSIFY PROCESS IMPROVEMENT PROJECTS

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1. Introduction

Customized products, the increasing number of product derivatives and shortened product life cycles have led to a rise of product complexity, which usually has to be handled in a shorter time in order to achieve the required time-to-market. In other words, designers have not only to deal with the increasing product complexity but also need to speed up the design process while maintaining or improving the product's quality, typically with reduced resources. Hence, product development processes have to be carefully planned and adapted as well as improved in order to achieve reduced lead times. To do so, it is important to scrutinize existing processes for possible improvements.
At the Institute for Product Development of the Technische Universitaet Muenchen, Germany, a number of projects to improve design processes are being carried out in industry every year, focusing e.g. on the improvement of the exchange of information and media continuity or on decision making processes. However, experience in analysing the as-is processes gained in one project is often difficult to transfer, both due to staff fluctuations and due to the difficulty of making the experience accessible.

1.1 Focus of this research

In the overall project, of which a part is presented in this paper, a compendium for the planning and analysis of process improvement projects is developed to provide advise to staff planning and selecting suitable and effective methods for their projects and to provide them with best practices and lessons learned from previous projects to organize the institutional memory and knowledge.
This paper is meant to introduce a part of the compendium: A classification framework for design process improvement projects. Its objective is to arrange projects in a three-dimensional space to be able to connect a new project to relevant knowledge gained previously. This is done to facilitate access to knowledge on project organization and methodology for process improvement projects.
Through a literature survey on existing method selection models and on process improvement procedures as well as through the study of several projects carried out in the institute, three significant classification criteria were selected. Afterwards, these classification criteria were reviewed in workshops with the institute's researchers. The feedback gained from these workshops was also used to construct more useful scalings for the classification criteria. The central classification criterion is the goal of improvement, which is de facto the project goal. The other two criteria, which are not fully independent of the first one, are the novelty of the design process in focus and its granularity.

1.2 Structure of this paper

First, a case study from an actual process improvement project in industry is presented in the following section to motivate this research; it is followed by the context and the methodology of this research. Then, a short survey on existing approaches to select and adapt methods is laid out to introduce the reader to how process improvement methods and knowledge in general can be made accessible. Equally, the state of the art on classification frameworks as well as the requirements to a process project classification framework are presented thereafter. Based thereon, criteria for classifying projects on process improvement are elaborated, which are assembled into a common model. The paper concludes with the same example of a project on design process improvement presented in the beginning to show the application of the proposed classification framework.

2. Problem description

In the following case study results of a recent project on design process improvement are shown in order to point out the importance of a project specific approach in selecting methods.

2.1 An example of a process improvement project: Collaboration in automotive industry

The project elaborated here was carried out in collaboration with a major German automotive manufacturer during a period of approximately 2.5 years with the goal of enhancing collaboration between the embodiment design and simulation departments developing the car's body. Several methods for process modeling and analysis were applied in order to achieve this goal and to create a detailed picture of the as-is situation and the actual causes for the problems at that interface: A process chart (using EPC notation) was created to represent the tasks, business objects, departments and IT-systems used, which was subsequently transformed into a MDM (Multiple Domain Matrix) to look more deeply into the process (see Kreimeyer (2007) for further details). Equally, MDMs were used to generate a general system's understanding of what domains there actually are to efficient collaboration between the departments in questions (i.e. how many views co-exist and need to be taken into account) and how these interact. Furthermore, a communication grid analysis, a statistically evaluated questionnaire as well as many workshops and interviews were used; while some provided great insight, others, e.g. a detailed review of data formats and IT interfaces between the IT tools used, turned out to be of little value to the overall outcome of the project.

