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TOWARDS AN INTEGRATION OF SIX SIGMA, DESIGN FOR SIX SIGMA AND DESIGN METHODOLOGY

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1. Introduction

The demand for higher efficiency and effectiveness throughout the product development process is induced by the fast changing global economy (e.g. [VDI 2221 1993, Ehrlenspiel 2007, Taguchi 1999, Pande et al 2000]). Within a value adding network, products and processes must meet the requirements of statistically reproducible quality, especially regarding fast and early failure detection and continuous improvement processes.
The selection and interpretation of methods and workflow within the product development process are not synchronous [Westkämper 2001] and practice usually varies between the departments involved (e.g. development and production) [Ehrlenspiel 2007]. This complicates the utilization of company potential. The integration of the different practices could increase corporate understanding, work-content consistency and generate synergy benefits.
This paper examines the possibilities and benefits of a consolidation of up to now detached approaches for problem solving, such as Design Methodology (DM), Six Sigma and Design for Six Sigma (DFSS).
First results of an industry study are presented, conducted within the context of a comprehensive continuous improvement measurement of a large automobile company and supporting external consulting partners. For the design research community, the topic design methodology is well known and often discussed, which pushes the focus on Six Sigma and Design for Six Sigma.
The term Six Sigma stands for an improvement strategy, which has been established in many companies throughout the world, and which is being steadily improved. In statistics, the standard deviation represented by σ (sigma) can be used to measure process capability and quality (Failure 6 sigma: < 3.4 parts per million) [Taguchi, 1999]. An existing problem is broken down into five phases, using Six Sigma: Define, Measure, Analyze, Improve (using knowledge gained in the DMA phases to improve parameter settings) and Control (monitoring sustainable implementation) [Taguchi, 1999, Pande et al, 2000].
In industry, DMAIC can be considered as a quasi international standard for problem solving using Six Sigma. Due to the fact that the focused systems already exist, the DMAIC strategy must be understood as a reactive one. Following up the Six Sigma philosophy for quality and the lean principles [Liker 1998] for industrial operation, the idea of preventive quality assurance and problem solving emerges.
Preventive aims at the avoidance of defects by applying a systematic approach for the development of problem solutions. Design for Six Sigma is meant to design products and processes in such a robust way that no operational defects will disrupt production. The foundation for this course of action is the utilization of available, company-wide knowledge.

To procure decisions within the product development process, this knowledge needs to be made available and extended such that within the overall system no defect sources will lead to a sustainable decrease of the targeted quality at a six sigma level. The term Design for Six Sigma accumulates the various approaches of state of the art literature, mainly from the United States and Japan [Taguchi 1999, Sleeper 2000, Pande et al 2000, Goh 2002].
In contrast to the DMAIC-process [Taguchi 1999, Pande et al 2000], there is no accepted, unified approach to product development within DFSS. At the same time, many companies do focus on DFSS to improve their preventive problem solving capabilities [Harry 2000, Chowdhury 2002, Liker 1998].
The value of the different methodologies has been proven. An integration of DM, Six Sigma, and Design for Six Sigma can be the basis for an holistic point of view, but one which is not trivial to realize.
This raises the following questions:

- How can reactive and preventive problem solving strategies be consolidated?
- How does the integration of existing methodologies (DM, Six Sigma, DFSS) eliminate waste within product development?

2. Methodology

The systematic approach of this study utilizes **D**esign **R**esearch **M**ethodology [Blessing 2002]. A first descriptive study (DS1) consisted of observations of the state of operational problems, belonging to a continuous improvement process, a broad review of the literature (> 250 sources), and a target oriented survey to capture current product development practice.
The observations were conducted from the perspective of an external quality consultant. Where needed, results were confirmed by staff interviews. Based on the data analysis results of DS1, requirements could be identified for a prescriptive model (PS). A second descriptive study (DS2) flowed for a first exploratory evaluation of the prescriptive study. DS2 was conducted with a group of experts from production-planning and optimization, Lean Quality Management, Lean Development and KAIZEN (continuous improvement process).

