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APPROACH OF PARTIALLY AUTOMATED MODELLING OF A PROCESS MODEL

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Keywords: knowledge management, process modelling, process analysis, process improvement, knowledge based engineering

1. Introduction

Knowledge management in general, including various process-oriented knowledge management approaches, has recently attracted increasing attention. Since [Nonaka and Takeuchi 1995] explained the transformation of tacit knowledge into explicit knowledge in an entrepreneurial environment for the first time, a large number of knowledge management methods and knowledge management tools have been provided and continually flooded the market with knowledge management solutions in the early 2000s. Several of these methods lack applicability in industrial environments due to their complex handling as well as limited acceptance among employees involved. A study by [Haufe 2014] discovered that small and medium-sized enterprises in Germany use their own knowledge insufficiently, although different knowledge management solutions still exist on the market. The reason why company-specific knowledge management in Germany is experiencing a kind of "renaissance" these days is the many discussions about the fourth industrial revolution (Industry 4.0). The major topics of Industry 4.0 are "Big Data", the "Internet of Things" and cyber-physical-systems [BMWi 2015]. Each of these topics provides or needs a huge amount of data, which should then be transformed into information and finally connected to knowledge contents. In order to face these new challenges, companies have to establish a holistic knowledge management system. However, it is widely acknowledged that a generic knowledge management support method that is universally applicable throughout every business process does not exist. Due to the lack of direct practical applicability in industrial environments, most knowledge management solutions are still not accepted. Reasons for this may be that several knowledge management approaches force companies to rearrange their established business processes or that there is no recommendation for target-oriented implementation within the supported business process [Remus 2002]. These and other challenges can be faced with a detailed capture of the process, supported by knowledge management solutions. Furthermore, the preparation of a digital process model, based on the experiences of the capturing process, provides new opportunities to apply suitable knowledge management solutions.

2. Problem statement and objective

A detailed delimitation between the terms "knowledge management approach", "knowledge management system" and "knowledge management solution" is presented in [Laukemann et al. 2015a]. As mentioned in the introduction, a process-oriented knowledge management approach offers possibilities to provide company-specific and target-oriented assistance by means of a holistic knowledge management support method. Instead of striving towards a generic knowledge management support method which is universally applicable, huge potential is offered by focusing only on knowledge-intensive business processes. [Eppler et al. 1999] examined all business processes within an entrepreneurial environment and proposed the criteria "process complexity" and "knowledge intensity" to classify business processes with regard to knowledge management. One result of this examination was a matrix categorising business processes with regard to process complexity and knowledge intensity in order to choose suitable knowledge management solutions. One of the most complex and most knowledge-intensive business processes is the product development process [Eppler et al. 1999]. As previously stated, a product-development-process-specific knowledge management method provides further advantages. [Laukemann et al. 2015b] presented a holistic framework (see Figure 1) of a product-development-specific knowledge management process for small and medium-sized enterprises (called WMKMU). This framework is based on the fundamentals of the generic product development process in conformity with VDI guideline 2221 [Verein Deutscher Ingenieure 1993] and the approach of the modelling language "Knowledge Modeling and Description Language" (KMDL) [Gronau et al. 2004].

