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Elicitation of Requirements for a knowledge-based Framework in Product Development Process

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Abstract: The main challenge in product development process (PDP) is to develop new or substantially improved, less expensive products and reduce time-to-market. In order to achieve these goals the product development process has to be supported by knowledge management tools. Therefore knowledge is becoming a key success factor in the product development process. Especially internal knowledge related with engineering process has to be situation-induced available within a company. Before the knowledge tools can be implemented the elicitation of requirements is necessary. In this paper elicitation of requirements for creating of knowledge-based framework to support virtual product and process development is presented. In this context the simulation process in engineering companies is examined as a process with high optimizing potential. This paper presents a methodology for gathering of requirements for knowledge-based framework in PDP. It is based on the workflows that are characterized by the SIPOC's elements. According this approach, the requirements for knowledge management system can be traced along the organizations workflows.

Keywords: requirements elicitation, knowledge management, SIPOC, product development process

1. Introduction

The knowledge and knowledge management (KM) play a pivotal role in modern economy and lead to change in strategic focus within the companies. The evaluation of knowledge management performance has become increasingly important since it provides the reference for directing the organizations to enhance their performance and competitiveness. (Zaied, Hussein, and Hassan 2012). The key strategy to companies' commercial success in engineering field is implementation of successful knowledge management in PDP. Especially product simulation is regarded as a process with high optimization capability regarding knowledge management.

The result of knowledge management process is that every knowledge worker in the company can get the necessary knowledge to fulfill his tasks according the corporate goals and strategies. The developing of adequate knowledge management strategy can based on a framework for gathering and formalization of company's knowledge. Situation-induced knowledge-based framework offers huge potential to improve product quality, providing efficiency in the product development process, reducing both development costs, and time-to-market. The development of knowledge-based framework has to be preceded by identification of stakeholders, their relations and requirements that results from a business process and general conditions. Therefore is it necessary to document the requirements in a form that makes possible their analysis and consider their implementation in a knowledge-based framework. The elicitation and documentation of requirements are strongly related to a number of essential difficulties. Stakeholders may be numerous and distributed. Their goals may vary and conflict, depending on their perspectives of the environment in which they work and the tasks they wish to accomplish. Their goals may not be explicit or may be difficult to articulate, and, inevitably, satisfaction

of these goals may be constrained by a variety of factors outside their control. (Nuseibeh and Easterbrook 2000). Organizational processes, especially in product development are often allocated in different departments, or different project teams. To create an integral knowledge-based framework, in which simulation-related methods, tools and best practices are structured and made available a multi partner research collaboration – FORPRO² was initiated. This framework should provide development engineers with a systematic support in the decisions regarding the use of simulation during PDP (Carro Saavedra, Schrieverhoff and Lindemann 2014).

An important question that arises is how to create an appropriate requirements elicitation methodology that would fit the specific dynamic business process and its stakeholders. An answer to this question should provide a concrete approach that could be applied in practice.

2. Methodology

2.1. General

This paper presents the process of elicitation of requirements for creating knowledge-based framework to support PDP. The methodology was developed for the companies in the mechanical engineering sector and successfully implemented in case studies conducted in two German engineering companies. The detailed capturing of the current situation in development process and elicitation of requirements for improvement were the main goals of our efforts. To achieve these goals twofold approach was taken. On the one hand the main processes and sub processes were structured and mapped. On the other hand the requirements for the knowledge-based framework were elicited. A multi stage approach was necessary to capture a high number of elements and reduce the complexity within the engineering development processes (Figure 1).

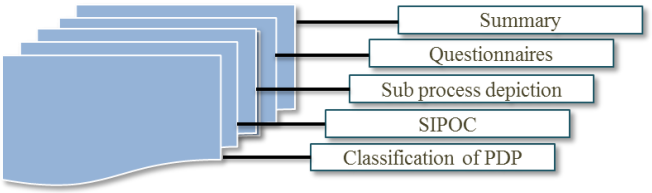

Figure 1. The multi stage approach to map a process structure.

First, PDP on very abstract level was analyzed and the relevant sub processes were extracted. According to our industrial partners the simulation process was regarded as a process with high optimizing potential respecting implementing of knowledge management tools. Therefore, the simulation process as a core business process was considered in our case studies. The steps of this process were recorded with relevant communication flows to gain a complete insight into simulation process. The SIPOC model is the central part of our approach and is detailed described in the section below. Using this model, the communication flows were captured and assigned to the activities within the simulation process. These activities were regarded as sub processes and divided into general documentation, standardization, and iterations. The raw data along these sub processes were collected from primary sources using survey questionnaires and semi-structured interviews. Before the interviews were conducted a workshop for all participants was held. During the workshop the questions were clarified to reach a joint understanding. The interviews were conducted with the employees that are responsible for carrying out sub processes. The employees from design and simulation departments were chosen as interview partners. Each of the interviews lasted about 1.5 hours and was conducted according to a guideline derived from the SIPOC model. The following aspects were especially emphasized: 1) status of process documentation, 2) status of process standardization, and 3) reasons for iterations and delays in processes (Figure 2). The processes and above mentioned aspects were documented by using the SIPOC diagram (Figure 3).

