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REQUIREMENT ANALYSIS FOR CONTEXTUAL MANAGEMENT AND SUPPLY OF PROCESS- AND DESIGN KNOWLEDGE – A CASE STUDY

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Keywords: requirement analysis, knowledge management, case study, product development process

1. Introduction

According to a study by the Fraunhofer-Institute for Industrial Engineering (IAO) [Bullinger 1997], the majority of surveyed companies appreciate that the share of the factor "production knowledge" is over 50 percent of value added of an enterprise. In addition 96 percent of the polled companies rated the importance of knowledge management with "high" or "very high". Particularly in the product development process the factor knowledge has a decisive impact on the final product [Ehrlenspiel 2009]. Providing the right and contextual process- and product knowledge of high quality in due time is nowadays a key function for an efficient product development process. The lack of knowledge and information especially in product development phase leads to additional costs for a company to a study about $ 20 per employee per day [Thel 2007]. Hence the cost of labour for each employee and year are about $ 5,000. This study reveals the high potential of an efficient knowledge management for enterprises. But companies are not only more and more confronted with the lack of relevant knowledge and information but also with the information explosion. According to a study by the University of California, Berkeley, five billion gigabytes of new information were created alone in 2002 worldwide [Lyman 2003]. Therefore employees are constantly faced with the task of obtaining the required information, amongst others, from e-mails, colleagues, databases, the Internet, offline archives.

1.1. Problems in handling knowledge

There are a variety of problems in handling design, process, product knowledge and information not only for employees but also for enterprises. The following figure (figure 1) shows the main problems in handling knowledge for small and medium-sized entities (SME) according to a study which is part of the funded project ProWis [Voigt 2009]. The interviewed companies rated the rapid integration of new employees into the company as the main knowledge management problem. The extensive use of existing knowledge to develop new products and the re-use of past experiences in projects is for many SMEs also problematic. The problems addressed by the companies occur particularly in the design engineering process because this process is primarily a knowledge and information handling process [Hubka 1976].

1.2. Research question and objectives

Consequently the question arises how an efficient and contextual management and supply of process and product knowledge in a company (especially in the field of product development and design) can be realised and which requirements arise for such a knowledge management system. This research

question will be answered in the present paper which is based on a case study. In particular the identification and classification and analysis of requirements for a knowledge management system are explained below. These requirements are essential for the development of a knowledge management system in order to handle design knowledge and information of the company. With an appropriate knowledge management system product development processes can be accelerated and development costs can be reduced and product quality can be increased [North 2011], [Thel 2007].