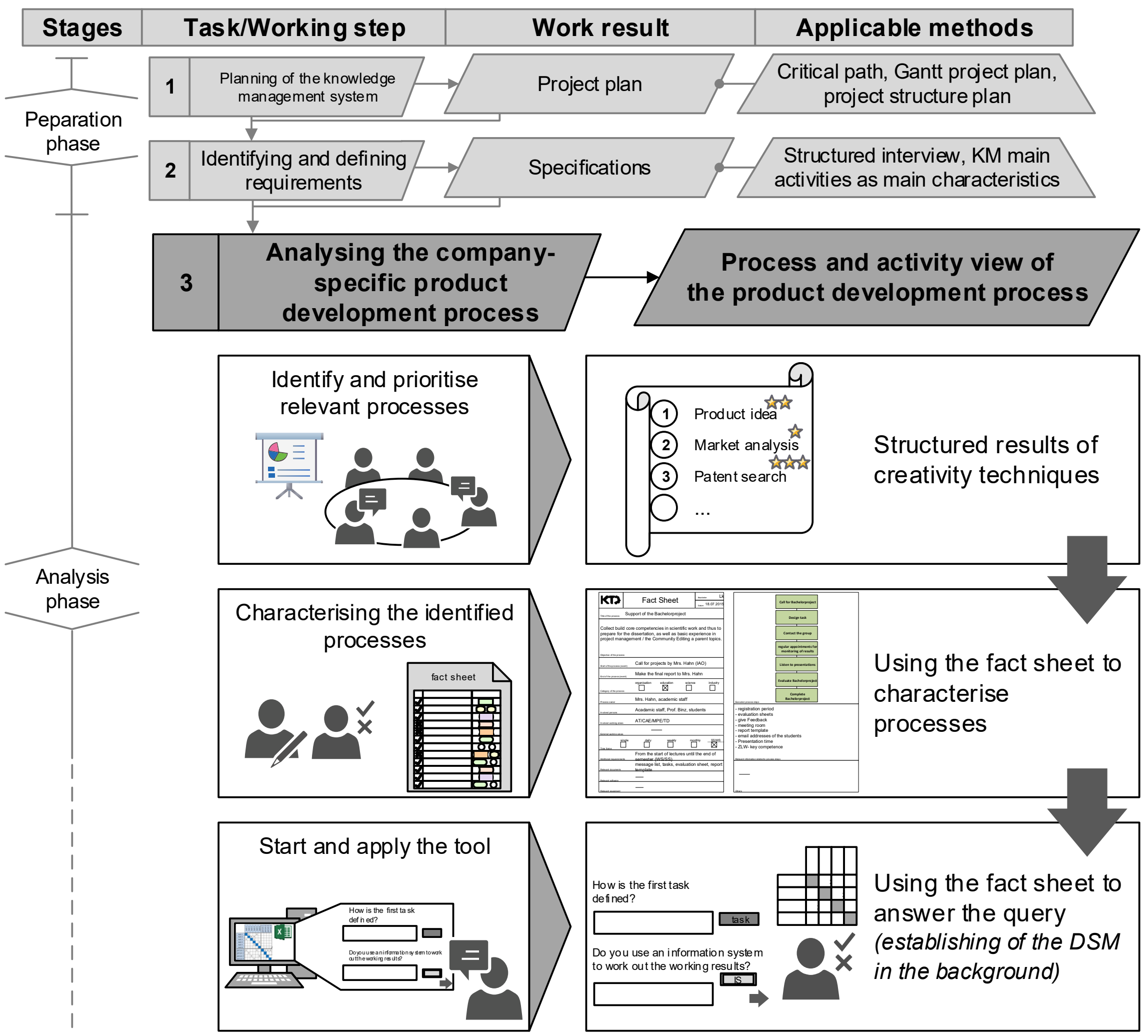

Figure 1. Section of the WMKMU framework with highlighted contribution of this paper

The framework of WMKMU can be categorised into four stages (preparation phase, analysis phase, synthesis phase, maintenance phase). Each stage contains different working steps or tasks which have to be passed. In sum, there are eight consecutive working steps. Excluding the preparation phase, the working steps of the analysis, synthesis and maintenance phases can be executed iteratively. The work result of each task is a necessary input for the following working step. Therefore, the quality of the work results directly influences the holistic knowledge management support which is to be developed. There

is a huge number of different methods available for ensuring high-quality results. The framework of WMKMU recommends the application of several methods. However, each company has to decide on its own which method suits to their entrepreneurial environment. In addition to the suggested existing methods and tools, WMKMU provides its own tools to reduce the workload of several working steps. Especially in the analysis phase, the initial working step (3) "analysing the company-specific product development process" is time-consuming and error-prone. The reasons for this are the high knowledge intensity as well as the high complexity and the varying degree of formalisation of the analysed product development process [Eppler et al. 1999]. Hence, a detailed modelling of the company-specific product development process is mandatory for the subsequent working step (4).
The main objective of this paper is to present an approach for a partially automated modelling of a digital KMDL process model within capturing the product development process in order to reduce the workload involved in the capture (see Figure 2). As a consequence, the research question can be formulated as follows: "How must an information technology tool be structured so as to facilitate capturing a product development process in order to develop a process model (by means of KMDL)?"
This paper therefore contains the approach and the structure of the tool whose application is highly recommended by WMKMU. Besides the placement within the framework, a detailed insight of the tool requires theoretical knowledge of process capturing in general, the modelling language "Knowledge Modeling and Description Language" (KMDL) and furthermore also the method "Design Structure Matrix" (DSM), which will be presented in the following chapter.

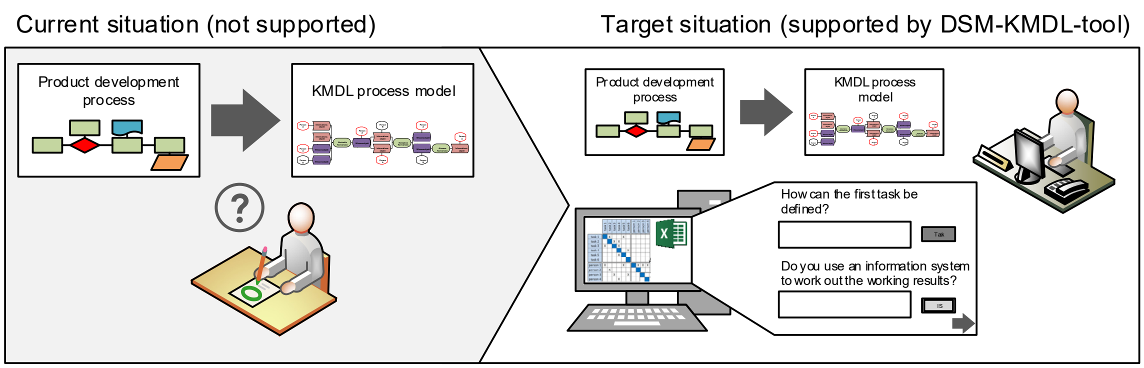

Figure 2. State of the art concerning process capturing and target support method

3. State of the art

This chapter examines the state of the art regarding the capture of processes in general, the modelling language "Knowledge Modeling and Description Language" (KMDL) and additionally the method "Multidomain Matrix" (MDM) as a sub-type of the method "Design Structure Matrix" (DSM).

3.1 Process capturing

The analysis of business processes plays a key role for process-oriented knowledge management [Eppler et al. 1999]. First, the notation business process has to be defined. Within the context of the relevant literature, there are several descriptions concerning the analysis and formalisation of business processes (cf. [Koch 2011], [Verein Deutscher Ingenieure 2015], [Wagner et al. 2015]). Furthermore, there is a huge number of approaches, theories and tools for analysing and capturing business processes. [Wagner et al. 2015] recommend implementing a four-step method within the context of a process lifecycle. The first two steps include the identification, delimitation and the subsequent capturing of the process. Regardless of the chosen approach, the overarching goal of capturing a business process is to increase the process transparency. Process modelling is an important instrument for process capturing as a means of achieving this objective. [Koch 2011] notes that process models are simplified illustrations of company-specific processes and represent the chronological and logical sequence of activities. The documentation of the process which should be captured is the basis for any process modelling and has a direct influence on the accuracy of the process model as well as the duration of the process capturing.