While the project planning in the beginning of the project was carried methodically and a detailed set of goals and sub-goals was developed to guide the project, it turned out very difficult of find a starting point of how actually to tackle the project. Partly, this was because the three involved researchers (three PhD students in the early phases of their theses, two of whom yet had several years' work experience in automotive industry) had little knowledge in how to carry out such a project, partly it was due to the fact that a later change of goals (turning the project's focus away from an IT-based cause of the problem to a more managerial focus) wasn't anticipated as it could have been when setting up the project planning in the beginning. That way, much energy was invested into analyses that were of no value in the end and planning was very difficult and time consuming in the beginning.

If a better overview of how similar projects can be run and how different projects encounter (often unexpected) problems of different nature had been available, a better planning and more appropriate analyses (i.e. the application of various methods to better understand, model and analyse the as-is situation) could have been carried out.

2.2 Context of this research and research methodology

A large number of resources are committed during the planning of a process improvement project, especially when planning tasks and selecting adequate methods for their support. The objective in this research is therefore to develop a "compendium" on process analysis and a classification for organizing and planning design process improvement projects and methods as a part of the compendium: It is meant to provide support when selecting activities to perform in order to achieve a project goal as well as when selecting suitable methods to support the activity performance by offering useful experiences from former projects in the form of lessons learned and best practices.

The undertaking was subdivided into work packages as shown in figure 1. The central element is the project classification. Five projects were analyzed so far and workshops with the engineers managing and running the projects were carried out to gain detailed insight. The goal of the workshops was not only to identify similarities between the projects and factors with major impact on the method selection but also to understand how the project was completed. Each time, the dependencies between the individual project goals, the project's phases, the activities carried out and the methods used were documented. Simultaneously, a literature survey was carried out to specify the state of the art in method selection approaches, business and design process analysis and improvement methods as well as to identify factors with major importance on the method selection and employment. The findings were finally used to select proper project classification criteria, to construct advantageous scaling for these criteria and to identify the most suitable methods for specific activities as well.

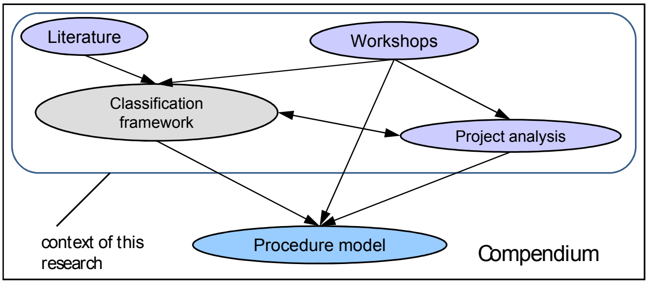

Figure 1. Set-up of the research

3. Accessing knowledge on methodology for process improvement projects

The selection and adaptation of activities and methods is an important factor for the success of any project. Several approaches and procedural models to assist the selection, adaptation and application of methods in product development have been designed and can be found in literature (see e.g. Braun 2005, Ernzer & Birkhofer 2002, Mulet & Vidal 2001 and Lindemann 2007). In the next section, these approaches are introduced.

3.1 Selecting and adapting methods

The approach by Braun (2005) presents how strategic product planning for a company can be carried out using – depending on the company's situation – different activities and methodical approaches. Braun's research is therefore similar – here, his approach is transferred to tackling process improvement projects. However, it does not provide a systematic procedural model to guide the user.

One way of supporting the selection of methods is to pre-select suitable methods by classifying them, while several criteria can be used in order to set up a classification framework. Braun (2005) provides a list of possible criteria such as the "phase of a product development project" or the "time and effort needed for the method employment", allowing for several views of classification to co-exist. These criteria can be attributed with specific values, e.g. the "product development project phase" can take values from "product planning" and "clarifying product employment" to "evaluating alternative solution ideas". Similarly, Mulet & Vidal (2001) set up a classification of methods according to the operational mechanism of the method. A subsequently introduced evaluation to measure the effectiveness of the methods applied is meant to support the right choice of a method. Although in this way an appropriate classification can substantially support the selection process by reducing possible alternatives, a lot of experience is required to identify the most suitable classification criteria for a specific task. At the same time, the integration of experience of previous projects is partly lost when abstracting the knowledge into an appropriate classification system.