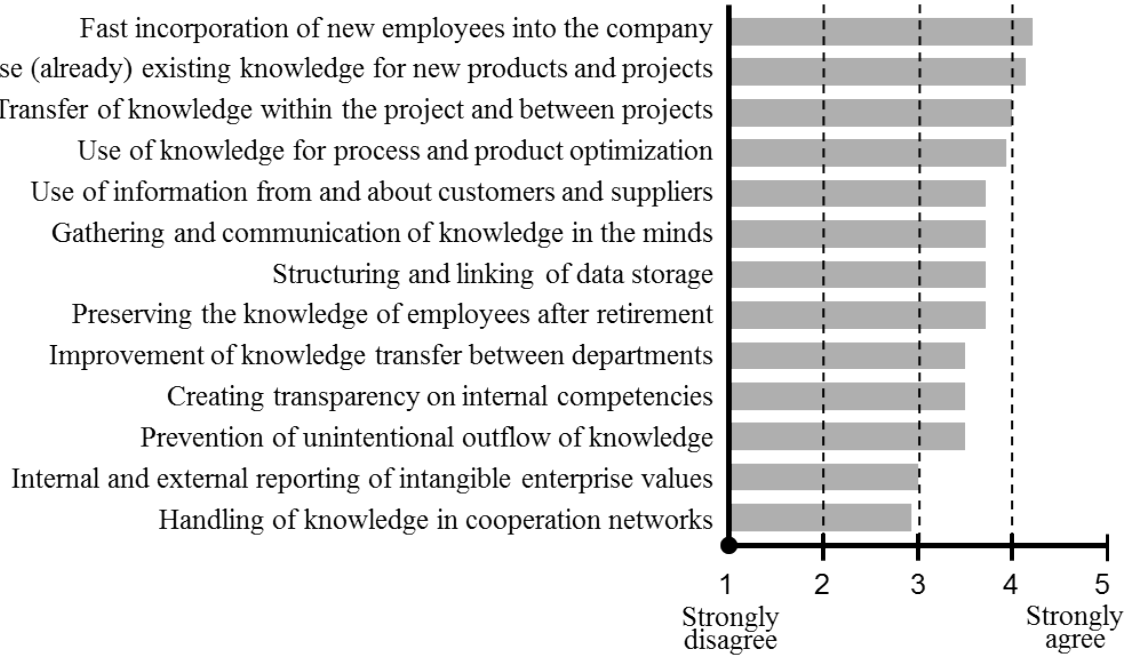

Figure 1. Problems in handling knowledge and information [Voigt 2009]

1.3. Procedural method and benefit

To reach this aim it is firstly necessary to delineate the theoretical foundations on the topics of knowledge (definition and dissociation of knowledge) and knowledge management (state of the art of knowledge management systems). In the third section the methodical knowledge and information analysis is described. After the definition of "Knowledge and Information"-Objects (KaI-Objects) and the need for their classification, the three analysis methods (document analysis, expert interview and moderated workshop), which have been used in the case study, are explained. Therefore it is necessary to consider their respective preparations and the aspects in their application. Based on this theoretical foundation follows the conducting of a requirement analysis for an integrated knowledge management system which consists basically of the management functionality and the searching functionality. For the case study an example of an enterprise from the special engineering industry is used. In the fifth section the advantages and disadvantages of the chosen methods as well as the basic approach of the conducted requirement analysis are evaluated. An outlook on possible fields of further knowledge management research can be found in the final section.

2. Fundamentals and related approches

In the following section some fundamentals and related approaches which are the scientific background of this paper will be discussed.

2.1. Definition and dissociation of knowledge

For a theoretical discussion of the term knowledge a precise definition is required. Due to the difficulty of giving a precise and uniform definition of the term knowledge, this paper is based on the following, relatively pragmatic and prevalent definition by PROBST [Probst 2010]: "Knowledge is the sum of all (cognitive) abilities and skills that are used by individuals to solve problems. This includes

not only theoretical insights but also practical everyday rules and routines as well as instructions. Knowledge is based on data and information and is in contrast to them always tied to specific individuals. It is constructed by individuals and represents their expectations about cause and effect interrelations."
In addition to an exact definition of the term knowledge is in particular a dissociation of character, data, information and knowledge in the context of this paper advantageous. The following figure illustrates on the one hand the differences between these terms and on the other hand how knowledge is created through information and data and characters [Probst 2010] (figure 2).

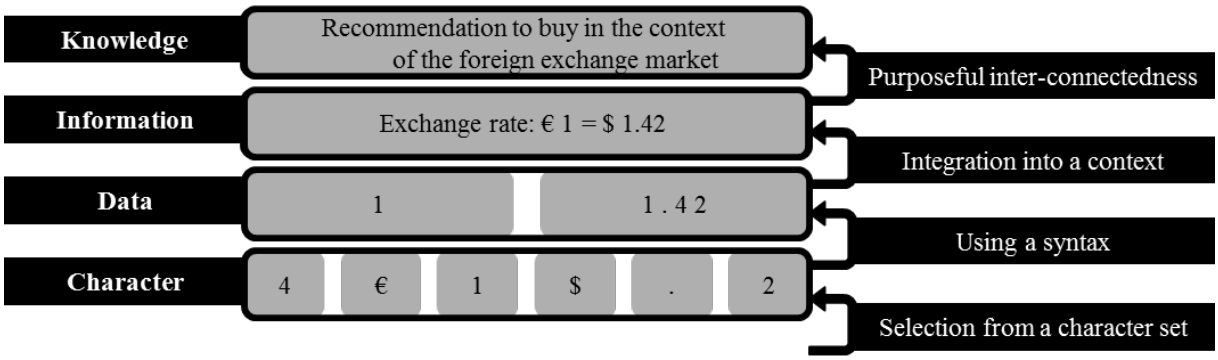

Figure 2. Relations between character, data, information and knowledge [Probst 2010]