In contrast to generic and literature-based business processes, the documentation of real processes in an entrepreneurial environment is often insufficient and does not represent the actual state of the situation [Schwegmann et al. 2012]. Besides increasing transparency in the context of process-oriented knowledge management, process modelling is also intended to indicate information flows, knowledge transformations and personal knowledge of the business process. Existing modelling methods such as ARIS [Scheer 1991], INCOME [Remus 2002] or PROMOTE [Hinkelmann 2003] were not originally designed to support the visualisation of knowledge transformations within knowledge-intensive business processes. [Gronau et al. 2004] identified this shortcoming and developed a modelling language which facilitates the combination of knowledge-intensive business processes and the principles of dynamic knowledge creation. The "Knowledge Modeling and Description Language" (KMDL) focuses on the emergence of process-specific knowledge and the distribution of related information. KMDL is not just a modelling language. [Gronau et al. 2004] provide a procedural model which contains nine phases to support a consistent KMDL project. However, this paper only considers the modelling language of KMDL, which will be presented in more detail in the next chapter.

3.2 KMDL - a modelling language to capture knowledge-intensive business processes

The "Knowledge Modeling and Description Language" (KMDL), latest version KMDL 2.2, constitutes a semi-formal and graphic modelling language. The language consists of a clearly defined set of symbols and a given syntax. In contrast to other modelling languages, a huge advantage of KMDL is the distinction between three different views (e.g. process view, activity view) [Gronau et al. 2004]. For each view, a defined set of objects with different characteristics is available in order to model the process. The superordinate process view contains objects such as tasks, roles, process interfaces, information systems and different joint operators (see Figure 3 above). The major KMDL object of this view is the task, which describes a general stage of the examined business process. [Laukemann et al. 2015a] showed how the process view can be derived in the context of a generic and literature-based description of the product development process to create an accurate KMDL process view. Here, the KMDL object "task" represents a set of activities. Successive tasks make up the superordinate process structure. Each task may be connected with the KMDL object "role", which comprises one or more persons involved from the same area of responsibility. An "information system" represents information or communication technology that is used in business processes and determines the requirements of conversions (see KMDL object "conversion"). "Process interfaces" are designed to connect partially processes to process chains. The individual "joint operators" manage the control flow and display the possible paths [Gronau et al. 2004]. Based on the modelled process view, the more detailed activity view can be derived in the next step. The KMDL objects of the activity view, such as conversion, information object, knowledge object, requirement as well as employee-related objects like the person, undefined person and team, are therefore required to develop a KMDL activity view (see Figure 3 below).

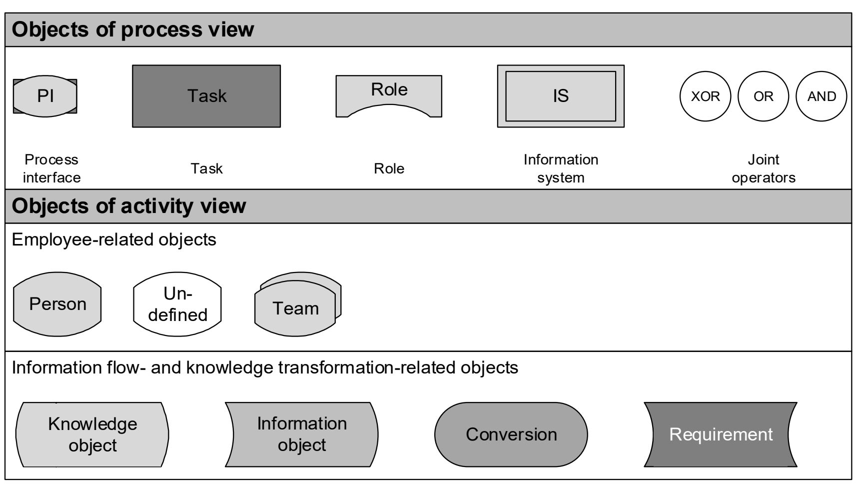

Figure 3. KMDL objects of the process and activity views (adapted from [Gronau et al. 2004])

With the provided set of objects from the activity view, it is possible to visualise information flows and knowledge transformations. The KMDL object "conversion" describes the transformation of tacit to explicit knowledge and the inverse transformation of explicit to tacit knowledge. Hence, the SECI (Socialisation, Externalisation, Combination, Internalisation) model of knowledge dimensions by [Nonaka and Takeuchi 1995] has been taken into account to visualise the knowledge transformation in the process model. By means of the KMDL object "conversion", the main activities of knowledge management can be addressed. The following main activities related to knowledge management result from various empirical studies conducted by [Probst et al. 2010] (see Table 1).

Table 1. Main activities of knowledge management to describe the KMDL object "conversion

Knowledge identification	Knowledge distribution
Knowledge use	Knowledge development
Knowledge preservation	Knowledge acquisition

In order to perform conversions in a structured way, certain requirements must be fulfilled. The KMDL object "requirement" can be met by the knowledge of individuals or teams, or through the functions of an information system. The "requirement object" therefore represents the recommendations for applying one of the main activities of knowledge management defined by [Probst et al. 2010] within the examined activity.