Another approach Braun (2005) introduces is the characterization of methods, similarly to Ernzer & Birkhofer's (2002) three-step procedure (classification of methods, description of application situation, and selection of methods). It is based on the fact that the method selection cannot only be supported by sorting them into classes but also through a detailed method description. Characteristics like the abstraction level of the method, the application area, the goal of the method, and many more can be used in order to describe a method. Application situations can also be characterized by such characteristics in a way that a comparison between method and application situation is enabled. Braun claims that the method selection can be facilitated by matching the characteristics of a method with those of the method application situation.

When selected, typically, a method has to be adapted. Again, this can be performed in two ways: One way is to adapt the selected method to the application situation considering boundary conditions like those mentioned in the previous paragraph. The other way is to adapt the context of the employment situation on the method, where the user's experience is required. Hereby, the congruency between the method and its application is achieved through differentiation and adaptation of the existed operational conditions e.g. required output, available input, resources to the requirements of the selected method. Hence, the importance of method selection becomes apparent through the reduction of the effort for method adaptation.

To properly carry out the selection of a method, a well formulated scheme has to be applied to guarantee the best result possible. This holds true for the classification proposed in this research, as by properly classifying the situation (i.e. the process improvement project) a sound basis for selecting the right methodology can be created. In particular, as the references given above have shown, the following elements need to be included to clarify the method employment (which are similarly summed up by the Munich Method Model by Lindemann (2007)):

- the goals – the comparison of goals permits to see if two projects for process improvement strive to fulfil the same requirements, i.e. if they can be compared and if the methodology of the one project might be applicable in the other project
- the questions to be answered ("sub-goals") – the questions that are to be answered give, as the literature review has shown, indications to what activities (supported by what methods) might be suitable
- the availability of information and experience – especially concerning the in-/output of the methods that will possibly be applied, it is important to be aware of what information (as explicit knowledge or as tacit knowledge and experience among the personnel in the process to be improved) is available

3.2 Classification of projects in a framework

Frameworks are commonly used to represent situations or procedures with their elements and their interrelations in a clearly arranged way according to specific criteria. A vast amount of frameworks was developed to display approaches of operational coordination in engineering design, where the main objective is the performance improvement of distributed design. E.g. Coates *et al*. (2000) propose a subdivision into five fundamental components of operational coordination, which consists of activity, agent, order, location and time, related to each other to identify weak points in a process and to achieve goals as reduced cycle times or low cost units. In business process analysis, a framework developed by de Bruin *et al*. (2000) provides business analysts with assistance in selecting appropriate techniques for analyzing a situation with an integrated and organization-wide framework. Nine aspects of business processes were identified, among them technology, housing, organization, personnel and relevant sub-elements to these aspects, like the technological flexibility or the physical location of departments. During the improvement of a business process under one of these aspects, its sub-elements have to be taken into consideration. These sub-elements form, more or less, activities that need to be carried out to achieve the improvement goal.

Yet, for the purpose of this research none of these frameworks or similar ones not given here can be used, as they only systematize the improvement of (single) design processes. The frameworks introduced by Coates *et al*. 2000 are especially designed to support the operational coordination, which is not the goal of this research. The framework of de Bruin, on the other hand, provides a useful basis to design a framework specifically for design process improvement projects, pointing to various possible goals as stated in section 3.1, i.e. where the project goal is translated to into a set of activities that have to be carried out and how these activities are matched to supporting methods.