2.2. State of the art of knowledge management systems

Due to the various and complex tasks of knowledge management a large number of computer-based tools were developed over the past years. An overview of existing types of computational tools to support the product development process gives the following list:

- Information Systems are databases to store ideas, experiences, information, knowledge
- Document Management Systems are used for the structured storage of documents
- Product Data Management Systems are used to manage product data and process-related information (e.g. computer-aided design data, models, parts information, manufacturing instructions, requirements, notes as well as documents)
- Workflow Management Systems are enabling distributed processing of integrated processes
- Project Management Software generally support the modelling and especially the planning, management and control of comprehensive processes
- Enterprise Resource Planning tools are used to structure and store the ressources of all relevant business areas
- Communication Tools are used to support the communication in and outside the company
- Computer Supported Cooperative Work support collaboration (e.g. team work) between employees

3. Methodology for the knowledge and information analysis

In the following section a methodology will be described in order to explain how the requirements for a knowledge management system can be determined in detail. The state of the art of computer support in product development process has shown that design engineers are faced with a variety of systems that manage especially characters and data. Thinking of a holisitc knowledge management system that integrates the currently existing systems (see section 2.2), it has to be distinguished between management and search functionality. Therefore the first step of a methodical requirement analysis is an adequate detailed and systematic description of the actual knowledge and information basis in order to determine the requirements for the management functionality that has to coordinate and maintain the already existing systems. The second step is to collect user requirements for the search functionality by conducting expert interviews as well as moderated workshops and by scanning internal company documents [Thomson 2011], [Thor 2011].

3.1. Definition and classification of "Knowledge and Information"-Objects

The knowledge and information basis of a company can be analysed with the help of "Knowledge and Information"-Objects (KaI-Objects). The definition of KaI-Objects, which is used in this paper, is based on the following definitions. In principle every KaI-Object can be associated with a certain knowledge carrier and a knowledge carrier can usually have several KaI-Objects. In addition, a KaI-Object can include both implicit and explicit knowledge. KaI-Objects, however, contain not only knowledge but also skills and abilities and experiences (partly also attitudes and behaviours) of individuals or teams. Furthermore, KaI-Objects are input (e.g. knowledge which is needed) and output (e.g. knowledge which is generated) of knowledge activities (e.g. development steps, work tasks). Consequently KaI-Objects are abstract classes of similar knowledge and information.

KaI-Objects have three elements: Content (i.e. what is described), type (i.e. how the content is presented, e.g. as a Word document) and location (i.e. where the knowledge is stored, e.g. in a database or in the heads of employees). To illustrate this description of KaI-Objects some examples of knowledge activities that require the KaI-Objects as input and generate KaI-Objects as output are shown in the diagram below (figure 3).