Another important KMDL object of the activity view is the object "person". There are different types of "persons". If the person/employee who is involved in the activity step cannot be identified or named, the notation of the object will be "undefined". If more than one person/employee can be referenced to an individual knowledge object, however, the KMDL object "team" will be used. Due to the fact that knowledge objects are always person/employee-related, the process participants can be indicated as knowledge carriers. However, the KMDL objects "information object" and "knowledge object" are of particularly central importance. The "information object" contains information that can be stored in various ways (text, images etc.).

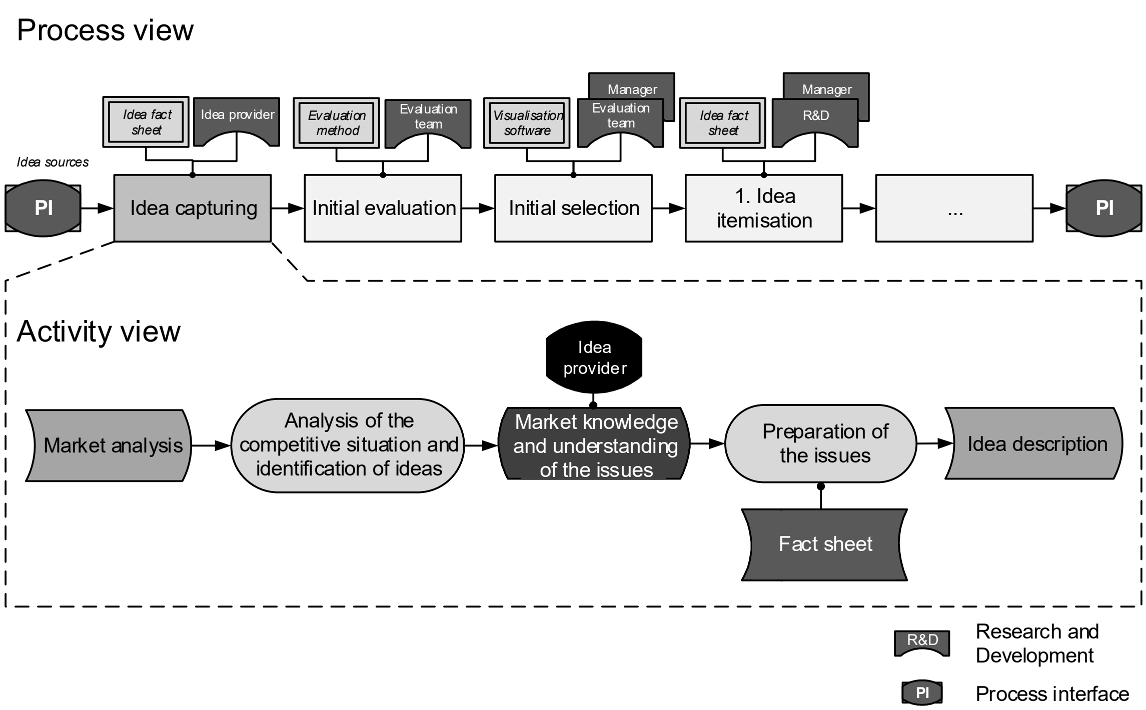

Figure 4. KMDL process model (process and activity view)

Thus, the "information object" can be the input or output object of a conversion (see KMDL object conversion). Depending on the type of information, this information can exist independently of employees and contains their explicable knowledge (e.g. technical drawing). "Knowledge objects" are exclusively related to employees and represent process-specific knowledge of these respective persons. Like "information objects", "knowledge objects" can equally be input or output from a conversion (see KMDL object conversion).

The knowledge creation within the process can be linked to the various conversions. Figure 4 shows a process model that includes an example of the superordinate process view and the derived activity view. This exemplary process represents a part of the IKTD idea evaluation process, which represents the continuous sample process of this paper. For reasons of clarity, this sample only includes one activity view for the first task (idea capturing) of the superordinate process view.

3.3 DSM - a method to model cross-linked systems

The "Design Structure Matrix" (DSM) is a method to represent the structure of a cross-linked system which contains a huge amount of elements [Browning and Eppinger 2012]. The work by [Steward 1981] on systems of equations forms the basis for further DSM developments. In the basic configuration, a DSM describes a square matrix where the diagonal cells characterise system elements and the off-diagonal cells characterise relationships between these elements. [Browning and Eppinger 2012] describes three different application areas for the "Design Structure Matrix" (DSM models of products, organisations and processes). However, [Steward 1981] originally developed the DSM to analyse the structures of processes. Since one of the topics of this paper is to establish a process model, only the DSM-process-specific type will be used.

Processes may be characterised using individual process architectures [Koch 2011]. These process architecture models comprise at least three requirements [Browning and Eppinger 2012]:

1. Hierarchical decomposition
2. Input and output relationships between activities
3. Other types of activity relationships

In order to develop a KMDL process model of a business process by means of a "Design Structure Matrix", each of the three requirements has to be fulfilled. For this reason, DSM is well suited to facilitating the capture of a company-specific product development process [Browning and Eppinger 2012]. In order to model the superordinate KMDL process view (see chapter 3.2) with its limited set of objects, the use of a simple DSM is sufficient. However, in order to capture the more complex KMDL activity view (see chapter 3.2), the further development of DSM in the form of the "Multidomain Matrix" (MDM) should be used. MDM allows the modelling of multiple domains which are connected by various relationship types. The numerous objects, in particular, which are available to develop the KMDL activity view require a "Multidomain Matrix" to represent all sorts of relationships. In contrast to the KMDL process view, and depending on the pursued granularity, the KMDL activity view can lead to a highly cross-linked system with a huge number of related elements [Gronau et al. 2014]. As regards the applicability of combining KMDL with MDM, the different views and the huge number of objects provided by KMDL offer high potential for analysis and optimisation (see Figure 5).