3.3 Requirements to a classification framework

The project classification framework introduced in this paper is designed to support, at a first step, the engineers working at the research institute this paper originates from; at a later stage, it is the intention to extend it to other organizational contexts. At a first step, this impacts the number of design process improvement projects carried out each year (i.e. the number of projects to be classified), the available

time of a project agent to apply the framework to a project, the required feedback or output and its visualisation form as well as the level of experience of project staff (limited, as many of them are PhD students or even student workers).
In turn, a framework with classification criteria on a medium level of detail is needed in order to allow for the identification of commonalities between the moderate number of projects available. Furthermore, this level of detail aims to reduce the time needed for the employment of the framework and its diagram form to provide a visualisation with a high clarity level. Finally the provided output contains information about the existence of relevant knowledge, activities that are useful to perform in order to achieve the project goals and methods that can support these activities as well.
At the same time, the classification scheme has to incorporate the requirements given in sections 3.1 and 3.2 to properly allow accessing the methodology that was used in the projects that are to be inserted into the classification framework.

4. The framework to classify projects on process improvement

4.1 The ordering criteria within the framework

Numerous commonalities and differences can be recognized when analyzing design process improvement projects. They spring from project parameters that influence the project implementation, procedure and the tasks and activities that have to be performed. Therefore, project parameters like the degree of freedom in design process improvement, the developed products, the optimization goal, the granularity of the examined process or even parameters like the company size, the available process-know-how in the organization and the number of the affected employees can be used to compare and classify projects. In the following, the classification criteria that were chosen for the framework are further elaborated. At the core of the framework, the goal categories of process improvement are summarized, then the granularity of the process in focus is added and completed with a novelty level, which considers the level of experience and knowledge about the process in question.

4.1.1 Optimization goal

As Coates *et al*. (2000) mention, design processes can be seen as goal-directed processes. The analysis of projects being carried out in the institute and a literature survey of process analysis and design coordination approaches (especially de Bruin *et al.* (2000), Coates *et al.* (2000), O'Donnel & Duffy (2005)) confirm that the optimization goal of a project is a factor with large impact on the project procedure and the performed activities. Therefore, the goal of the individual process improvement project was chosen as one axis of the classification framework.
In order to keep the degree of detail in a medium level and to facilitate the employment of the framework, a three level scaling of the project optimization goal is selected as shown in figure 2. Ten general goal categories were identified, ranging from the improvement of requirement management to the improvement of distributed design coordination and covering the field of design process improvement projects. These goal categories are grouped into four goal domains or aspects of product development – that is product management (i.e. the product focus), decision support (i.e. decision making, focusing on the uncertainty aspect of product development), operations/workflow management (i.e. the actual process of designing) and design team coordination (i.e. the setup of the organization of a company). Similar categorizations can also be found in the works of O'Donnel and de Bruin. Furthermore, a list of activities is provided that covers a wide range of activities performed in design process improvement projects. From this list, an engineer starting a project on process improvement can then select a number of activities that need to be performed to achieve the project goal. As already mentioned, these specific activities can be matched to supporting methods. This list is, possibly, not exhaustive and, probably, never will be; it is based on the projects that were available to the authors so far and on their experience and was chosen as such to be in line with the core competences of the work done at the institute.

4.1.2 Process granularity

The process granularity determines the level of detail of the process modelling and analysis. This classification criterion was selected because of the major impact on the method selection (Kreimeyer *et al.* 2007) and on the situation specification as well by setting constraints of what can be modelled and how it can be modelled. Furthermore, with this criterion the position of the process in focus inside the organisation is determined. With the classification of the optimization goal, a design process improvement project is positioned in a two-dimensional space. That is, what needs to be improved in regard to the process in focus and further where is this process located according the product design organization. A three-level scaling of granularity was chosen to keep the framework simple and to facilitate its use (low, medium, high).