3. Descriptive Study 1: Analysis of a product development process of a large automotive manufacturer

So far, the overall explorative analysis was conducted within the context of a continuous improvement process with a timeframe of four months. While advancing with operational quality work, some problems connected to the different perspectives of the involved departments could be identified. The most critical were:

- Unclear responsibility allocation
- Hindrance of process improvements due to divergent interests of different departments.

The literature tended towards holistic views, e.g. Integrated Product Development (IPD) [Pahl&Beitz 2007, Ehrlenspiel 2007], Product Life Cycle Management (PLM) [Seliger 2004], Quality Management (QM) [Theodore et al 2006], Supply Chain Management [Busch 2004] and continuous improvement processes [Liker 2004].
Usually, existing processes are domain specific. The application of DM is not state of the art for development departments and only few developers in industry can claim to be in the know about design methods and their interactions [Pannenbäcker 2001]. Especially the concept generation for new products in the early phases is considered complicated and insufficient. From the production point of view, continuous flow and leveled processes are preferable [Harry 2000], because in a non-continuous system more types of waste occur (e.g. buffer time for the resumption of work procedures).
In addition to the observations and the broad literature research, an explorative survey was conducted, aimed at the relative utilization of company potential (this means mandatory knowledge and methods are available but are not being used), questioning different experts in high level management (n=5). This was conducted as a structured interview. Corresponding to the identified problem areas, five to ten questions were presented and the participants were asked to estimate between 0-100%. For leveling and interpretation, the mean was calculated.

The use of potentials coming along with *use of new methods* and *interdisciplinary collaboration* were rated very low [FIGURE 1]. For all identified problem areas, the overall rating is below 50%.

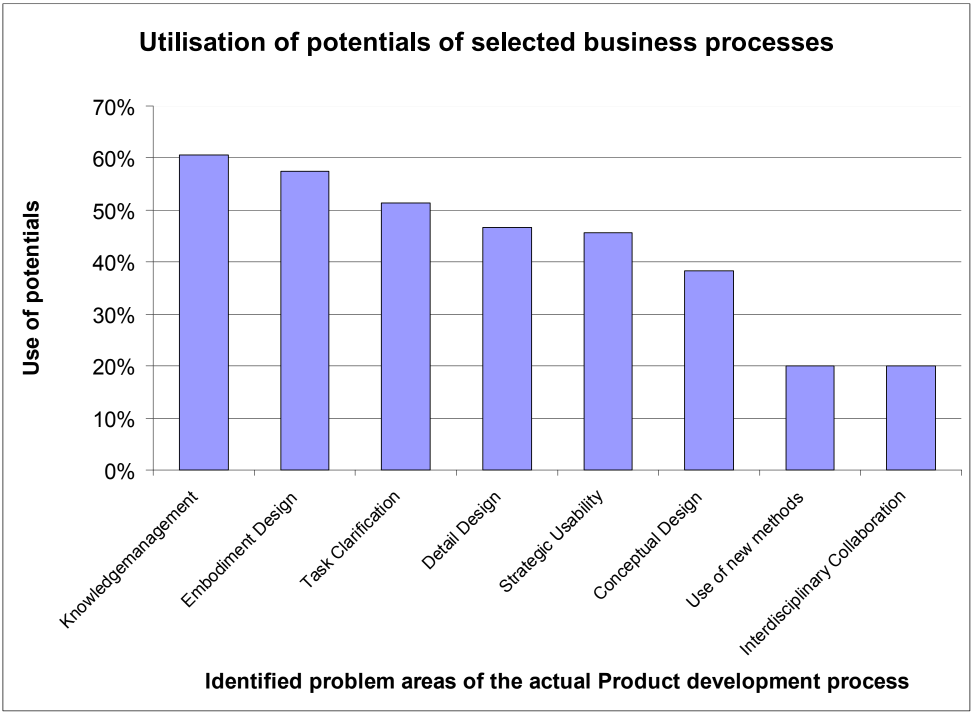

Figure 1. Survey of state of Product Development Process - Results

The low exploitation of potential, regarding *use of new methods* and *interdisciplinary collaboration*, gives evidence for a strong need for action.