Figure 5 represents a fragmented "Multipledomain Matrix" (MDM) of the KMDL process model (see Figure 4). The first domain obtains the superordinate KMDL process view including all dependencies between modelled objects. The dependencies among the objects are marked with a cross in the respective column and row. As stated previously, each task of the process view can be modelled in more detail by developing an activity view. The KMDL activity view of an individual task can be described with the second domain. Again, the dependencies of the KMDL activity view objects are characterised with a cross in the respective column and row.

Furthermore, in accordance with [Nonaka and Takeuchi 1995], the conversion of process-specific knowledge can be explained with the SECI (Socialisation, Externalisation, Combination, Internalisation) model in the third domain. The SECI model describes the four modes (tacit-tacit, tacit-explicit, explicit-tacit, explicit-explicit) of how tacit and explicit knowledge can be converted.

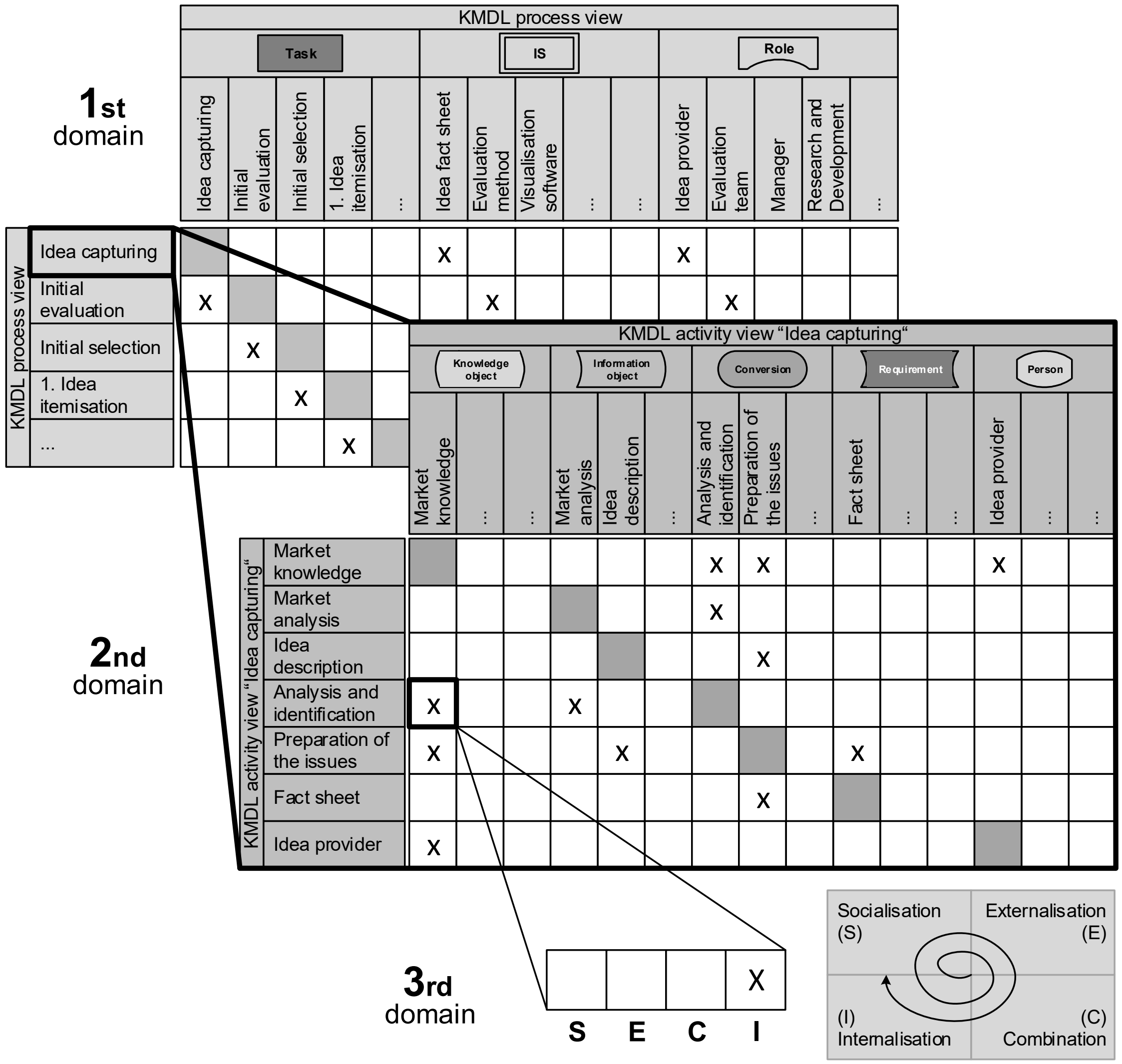

Figure 5. MDM of different KMDL views considering knowledge transformation (example)

4. Approach for partially automated modelling of a product development process

Based on the problem statement and the described objective, this chapter represents an approach for a tool to assist the third work step within the analysis phase of WMKMU. The three topics (process capturing, KMDL and DSM) dealt with in the state of the art (see chapter 3), have served as a basis for the development of the tool.

The first step of capturing a business process is to identify the process which should be examined [Koch 2011], [Wagner et al. 2015]. [Eppler et al. 1999] recommend categorising business processes using two criteria: "process complexity" and "knowledge intensity". The complexity of the examined processes can be identified by a set of attributes such as, for example, the number of process steps or the dynamic of a process. In order to define the knowledge intensity of a business process, [Eppler et al. 1999] provide several characteristics such as, for instance, contingency (weak contingency if process activities are defined) or decision scope (strong decision scope if participants of the process have several possibilities) of a process.