<table>
<tr><th>Goal domains</th><th>Goal categories</th><th>Elements of activity / tasks</th></tr>
<tr><td>Design team coordination</td><td>1. Optimize team composition
2. Improve coordination of distributed design
3. Improve information exchange</td><td rowspan="4">1. Analyze characteristics of personnel: education, experience, capabilities, motivation
2. Analyze job profile: tasks, responsibilities, authorities
3. Examine sequence of tasks
4. Analyze job assignment: consistency between characteristics of personnel and job profile
5. Examine knowledge available and information technical requirements, match and media continuity
6. Analyze organization structure
7. Coupling / grouping of tasks
8. Decomposition of tasks
9. Construct product structure model and examine product complexity
10. Construct product function model
11. Link product function and structure model
12. Analyze impact of alternatives to the system
13. Integrate customers in product development
14. Interdisciplinary / concurrent product development
15. Synchronize processes</td></tr>
<tr><td>Operations – workflow management</td><td>4. Speed design maintaining design quality
5. Improve design quality
6. Find optimum between design time, quality and required resources</td></tr>
<tr><td>Decision Support</td><td>7. Speed decision making
8. Secure decision making process</td></tr>
<tr><td>Product management</td><td>9. Improve requirements management
10. Improve / secure disposition process</td></tr>
</table>

Figure 2. The scaling of the project optimization goal

Low-level design processes, as they are defined by Browning (2001), constitute the finest possible detailing of process analysis, i.e. looking into individual tasks or design activities. They link, on the methodology side, e.g. to observations, to using questionnaires at a large scale or to workshops with engineering staff to determine individual parameters. Also, an integration of low-level processes (i.e. their abstraction to a medium granularity) can provide process structure insights of processes with a higher level of granularity. A project on what tacit knowledge is applied in what phase of a design process could be a suitable example. Medium-level granularity refers to sub-processes of an overall product design process. It consists of tasks and can, often, be modelled using e.g. EPC flowcharts or activity-based DSMs. The example of the collaboration project given before is a typical example. On the other hand, high-level design process improving projects deal with the optimization of product design processes from an organisational and coordination point of view without looking into the actual arrangement of individual tasks or activities. The design of a management model to provide better decision making is, for example, such a case. Subject of improvement hereby is the whole design process and its phases and interrelations to other processes.

4.1.3 Novelty

The re-engineering of the automotive design process presented insection 2.1 is highly different from how, e.g. a design process for getting a new technology ready for the market needs to be reviewed, as an automotive design process is a highly adaptive design, faced with different obstacles than an original design. This very fact is translated by the novelty level as a further classification criterion of the framework, representing the level of experience and knowledge on a process (i.e. how well information is available). The product novelty, the novelty of the process organisation and the novelty of the process itself as well are influencing factors of this criterion. Thus, the novelty level has an important role in process improvement projects because of its impact on the problem identification and process analysis phase of the project. A high degree of novelty can furthermore raise attention to the higher risk of unexpected problems or obstacles during the project.

As the novelty level consists of three aspects (product, process operation, company organization), each needs to be classified: The product's novelty is, as formulated by Pahl and Beitz in their various works, classified as original design (i.e. NPD), adaptive design, and variant design. The other two aspects of novelty are only classified as “new” or “established”. The overall novelty is translated into the framework as low-, middle- and high-level novelty and indicated through geometric shapes.

4.2 Classifying a project in the framework

Figure 3 shows the project classification framework, where a project with a medium novelty level (=elliptic shape) is incorporated. The goal categories as given in figure 2 are represented as numbers 1 through 10. As can be seen, the project goal was assigned to three (non-neighbouring) goal categories; numbers 2 (“improve coordination of distributed design”), 4 (“speed design”) and 6 (“resources”). Equally, the framework can be used with the information on the granularity or the novelty missing, as this information may not always be available or is, especially for smaller projects, not purposeful to extract. The granularity level of the examined process is determined by considering the position of the process inside the product design organization and the project goals, as described in chapter 4.1.2. In order to determine the novelty level, the three aspects of this criterion have to taken into consideration. A well “established” organization, a “variant” product design as well as an “established” process design are influencing positive the novelty level, as the level of experience and knowledge needed to achieve the project goals is high. Therefore, these aspects are quantified with lower values. The overall novelty level is then determined by the summation of the three aspects. On the contrary, aspect values such as “NPD” or “new” organization structures lead to higher novelty levels and thus are quantified with higher values, as the existed information and experience about the process in focus is low.