After the interviews were completed a comprehensive view of simulation process was created and the process structure maps were derived. Thus, the success-critical factors in the context of simulation could be identified. The final factors were discussed in a workshop with representatives from the companies. The implications as elicitation of requirements were described in section 3.

Documentation Process

Communication Process (Input)	Acitivites	Communication Process (Output)
How are the communication processes documented? How are the documents with supplier exchanged?	How are the activieties documented? How are the documents archived and made available?	How are the communication processes documented? How are the documents with customer exchanged?

Standardization Process

Communication Process (Input)	Acitivites	Communication Process (Output)
There is any formalized exchange process with supplier? Is Input from previous project used?	There are any formalized activities? Is knowledge from previous projects used?	There is any formalized exchange process with customer? Is output from previous project used?

Iteration Process

Communication Process (Input)	Acitivites	Communication Process (Output)
How long does it take to get necessary information? When do occur any iteration? Does supplier know the requirements?	How long does take to compete the acitivity? When do occur the iterations Does you know the requirements another depertments?	How long does it take to send necessary information? When do occur any iteration? Do you know the customers requirements?

Figure 2. The sub processes within the simulation process.

2.2. SIPOC Model

The questionnaires and interviews were created using the SIPOC model. The purpose of SIPOC is to define and document the elements of a business process. It is a powerful mapping tool, whose name corresponds to the following five items: **S**upplier, **I**nput, **P**rocess, **O**utput, and **C**ustomer (Marques and Requeijo 2009). The SIPOC model helps capturing the present state of different processes as it is. On this base the affected and related processes can be understand and analyzed. SIPOC is especially helpful for planning of management or improvement activities in order to get a high level understanding of the business process. It helps both structure a business process and define the boundaries between the stakeholders that are involved in process organization. It provides a structured way to discuss business process and get consensus before drawing process maps.

For our purposes we have adapted the SIPOC model to map the processes of knowledge flows, knowledge structure, and knowledge documentation in engineering companies. The survey's analysis was resulted in identification of main problems within the engineering companies. On this basis the stakeholders' requirements could be formulated and appropriate knowledge management tools chosen or designed. The very first step in SIPOC modeling is to create a SIPOC diagram (Figure 3).This diagram gives an overview of a business process and identifies following elements: 1) key process activities, 2) inputs to the process and suppliers, and 3) outputs of the process and customers.

To create a SIPOC diagram some rules must be regarded:

1. The name of the process: verb + noun format (e.g. exchange knowledge).
2. The output: This is a tangible item that is created within the process (e.g. report, or letter).
3. The customers: There are employees or devices that receive the outputs. Every output should have a customer.
4. The input: This is an event that triggers the process. It is often tangible (e.g. customer request)

5. The supplier: There are employees or devices that send the inputs. Every input should have a supplier. In some processes, the supplier and the customer may be the same person.
6. The sub-processes that make up the process. These are the activities that are carried out to convert the inputs into outputs. They are the basis of a process map.

Process name:
Initial situation:
Purpose:
Owners (roles):

Supplier (role)		**Input**		**Process**	**Output**		**Customer**
Initiator	Supplier	Name	Form		Name	Form	

Figure 3. SIPOC-diagram used in the case studies.

Using the SIPOC diagram a guided interview series was conducted in both companies. The collected findings were analyzed and discussed with company representatives in common workshops.

3. Case Studies

3.1. Description

The presented methodology was applied in two German development companies. The development processes in these companies are only partially standardized and documented. Therefore, there is no clear overview of the overall development process and the point in time in which the different development activities should be integrated in it. The situation is especially unclear regarding the integration of virtual simulations to verify characteristics of the product concepts. Designers are not simulation experts and thus not aware of the needs and possibilities of simulations. Therefore simulations are usually integrated in the development process without the proper knowledge and not at the right time, what causes iterations and delays. These companies aim to identify the reasons for their inefficiencies and overcome implementing knowledge management methods. The two companies present following characteristics:

Company A is a large company that develops complex systems. In this company the departments involved in the development are responsible for only one component of the system. Interviews were conducted with people involved in the development of four different components. Employees from three departments (design, simulation, and thermodynamics) involved in different aspects of the development were interviewed per component.