Within the scope of WMKMU, an identification of the business process is not necessary due to the product-development-process-specific orientation of WMKMU. Nevertheless, it is appropriate to start a rough analysis of the several sub-processes of the company-specific product development process concerning process complexity and knowledge intensity. The rough examination could be performed by applying creative techniques such as brainstorming, method 635 or the gallery method [Pahl et al. 1988]. After the examination as to which sub-processes of the company-specific product development are of interest, these sub-processes should be prioritised before characterising them using a fact sheet. There are various methods available on the market for prioritising and subsequently preselecting the gathered sub-processes [Pahl et al. 1988]. In consideration of company-specific demands, it is useful to use an employee-accepted method or to develop an individual tool (e.g. company-specific selection chart with own defined criteria) while considering the needs of the employees. The next working step is the characterisation of the identified sub-processes of the product development process. Therefore, [Koch 2011] recommends the use of a defined set of questions. [Wagner et al. 2015] provide a structured fact sheet to describe the process in detail. The process description sheet of WMKMU is adapted from the fact sheet of [Wagner et al. 2015] and outlines similar main aspects (see Figure 6).

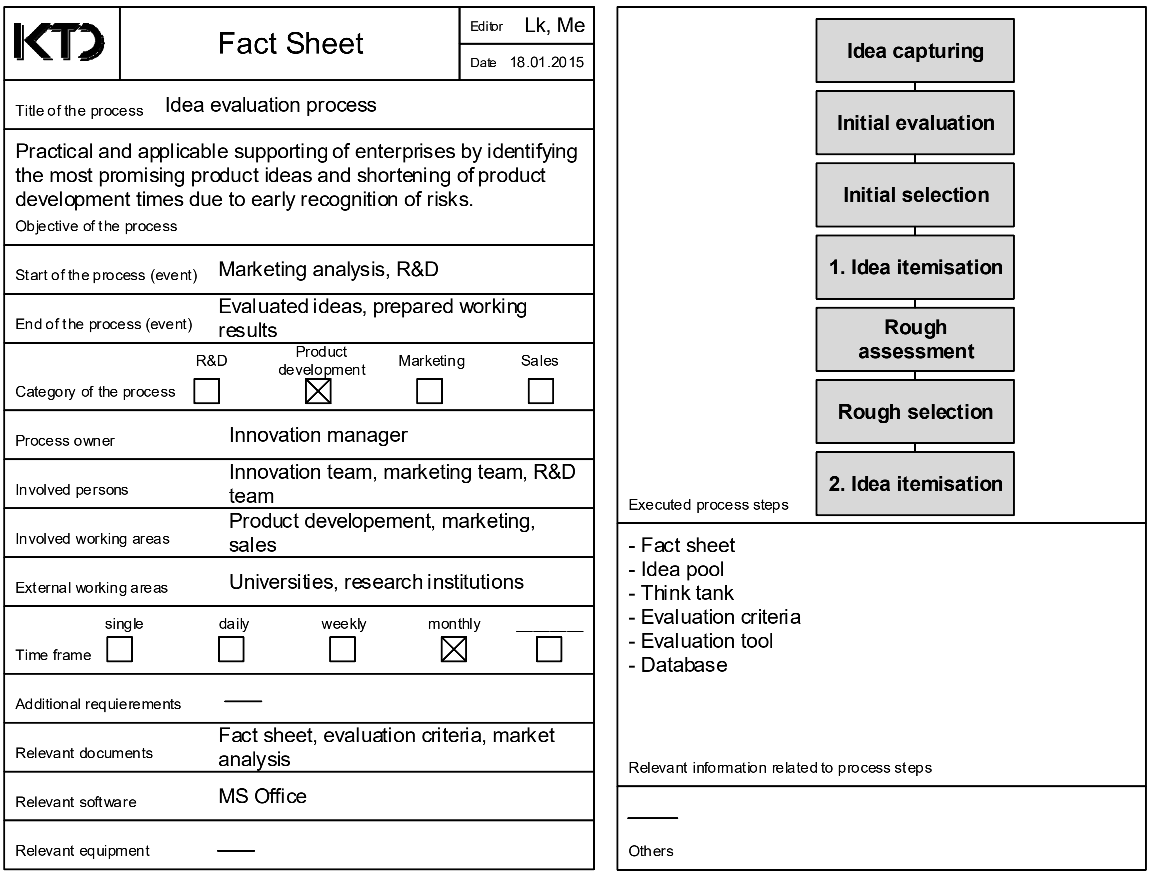

Figure 6. Completed WMKMU fact sheet of the IKTD idea evaluation process

The completed WMKMU fact sheet allows to establish a structured basis (prior knowledge), which is necessary for an efficient use of the WMKMU tool. Before explaining the approach in more detail, an overview and placement within WMKMU will be presented (see Figure 7 derived from Figure 1).