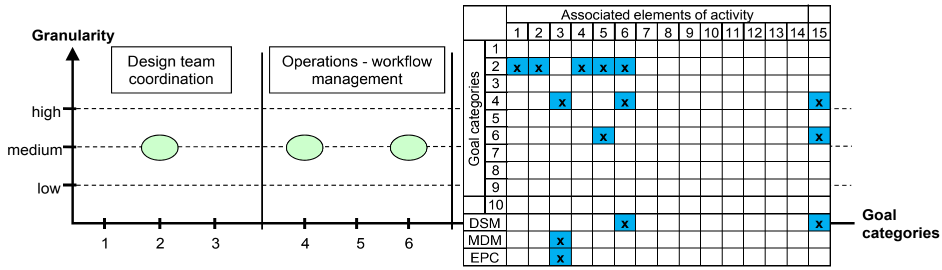

Figure 3. Table form of the classification framework

4.3 Case study

In order to determine the project’s position, the following procedure was applied. Firstly, the general optimization goal was assigned to relevant goal categories and activities that had been carried out to achieve the project goal were set. These are not only necessary for placing the project but also to later relate methods that were applied. To satisfy the project goals, activities 1 through 6 and 15 were chosen (see table 1, right hand side column). Secondly, the level of granularity of the examined process was defined. As the communication and information exchange process between a number of departments of product design constitutes a sub-process of the product design process, it was characterized as a process with a medium-level of granularity. The novelty level was evaluated as medium, as the product design has been adopted continuously over the past years and therefore the product novelty level was determined as low; equally the organization has reached a well consolidated level and was evaluated as “established”. The overall novelty level was not placed as low, as the involvement of simulation on a larger scale still is a novelty to that company. Therefore, the existence and the accessibility of know-how relevant to the process analysis and problem identification phase of the project were poor. Hence, the third influencing factor of the novelty level – that is the process novelty – was evaluated as “new”. Figure 3 visualizes the project position. The connections between activities and methods are modelled in a modification of a Multiple Domain Matrix (lower part of the matrix, only three methods shown to transport the general idea: EPC, DSM, MDM).
To access the knowledge coded this way, typically, selecting one or more goal categories will point the project planner to previous projects documented in a fashion as explained here; briefly scanning each project’s description (of course, every project is described in more detail in an appendix to the

framework to complete the overall compendium) will allow the project planner to choose relevant activities to his project. Using the matrix shown in the right end of figure 3, the project planner can then choose suitable methods for the project and see how these were used in what project previously.

5. Conclusions and further work

Design process improvement projects are characterized largely by their complexity and uncertainty. Although they can be methodologically supported, the achievement of the goal cannot be guaranteed. This project classification framework aims in assisting project planners, who are faced with the task to organize a process improvement project, to categorize their projects according to the optimization goal, the process granularity and the project novelty in order to show them if relevant knowledge is available and to assist them during the selection of appropriate activities to achieve the general goal and adequate methods to perform these activities as well. The classification framework is intentionally kept simple, being developed mainly for the use at a medium-size research institution (approx 45 staff at a time). The scaling of these classification criteria and especially the number of goal categories is being adapted as further projects are analyzed. In the same way, by mapping projects onto the framework the scaling of the granularity and novelty level is tested and evaluated.

Further research is currently done into developing a project analysis procedure model for recognizing the structure of the optimization goal, the project steps and activities as well as the interrelations between those and process modelling and analysis methods. This is done to design a form to characterize projects best possible to allow for a simple form of reviewing projects to generate a larger population of best practises. Secondly, the procedural model, of which the framework is one part, is being developed to guide the user through the review of a project as well as through the planning phases of a new project. Ultimately, the overall compendium regrouping these tasks is set up this way, allowing, on the long run, for a classification typology of process improvement projects.

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