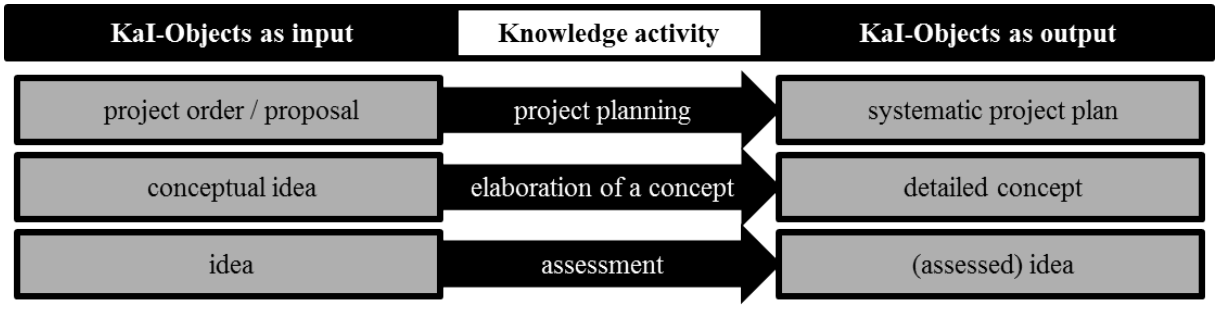

Figure 3. KaI-Objects as input and output

Appropriate knowledge representation forms have to be developed and implemented to enable an IT based and efficient knowledge management system. Knowledge representation forms can be modelled among others by thesauri, taxonomies, hierarchical or networked ontologies (e.g. in terms of Knowledge and Topic Maps). The foundation or precondition of the mentioned knowledge representation forms is the classification of all KaI-Objects of a company. Further explanations about knowledge classification can be found in [North 2011], [Thel 2007]. Therefore the KaI-Objects are classified according to a certain classification principle (e.g. after selected criteria). The resulting classes are sets of objects with common characteristics. Therefore it is necessary that these classes have distinctions which are both specifiable and differentiable.

However, experience from practice has shown that the classification of objects into classes is very difficult and time-consuming. Nevertheless an unambiguous classification of KaI-Objects is essential for computer-based knowledge management systems. The following figure (figure 4) shows theoretically and practically that knowledge and information are assembled into KaI-Objects and these are classified into appropriate classification levels again.

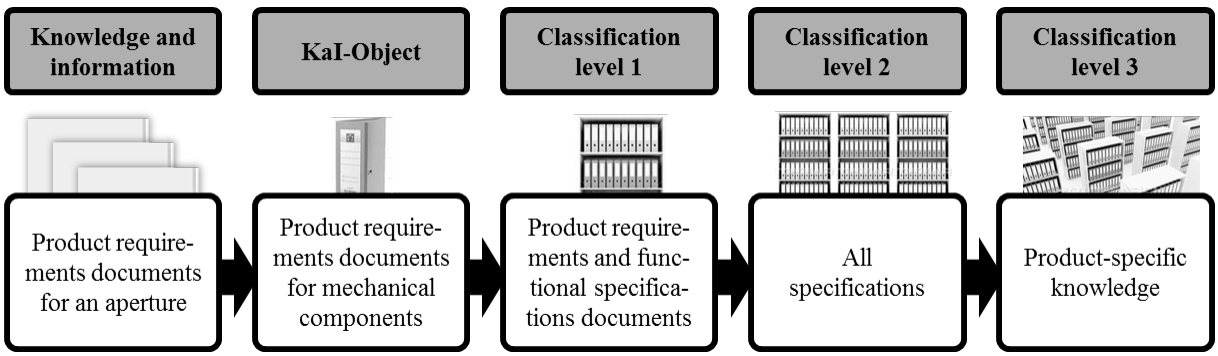

Figure 4. Approach of the theoretical and practical classification

3.2. Acquisition and analysing of knowledge and information objects

The following three analysis methods (document analysis, expert interview and moderated workshop) are described with their respective preparation, which is required and has to be taken, as well as the most important aspects to be considered in their application.

As part of the preparatory meetings for the document analysis, the relevant processes have to be defined. In addition, the related documents have to be sifted and evaluated with respect to their up-to-dateness and relevance for the analysis [Thor 2011]. Furthermore it is significant to specify the level of detail in which the product development processes has to be analysed. On the one hand it is important to be careful in the context of the activity analysis that the chosen level of detail is not too fine because otherwise the cost-benefit ratio is negative. On the other hand it is also not advantageous if a too coarse level of detail of the activity analysis is used because thus no analysis of the requirements for context-based administration and supply of process and product and design knowledge are possible. If there are process descriptions (in written or electronic form) available (e. g from previous activity analysis in order to optimize the process management) they can be used as a basis for the document analysis [Thor 2011]. The selected documents are searched for KaI-Objects. The next step is to describe the identified objects according to the following characteristics:

- Expressive and concise and unambiguous designation of the KaI-Object
- Common synonyms for the description of the KaI-Object (optional)
- Detailed and specific description of the KaI-Object (e.g. content, purpose, input, output)
- Concrete indications about the maturity level of the KaI-Object
- Traceable source(s) for each KaI-Object (e.g. name of the process description)
- Chronological classification of the KaI-Object in defined product development phases
- Specifying the administration systems in which the KaI-Object is currently administered