The experts of the companies allocated fewer problems to *task clarification* activities, in contrast to studies of [Ehrlenspiel 2007] which imply that many projects fail due to inadequate task clarification. Six Sigma offers a distinctive set of methods for capturing the voice of the customer, as does DM. The estimation of shortcomings in conceptual design activities corresponds with the tendency to buy-in conceptual development work (though this is declining).

The *strategic reusability* of project documents and findings of completed projects is rated at an average level. Reasonings are deficient knowledge management. In comparison, the field knowledge management is classified as relatively developed, although in research, only the conceptual beginnings of technological development can be identified [Nigro 2007].

4. Prescriptive Study: Integrated Model

Content of the prescriptive study is the development of an approach that eliminates or at least reduces the detected problems in DS1. Following up, objectives can be derived. The initial situation, considering the application of Six Sigma, DFSS and DM, is very different. The major problems are the result of poor collaboration between departments [Ehrlenspiel 2007], [FIGURE 2].

Due to its broad acceptance, there is a lot of experience regarding Six Sigma and problems of the implementation of new methods or even a new methodology. The independent organizational structure of Six Sigma supports successful implementation. Especially the start-up phase determines employee acceptance and therefore the sustainable implementation success (usually there is no second chance).

Six Sigma takes the interests of high management into account. The main interests in this field are monetary measurability and savings through the elimination of process inherit waste. Informational transparency of the product development process, standardized work as well as the consolidation of terminology will improve communication and decision making. Completed projects can be compared because of standardization and evaluated with respect to performance.

Initial situation

- Six Sigma is established and widely accepted
- Design for Six Sigma is not standardized
- Unclear responsiblities
- Divergent interrests of domains
- Domain specific processes
- Communication problems between domains
- Design Methodology not utilized enough
- Unclear coherence of methods

Integrated Process

Objectives

- Use and value Six Sigma acceptance
- Reduce waste by using DFSS
- Using Synergies by process implementation
- Strengthen conceptual design by utilization of DM
- Good interdisciplinary collaboration

Figure 2. Initial situation and objectives for PS

The superior objective of the continuous improvement process is the elimination of waste in a company and thus the application of a zero defects production strategy. With successful implementation, the processes will shift towards more effectiveness and efficiency.
The overall improvement of informational quality within the product development process implies the identification of different types of waste. For production there are already seven different types of waste, coming from the field of Lean Manufacturing. These are: Waste from overproduction, Waste from waiting times, waste from transport and handling, waste related to useless and excess inventories, waste in production process, useless motions, and waste from scrap and defects [Harry 2000].
The comparison of the contents of the sub-processes shows strong similarities between Six Sigma and DFSS, when using the most common, but not widely spread, DMADV approach. This acronym stands for: **D**efine, **M**easure, **A**nalyse, **D**esign, and **V**erify. The first three sub-processes (**D**efine, **M**easure, **A**nalyse) are considered as knowledge generation phases and can be merged. At the end of the **A**nalyse phase, enough knowledge should have been generated to enable the classification of a problem as either an improvement task which does not require system design work, or as a design task which then utilizes DM.