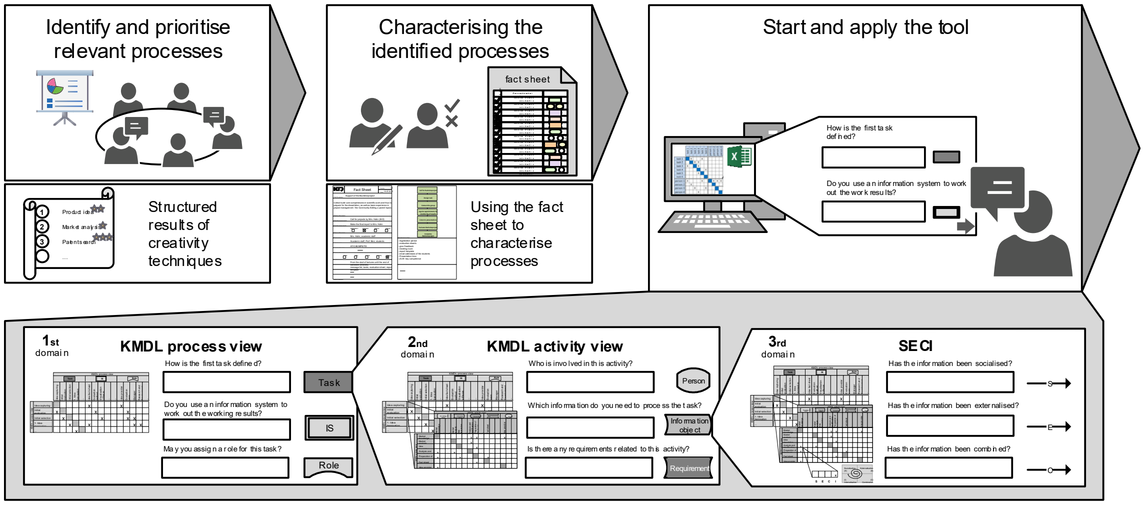

Figure 7. Overview of the sequence of process steps using the WMKMU tool

The first two steps constitute a comprehensive preparation before using the tool. Instead of performing a paper-based expert interview with the process owner, the third step of the presented approach, i.e. to capture the product development process, comprises a guided investigation using the tool provided. According to [Koch 2011], a defined set of questions are asked at the beginning of the investigation. Furthermore, the aspects of the fact sheet have to be entered into the tool. So far, the compiled database is sufficient enough to ask detailed questions concerning the information previously entered (taking KMDL and DSM into account).In addition to this, the tool automatically compiles the notations and rules of DSM in combination with KMDL. For this reason, irrelevant information or error-prone data will not be gathered in the first place. Moreover, the capturing process probably requires less time due to the fact that the time-consuming modelling of the KMDL process model is assumed by the tool. At the same time, the reproducibility and standardisation of the capturing process is ensured by the presented approach. A further advantage is that experts in knowledge management or process capturing are no longer necessary for capturing a company-specific product development process.

In order to create a new project, the completed WMKMU fact sheet (see Figure 6) is necessary to answer the first query (WMKMU fact sheet) about the examined process. After this rough description of the process, the tool will prepare all relevant information for the next working steps (e.g. "Process owner" as KMDL object "Role", or "Relevant software" as KMDL object "Information system" etc.). The prior knowledge of the previous working steps is now transferred to the tool and serves as a basis for further target-oriented queries (see Figure 8).

The graphic user interface (GUI) of the WMKMU tool has a similar structure to the WMKMU fact sheet and supports the transfer of information. On the basis of the working results by the preparation steps (identified process, fact sheet), the WMKMU tool uses the input data in order to develop a DSM (or in subsequent steps also MDM) in the background (see Figure 9, arrows and crosses).

When all necessary inputs are made and queries have been completed, the DSM/MDM is developed and the KMDL process model can be modelled automatically.

In summary, KMDL provides all objects required for developing a process model, although the objects must be structured by the process manager, who also has to be familiar with knowledge management and the applied modelling language. This work step (even for the less complex process view) is as time-consuming as it is error-prone and offers a high potential to be supported by means of DSM [Gronau et al. 2014]. As mentioned in the problem statement (see chapter 2), the development of a tool is motivated by lack of applicability of the current approach to capture the product development process in order to develop a KMDL process model. The information and explicable process-specific knowledge captured by the tool constitutes the basis for combining each KMDL process model into a holistic KMDL process model for the company-specific product development process (including all process interfaces). This will be the content of the next working step (4) of WMKMU.