Not only by the document analysis but also by interviewing of employees (so-called expert interviews), KaI-Objects can be determined [Thomson 2011]. In the interaction between the interviewer and the interviewed person two levels have to be considered. On the one hand data, information, knowledge are exchanged using the content level. On the other hand a relationship between the interviewer and the interviewee is being developed through the relationship level. A careful preparation (i.e. technical and methodological competence) is required for a successful interview as well as the necessary empathy (i.e. social skills). An efficient and effective conduct of expert interviews requires a good preparation in which the following aspects have to be considered:

- Professional training in the relevant subject area
- Defining and clarifying the objectives of the expert interview
- Distinction of the process step by a unique process name
- Sourcing of experts who are adept in the subject area (i.e. long work experience)
- Notice of the interview by e-mail or telephone
- Making an appointment and booking a room for the expert interview
- Compilation of all the required documents
- Preparation of a structured interview sheet

After this preparation the detection of the KaI-Objects with the selected employees will be conducted. In a short introduction the objectives and the proceeding of the interview are explained. Then the questions of the interview sheet will be sequentially discussed and recorded. The interviewer has to ensure that no false or incomplete information is gathered about the current state. Due to asking specific questions it is possible to close any content-related gaps and to clarify comprehension problems [Thomson 2011]. Because of the limited time the following principle has to be considered: It should be gathered only as much information as necessary and as few as possible. After the questioning of experts by the interviewer the obtained information are written down from memory and

carefully prepared. The documented interviews are presented to the respective experts for review in order to correct mistakes or misunderstandings.
The third analysis method for the acquisition of KaI-Objects is in addition to document analysis and expert interview the conduct of a moderaded workshop with several employees. For the efficient and successful conduct of a moderaded workshop is an extensive preparation required. Therefore the moderator of the workshop has to clarify several key questions that are shown in the following figure in advance (figure 5).

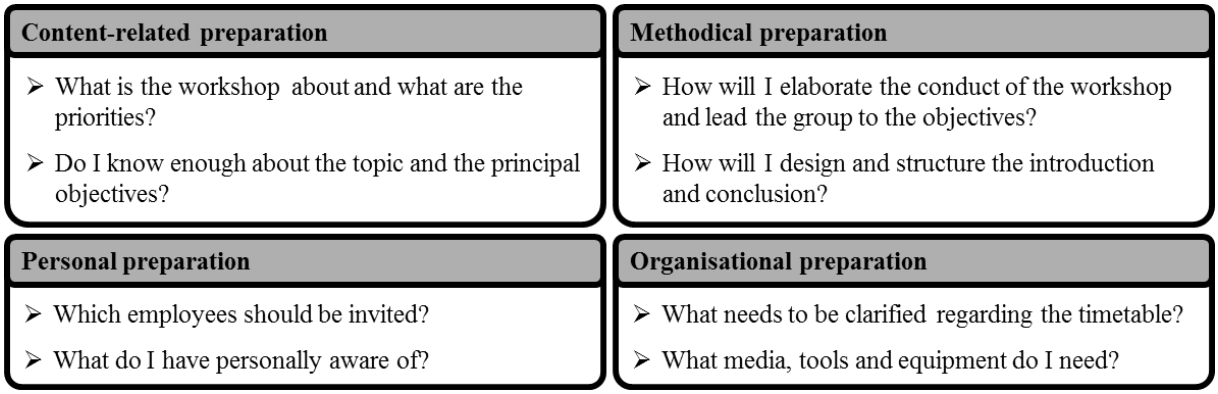

Figure 5. Key questions in preparation for a workshop

The conduct of a moderaded workshop can be divided generally into the three following consecutive phases:

- Positive initiation and introduction: A positive beginning is important, as the basis for the working atmosphere is created with the introduction of the workshop. Therefore, after welcoming the present participants by the moderator, a brief introduction of participants (e.g. with name and expectations) is useful because getting to know each other encourages the cooperation between the workshop participants. In addition, the moderator has to explain the tasks that have to be worked out by the participants and objectives of the workshop.
- Working with the topic by asking questions and leading: After the introduction the moderator is following the planned questions from the preparation. During the processing of the topics the moderator must always pay attention to an atmosphere of mutual respect between all participants so that a constructive cooperation can be achieved on a factual level. It is important that the moderator shows interest in the contributions of each participant in order to encourage their motivation. Furthermore it is the task of the moderator to interrupt if the participants digress from the topic. As a result, the different perspectives and ideas of the individual employees will be better taken into account.
- Positive conclusion and ending: The moderator should always summarize the partial results after processing of a theme block. This ensures that the participants are agreeing with the result. At the end is the opportunity for further questions and it is clarified whether an additional appointment is required. The workshop will be finished by the moderator with a sincere thanks to the participants (e.g. the approach to work was constructive and efficient) and a positive conclusion. Afterwards the results of the workshop will be summarized in a document by the moderator.

4. Requirement analysis for a knowledge management system in a case study

After describing the theoretical foundations and methods, the practical approach is summarized in this section. The main objective of the case study is to identify and analyse the requirements for an effective and efficient management and supply of contextual knowledge and information. Therefore an appropriate knowledge management system which basically consists of management functionality and search functionality is needed. This section explains first of all the procedure for the analysis of the requirements for the management functionality and subsequently for the search functionality.

4.1. Analysis of knowledge and information basis

The analysed company of the special engineering industry has a plenty of knowledge and information flows between the product development department and other internal departments and external entities that need to be considered. The KaI-Objects that are included in this knowledge and information flows are managed by the company in most cases with the help of various technical systems. The main management systems of the company are listed below:

- The Intranet is a company-wide, web-based information, communication and application platform. Recent corporate news, guidelines as well as standards are stored in it.
- Process Management System (PMS) is a software package for documentation, analysis, optimization and management of business processes. Therein process descriptions, templates, organizational charts can be found.
- Enterprise Resource Planning (ERP) is a software package for a company-wide information system. ERP is used for the structured storage of important documents.
- The numerous existing databases and fileservers are used for various tasks. On these information and protocols of the process and product quality can be found among other things.
- The Company Wiki (CW) has been under construction during investigation. Almost all department-specific information can be found in this wiki.
- A Document Server for archiving a large number of unstructured documents from the entire company. In corresponding directories of development, particularly development-related concepts and draft versions are filed.

In the context of document analysis, all management systems are searched for KaI-Objects. Furthermore individual experts are interviewed about their activities and the associated KaI-Objects. Additional KaI-Objects are gathered through moderated workshops in different departments. The following figure shows the principal methodological execution of collecting KaI-Objects (figure 6).

