Picking Process Variability in Small and Medium-Sized Enterprises: State of the Art and Knowledge Modeling

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Keywords: Process Variability Modelling, Order Picking Process, Knowledge Management, Information Modeling, Adaptive Process Modeling.

Abstract: Information modelling is an established standard for knowledge representation in companies. However, small and medium-sized companies (SME) often lack the resource to use it for their own purpose. In this paper a solution to model business process variability in order picking processes is discussed. Therefore we did a knowledge extraction from different companies using a questionnaire, expert interviews and workshops with different experts from the field of production logistics in SME has been done. Based on their knowledge different variants of order picking processes in SME were defined and put together in an adaptive process model. Using configuration terms to enrich the adaptive process model allows the distinction between these different variants. Based on different influencing factors a specific process variant can be generated from the process model using element selection and further process optimizations including introducing new technologies can be made.

1 INTRODUCTION

Knowledge management is an important component for the documentation of business processes and at the same time the starting point for the digitization strategy in companies besides the reduction of waste in the processes (Becker et al., 2012). The non-use of employee knowledge is wasteful and of crucial importance for operational processes. Shared knowledge is the basis for process improvements, prevention of knowledge loss (e.g. employee fluctuation, demographic change) and support of learning and coaching processes.

The analysis of the actual situation and the modelled processes are the basis for the identification of strengths and weaknesses in the process and for the elaboration of development potentials. In addition to the core processes which create value in the company, there are also so-called support processes (Becker et al., 2012). One of these support processes in manufacturing companies is logistics with order picking as a sub-process. In this paper we focus on picking processes in SME, because they are an important part of the value chain. The preparatory activities of logistics staff in this process reduce waste in the value-adding production process. The production employees do not have to collect their goods themselves, which shortens distances and reduces access times to the necessary goods (Womack et al., 2006).

Information modeling is a well-established standard for knowledge representation in companies (Seel, 2010). Expert interviews and results from a questionnaire in various SME showed a deficit in workflow documentation using information modeling techniques. In practice, problems arise when dealing with model variants. Problems in the management of business process variants can be seen in many industries and application areas for example in logistics or project management (Timinger and Seel, 2016).

Creating a separate model for each variant, which differ only in a few details, will lead to great effort in model maintenance, expansion and inconsistencies. Instead we can combine multiple process variants to an adaptive process model and extract concrete variants based on defined influence factors. Constructing an adaptive information model helps to reduce effort in maintenance and inconsistencies.

The purpose of the paper is to answer the following research questions related to knowledge management through information models in the field of order picking processes. Furthermore technologies are presented which can enhance the order picking process.

Hilpoltsteiner, D., Bäuml, S. and Seel, C.
Picking Process Variability in Small and Medium-Sized Enterprises: State of the Art and Knowledge Modeling.
DOI: 10.5220/0006896901200127
In *Proceedings of the 10th International Joint Conference on Knowledge Discovery, Knowledge Engineering and Knowledge Management (IC3K 2018) - Volume 3: KMIS*, pages 120-127
ISBN: 978-989-758-330-8

RQ1 How is knowledge management of picking processes implemented in SME?

RQ2 How can information modeling support knowledge management in picking processes?

The article is divided into the following sections: At first, the state of research is presented as related work. Subsequently, the research methodology used and the structure of the empirical study are discussed. The next chapter presents the results from the empirical study. Chapter *Variability modeling in picking processes* presents the different variants of information modeling and explains the resulting adaptive information model in picking processes. An evaluation of the results completes the contribution.

2 RELATED WORK

According to the VDI (Association of German Engineers), a picking process is defined as (Verband Deutscher Ingenieure, 1994) "assemble a partial quantity (assortment) from total quantities of goods based on requirements (order)".

The picking processes of the participating SME in the transfer project were analyzed which are conducted according to the "man to goods" picking system. The three building blocks defined by GÜNTHNER (Günthner et al., 2009) are preparation, picking process and follow-up were analyzed. In accordance with VDI guideline 3590, the order picking process is divided into the following sub-tasks: specify transport information, transport goods to preparation area, provide goods for picking, specify pick information, picker move to preparation area, picking goods, deliver pick, confirm pick, transport collection unit for hand over (Figure 1). The main focus of this paper lies on the picking process itself, because no variants were found during preparation and post processing of the picking.

For the examined SME, information is provided exclusively by means of a picking list. This form of information provision is the most widespread one (Günthner et al., 2009). All relevant order data is listed in the picking list. Among other things, the article, its storage location and quantity is listed. If the individual items on the picking list are sorted by location, it is referred to as a guided picking list. In contrast to an unguided picking list, which leads to longer picking times through not optimized routes.

The prerequisite for process improvements are described and modeled processes in the form of information models (Becker, 2007). Consistently managed, complete information models can also lead to an improvement in knowledge transfer within the company. As already mentioned in the introduction, problems often occur with variants in business processes in various industries and applications, such as logistics, automotive and project management (Timinger and Seel, 2016). If one maintain each of these variants, which differ only in partial steps, in a separate information model, their consistent maintenance leads to increased effort and an increased risk of inconsistencies. It makes sense to combine variants of a process in a single adaptive information model in order to achieve a reduction in effort. An adaptive or configurable information model contains different variants of a process in a single information model.