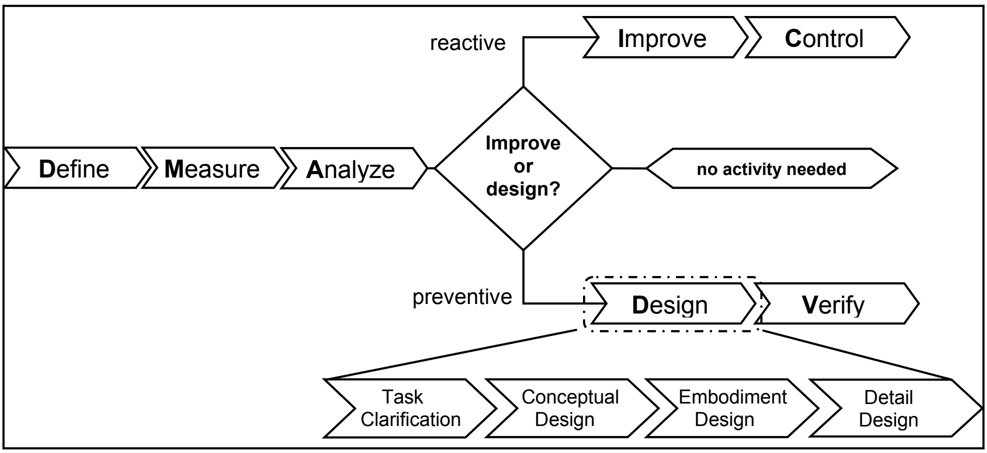

Figure 3. Integrated approach of: DMAIC, DMADV and DM

Considering the systematically derived decision for an improvement project, the system boundary and elements remain the same. Only the system parameter settings need reconfiguring. To achieve this, the

phases **I**mprove and **C**ontrol utilize the Six Sigma toolbox. If the problem can be classified as a design task, the phases **D**esign and **V**erify include the strengths of DM to support the overall general goal of defect free products, [Figure 3].
As stated, the integration of DM can be deployed with the **D**esign and **V**erify phases of DMADV. If, at the end of the **A**nalyse phase, the decision between improvement and design lead to a design task, the problem defined in the **D**efine phase needs reclarification. In general, this is due to the need to change staff. The core expertise of improvement can be seen in production, whereas for design work it can be found in development departments. FIGURE 3 illustrates the complete integration of *reactive* Six Sigma (DMAIC) and *preventive* Design for Six Sigma (DMADV), utilizing Design Methodology. This meets the nature of general continuous improvement process projects.

5. Descriptive Study 2: Capturing expert feedback for the prescriptive study

The PS as an approach for the integration of Six Sigma, DFSS, and DM was presented to an interdisciplinary group of senior consultants of the corresponding divisions (production, development, logistics, and quality management) of work. It was questioned if the proposed integrated model would lead to a reduction of waste in the identified problem areas.
The experts were certain that the integration of reactive and preventive problem solving offers a practicable approach to the reduction of operational problems within continuous improvement processes. At the same time, the stronger focus on good practice concerning Design Methodology would improve conceptual design activities by better structuring and therefore improving common understanding.
The implementation of new design methods could benefit from the Six Sigma implementation strategies. Furthermore it is implied that DM has positive effects on the design processes by structuring the activities better than the compared process in practice.
The experts were convinced by the new integrated model consisting of Six Sigma, Design for Six Sigma and DM, especially, due to the implied positive effects on interdisciplinary collaboration and concept generation. To the experts, the model seemed to be better and more advanced in comparison with the product development processes, which are still often not very synchronized.
As very basic, the experts recognized the need for a holistic approach for knowledge management as a foundation for the interdisciplinary implementation.

6. Conclusion

The present study is orientational and does not stand up to critical statistical analysis, due to the marginal sum of spot tests. Therefore, it is only possible to identify trends. In terms of an integrated approach, experts think that linkage between reactive and preventive problem solving competencies could lead to a reduction of waste, particularly in communication processes. In general, the preventive problem solving skills in industry are not as strongly developed as the reactive Six Sigma. The study examines and describes a possible first approach to an interdisciplinary consolidation of viewpoints and presently applied approaches, bearing the entire product development process in mind, beyond the classical boundaries of production and design. During the implementation of an integrated approach, the broad acceptance of Six Sigma could play an important role in overcoming the acceptance boundaries, also for presently neglected methods (as with DM). Tangible methods for the introduction of design methods in an enterprise are not available, at least not in the fields of DM or with respect to Six Sigma.

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