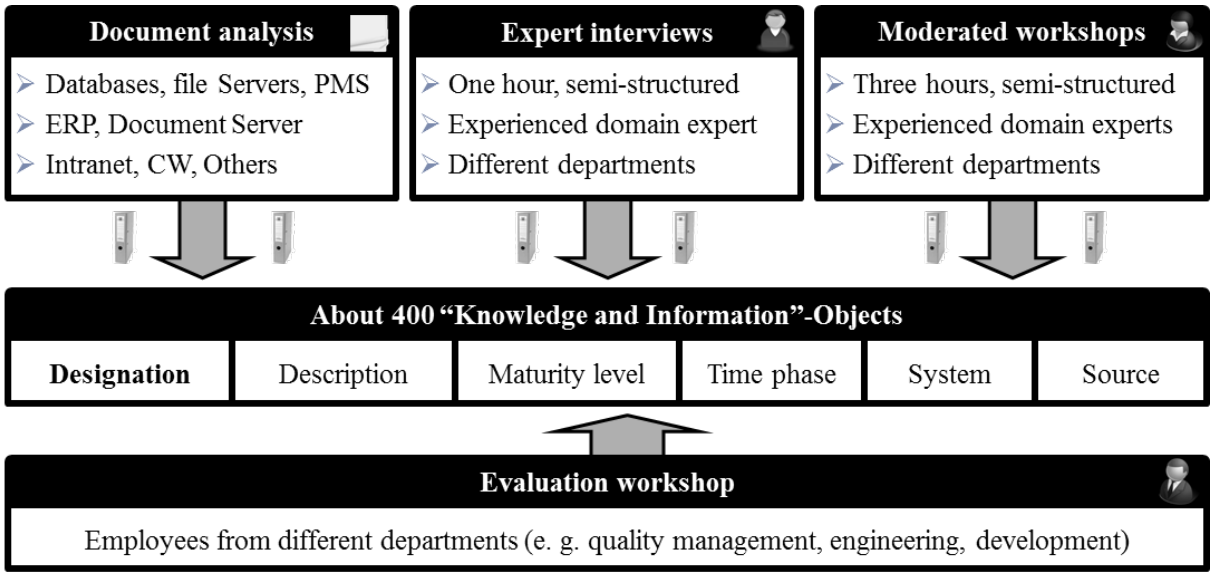

Figure 6. Execution of collecting KaI-Objects

Using this approach about 400 KaI-Objects were collected in this case study. These objects were classified afterwards according to a content-based systematic classification (e.g. product-, process-, method-, company- and manufacturing technology-related knowledge) as well as according to a source-based systematic classification (e.g. documented knowledge or empirical knowledge, internal or external knowledge and project-related and project-unrelated knowledge). These two systematic classifications were evaluated by a workshop with experts from different departments (e.g. quality management, engineering, developement).

4.2. Requirements for the management functionality

Based on these findings, the requirements for the management functionality can be determined (see also requirements collected by THOMASON [Thomson 2011]). In the following figure are four pooled requirements which are derived from the analysis of the collected KaI-Objects (figure 7).

Collection of all KaI-Objects
Gathering of all KaI-Objects, that are not administered, with the corresponding documents by closing the gaps in the actual administration of KaI-Objects.
Classification of gathered KaI-Objects
Classification of all KaI-Objects according to certain principles of classification in specific classification systematic, e. g. in order to verify the completeness.
Maintenance of the KaI-Objects and the management functionality
The role of one or more knowledge engineer(s) is necessary for the classification of the KaI-Objects and the maintenance of the management functionality of the knowledge management system.
Planning of the system landscape
Allocation of all KaI-Objects which are already managed as well as all KaI-Objects which are not yet managed, to exactly one existing system.

Figure 7. Pooled requirements for the management functionality

4.3. Analysis of employee needs and mentalities

In contrast to the management functionalities are the search functionalities of a knowledge management system for all employees important because only through a user-friendly and intuitive input and output mask a context-sensitive and efficient search for knowledge and information can be achieved. Lots of employees from different departments have to be interviewed in order to meet the requirements for a user-friendly search functionality of a knowledge management system that is customized to the needs of the employees. To collect more and detailed user requirements a mock-up which is based on general requirements for the supply of information and knowledge has to be created. With the help of a mock-up, for example, several search functions of the user interface can be simulated and discussed with each employee. In this way the needs and mentalities of all employees can be identified more efficiently. The methodology for collecting user requirements is basically shown in the figure below (figure 8).