Company B is a medium-size company that develops systems with a medium level of complexity. In this company the departments involved in the system development are the same for every component of the system. Employees from two departments (design and simulation) involved in the development were interviewed.

3.2. Results

The interviews have fulfilled a double objective: On one side, to document the processes realized in each department, and on the other side, to obtain information about the current situation in the company to derive the requirements for improvement in knowledge management. The processes were documented in a table using the SIPOC model. Afterwards this information was applied to represent the communication flows between departments and the storage locations of the documents used and produced during the process. The representation was exposed the complexity of the current situation in both companies. It visualized the starting point for the generation of potentials for improvement. It results in a deeper understanding of the workflows including communication flows and documents that

are generated and exchanged within simulation process. Reasons for delays and iterations collected during the interviews were listed and rated according to the times they were named in order to identify the main ones. This list was discussed with employees from the companies to confirm veracity of the results. The challenge is to reduce delays and iterations and as a consequence to shorten development times. This is seen in both companies as a direct economic benefit. The following points were identified in both companies as main reasons for delays and iterations in the processes.

Company A:

- Changes in the priority of the projects
- Not informed about changes in the requirements of the components and boundary conditions
- Inputs from other departments are not available at the necessary moment
- Errors in the development of models for simulation and during the implementation of simulations

Company B:

- There is no transparency in knowledge items
- There are no clear criteria for creation and transfer of knowledge
- Employees do not share best practices and lessons learned
- Knowledge has to be forced on employees
- There are not key employees responsible for creation and transfer of knowledge

The status of documentation and standardization of processes, documents and lessons learned were evaluated using templates like the one exposed in Figure 4. The influence of the current situation in these aspects with the identified problems was discussed with responsible from companies in order to derive the needs and establish the requirements for the knowledge-based framework.

		Activities during the development				Communication between actors			
Documentation of the process	Formal								
	Partially formal								
	Informal								
	Not existent								
Documentation of documents and information	Formal								
	Partially formal								
	Informal								
	Not existent								
Documentation of lessons learned	Formal								
	Partially formal								
	Informal								
	Not existent								

Figure 4. Template for evaluation of the status of documentation. Example for six interviewed.

The results derived from both companies were confirmed at ForPro² industrial colloquium. Therefore, they can be regarded as a reference to universality of problems within simulation process in mechanical engineering sector.

3.3. Requirements for the knowledge-based framework

The requirements for the knowledge-based framework were derived from the identified reasons for delays and iterations and discussed with representatives from other companies at ForPro² industrial colloquium in June 2015. The representatives from other companies have confirmed the results derived from our industrial partners. The discussion about the current status of the companies in documentation and standardization of their processes and documents served as a basis to be aware of the needs. The final requirements are exposed in Table 1.

Furthermore, a comprehensive document management system and a Lessons Learned database should be implemented in the knowledge-based framework. This should increase the efficiency of workflows and help companies decrease the complexity within simulation processes as well as reuse the existing knowledge assets from previous projects. The concrete measures to fulfill these requirements and needs will be discussed with companies' representatives.

Table 1. Derivation of requirements for the knowledge-based framework

Reason for delays and iterations	Success factor	Derived requirement
Changes in the priority of the projects	Process standardization	Contain descriptions of standarized processes
Inputs from other departments are not available at the necessary moment		
Not informed changes in the requirements of the components and boundary conditions	Communication, transparency	Automatic communication of changes to the concerned actors
Errors in the development of models for simulation and during the implementation of simulations	Knowledge about simulations	Provide designers with knowledge about the requirements of the models for simulation
There is no transparency in knowledge items	Transparency	Provide overview of existent knowledge and actors
There are no clear criteria for creation and transfer of knowledge	Knowledge management	Define mechanisms for knowledge creation and transfer
Employees do not share best practices and lessons learned		
There are not key employees responsible for creation and transfer of knowledge	Knowledge management	Define actors for knowledge creation and transfer
Knowledge is forced on employees	Implementation, manteinance	Provide methods for implementation that increase the acceptance of employees

4. Conclusion and Outlook

The contribution of this paper is to introduce a methodology for the elicitation of requirements to provide reliable input for creating a knowledge-based framework. We show its application in two case studies within the PDP in two mechanical engineering companies. The results of elicitation will be used in a knowledge-based framework with the aim to improve the product development process in manufacturing companies. This framework should help to set clear vision for knowledge management and provide a roadmap to support the activities for successful implementation of knowledge management tools. The framework will be focused on company's infrastructure, business processes, and can be situation-induced implemented.

The effect of knowledge management strategies within the companies resulting from the proposed framework will be explored in the next steps.

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