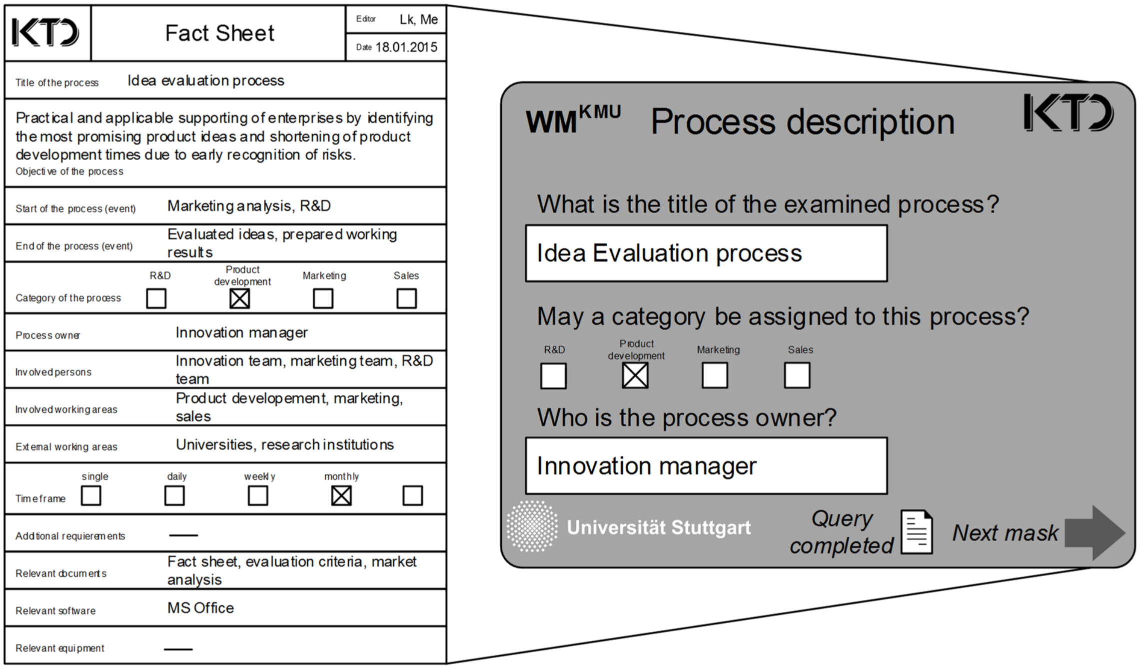

Figure 8. Transfer of information from the fact sheet to the WMKMU tool

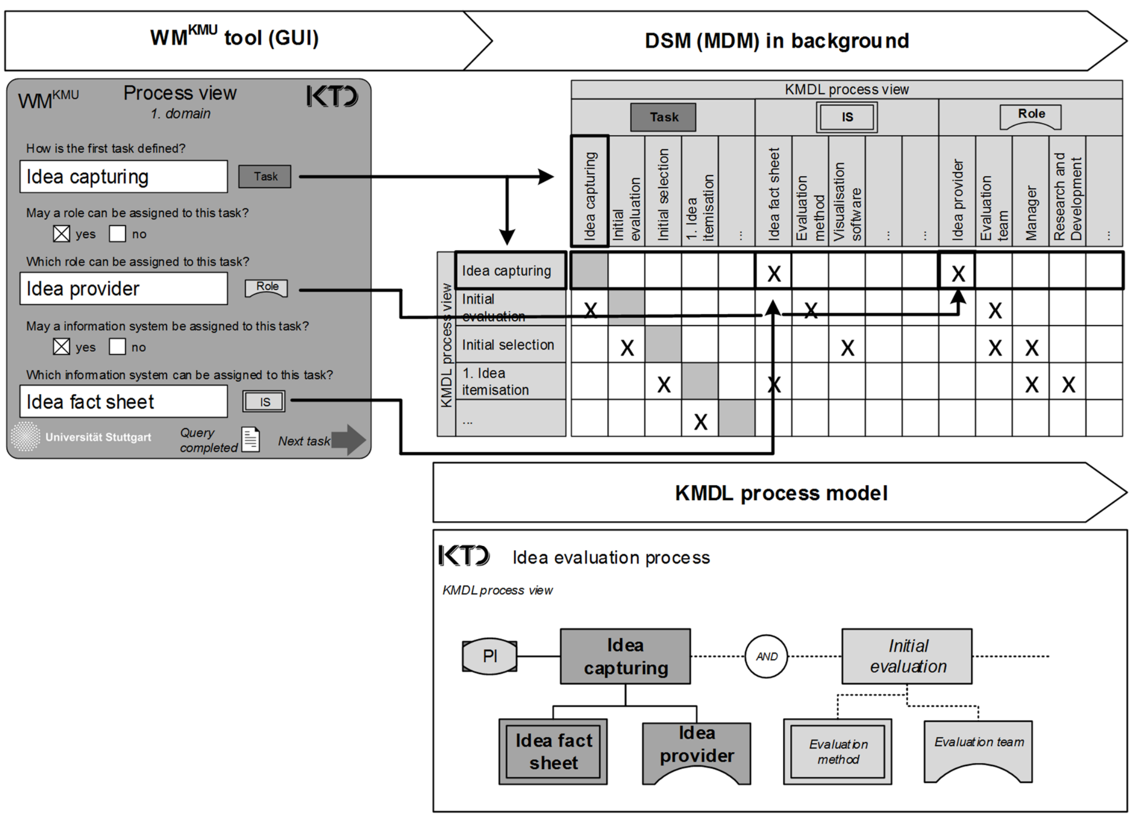

Figure 9. Example of using the DSM (MDM) to model a KMDL process view

5. Discussion of the results

The formulated research question of how a tool must be structured to facilitate capturing a product development process in order to develop a process model (by means of KMDL) has been addressed by presenting a logical, step-by-step approach including a tool. The presented approach has still not been finally evaluated. An initial evaluation with an expert has taken place. The results achieved should be viewed positively, but have to be treated with caution in terms of their generalisability. For this reason, a comprehensive evaluation in industry is still pending. The explanation of the detailed functionalities of the tool (especially the combination of DSM and KMDL) was not part of this paper and will be presented in further publications. However, the rough approach of a partially automated modelling of a digital KMDL process model within capturing the product development process has been demonstrated and the overall context for the framework of WMKMU has been described.

6. Conclusions and outlook

Based on the described problem statement and the lack of applicability of current approaches to the capture of the product development process, the presented approach was developed based on research in the literature and the gathered empirical knowledge of experts. Most of the described working steps were iteratively implemented and optimised in a research-institution-specific project. At present, a quantitative evaluation of the results is not possible due to a lack of industrial project partners. However, the support potential of DSM by modelling a KMDL process model of a company-specific product development process can be drawn. The next step of the research is the further development of the automatic process modelling concerning the notation of KMDL. Furthermore, the subsequent expansion with additional information of each KMDL object should be implemented in the tool. The further development of the intuitive user interface and the preparation of a manual are also research topics. After this, a comprehensive evaluation with different industrial partners is planned and should be used to prove the presented approach in industrial environment.

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