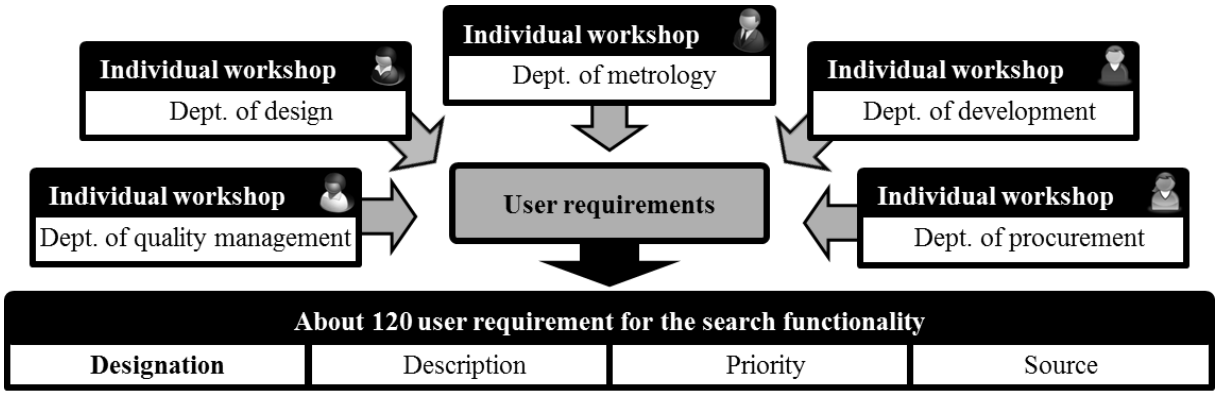

Figure 8. Execution of collecting user requirements

4.4. Requirements for the search functionality

Based on these findings and the prioritisation of all user requirements, the main requirements for the search functionality can be determined. In the figure below are the requirements, which were mentioned by the workshop participants, grouped into four aggregated requirements (figure 9).

Implementing a cross-system search
All existing systems of the company have to be integrated with an overarching search mask for knowledge and information.
Finding efficient knowledge and information
Through an intuitive and flexible filtering and sorting of the search results the required documents will be found quickly and easily.
Secure and transparent access rights management
The granting of read and write permissions for internal and external employees at different hierarchical levels must be run safely and transparently.
Minimal documentation effort of the employees
By minimizing the documentation effort which is required for the management functionality the acceptance of the employees can be achieved.

Figure 9. Pooled requirements for the searching functionality

5. Evaluation and discussion

The chosen methodological approach to identify and analyse the requirements for the management functionality as well as the search functionality of a knowledge management system for a company from the special engineering industry will be evaluated in this section.

Using the document analysis lots of KaI-Objects can be identified over a relatively short time. In addition, the analysis of documents can be done without the involvement of employees. However, it becomes apparent that not all documents are up to date and this has to be evaluated negatively. Another disadvantage of the document analysis is that tacit knowledge (e.g. knowledge or skills that are not completely expressible in words) is not taken into account. One advantage of expert interviews is that important KaI-Objects from the daily work of each respective employee can be considered. This method of collecting KaI-Objects increases the motivation of the participants through an open and vivid organization and consequently encourages truthful answers. A disadvantage is the high effort of preparation and documentation. Furthermore the responses are dependent on the subjective opinion of the experts. The advantages of moderated workshops are not only the enhanced acceptance of the joint findings but also the reduced risk that some KaI-Objects are forgotten. However, this method necessitates much time and employees and enables a mutual influence. The practical experiences have generally shown that the analysis of documents in advance of the expert interviews and workshops is certainly advisable. Although the moderated workshops were more suitable than the expert interviews to collect KaI-Objects lots of important information and findings for the requirement analysis could be gathered through the interviews. Moreover, the conduct of a workshop to evaluate the systematic classifications of the KaI-Objects has also proven to be useful.

Based on practical experiences the chosen approach for the analysis of the requirements for the search functionality can be described as very efficient and effective. This can be explained not only by the positive feedback of the participating employees but also with the numerous user requirements that could be fully and accurately gathered. In conclusion this approach enables the compilation of all requirements for efficient and holistic management functionalities as well as the contextual and user-friendly search functionalities. Based on this analysis and the derived requirements a product requirement document which can be used to implement an appropriate computer-based knowledge management system for the analysed company can be created.

6. Summary and future work

A methodology for the requirement analysis for a knowledge management system was theoretical as well as practical in a case study presented in this paper. This approach distinguishs between management functionality and search functionality. On the one hand the requirements for management functionality were derived from classified KaI-Objects that were collected by document analysis,

expert interviews, moderated workshops. On the other hand the requirements for search functionality were deduced from prioritised user needs and mentalities that were identified through several individual workshops with the support of a mock-up.
The way of working of each employee was until now determined by the data management systems which are currently used in a company. By separating the management functionality of the search functionality a user interface that is adapting to the needs of employees and thus support the individual ways of working can be realised independently from the existing systems. This user-friendly and intuitive input and output mask enables a context-sensitive and efficient search for knowledge and information in all existing systems. The maintenance and coordination of the various data management systems is entirely ensured by knowledge engineers.
In a further step existing knowledge management systems have to be evaluated with regard to the requirements of the described product requirement document. In addition to the technical requirements, the financial requirements have also to be taken into account. Therefore cost-benefit analysis should be conducted.

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