Variant management is a permanent and ubiquitous problem in information modelling and the state of current research (La Rosa et al., 2017). The general goal of variant management is to combine several variants of the same domain in one model. This can be adjusted by adding or removing parts of a model. The existing approaches consider configurable nodes, element annotation, specialization through various activities and adapted model fragments. The greatest scope of research comprises the element annotation, where predicates are linked to elements of a customizable process model through annotation. (Becker et al., 2003; Delfmann, 2006).

To annotate the configuration terms on the elements of the information model, the configuration procedure "element selection by terms" is used (Becker et al., 2003). The problem with this method is not the configuration of the models themselves, but rather the consistent and efficient construction of the information models. After executing an element selection, the result is a meta-model based model projection that only contains elements whose terms are evaluated to true (Delfmann, 2006). A similar but simplified approach to meta-model based model pro jection is the evaluation of the information models using configuration terms (Seel, 2017). These are annotated to the elements of the model and ensure the extraction of individual variants from the adaptive process model.

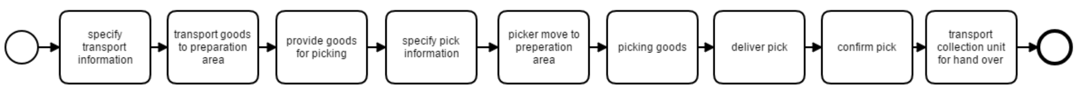

Figure 1: Reference picking process in BPMN 2.0 based on VDI3590.

3 RESEARCH METHOLOGY

The paper follows the design science research paradigm proposed by HEVNER et al. (Hevner and Chatterjee, 2010). According to them two complementary research paradigms have been established in the field of information science. A distinction is made between behavioral and construction-oriented research. The former is based on the formation and verification of theories about artifacts. This also includes the search and empirical validation of hypotheses. The aim of the paradigm is to test the correctness based on the empirical suitability of theories. Design science, on the other hand, is based on the engineering approach and focuses on the construction and evaluation of developed artifacts. The latter can be implementations, methods, models and languages.

The first research question (**RQ1**) is based on an empirical study and is assigned to behavioral research. A questionnaire was issued to the companies involved in the technology transfer project. After evaluation of the questionnaire, a structured interview guideline was developed and expert interviews were conducted with four SME using the interview guideline. In addition, there is an “intelligent logistic systems” working group consisting of specialists and managers from different SME and large companies in the region. This enables an interactive exchange of technical and expert knowledge on various problems in production logistics. The structure of the questionnaire, the structured interview guideline and the working group is explained in more detail in the following chapter *Structure of the empirical study*.

The second research question (**RQ2**) is answered with the help of the construction oriented paradigm. This involves modeling the companies picking processes in BPMN 2.0 and transferring them into an adaptive information model. The picking process variants and the adaptive information model represent artifacts of the design science process. An evaluation is ensured regarding to the completeness and functionality of the adaptive information model in comparison to the collected picking process variants.

4 STRUCTURE OF THE EMPIRICAL STUDY

The results of this chapter are based on an empirical study in form of a quantitative approach using a questionnaire (Meuser and Nagel, 2009). In the questionnaire various information about the companies were requested including general company information such as the number of employees, the type of production and the industry they belong to. Further questions dealt with the self-assessment of companies in certain areas such as production logistics, applied technologies and the degree of digitization. In addition, the characteristics of information modeling and its complexity in the company were queried. More precise, the consistency of information modeling, the frequency of adaptations to information models, but also the access possibilities of the employees were questioned. In addition, they were asked about modeling languages and tools used in the company as well as the responsibility for information modeling. The questionnaire included closed questions, semi-open and open questions. The last ones were used to obtain more detailed statements in certain areas. The results of the questionnaire serve as initial indications and are incorporated into the structured interview guidelines for the expert interviews. The quantitative approach is supported by a qualitative approach in form of expert interviews with staff from the four SME participating in the EDRF Project and workshops with specialists and managers from production logistics.

Expert interviews in four companies were used to determine the picking process variants and the factors influencing the process. The structured interview guidelines were discussed with employees and managers. It was divided into the three parts: knowledge management in the company, consideration of the picking process including influencing factors and their impact on process variants. The findings on the picking processes in the SME serve as a basis for the developed artifacts, which are presented in the chapter *Variability modeling in picking processes*. This includes influencing factors for the picking process and the resulting variants. After the parts of the empirical study have been shown, the results are presented in the following chapter.

5 RESULTS OF EMPIRICAL STUDY

A questionnaire as described in the previous chapter was sent to 23 cooperating companies. At the end of the survey, the response rate was 70 percent. Nearly all companies are affiliated to the NACE (Nomenclature Générale des Activités Économiques dans les Communautés Européennes)-Codes for manufacturing industry and the spectrum ranges from very small companies to global players. Some relevant information are shown in Figure 2.

The key findings from the questionnaire on knowledge management and information models in the companies are as follows (**RQ1**). In general, the questionnaire shows that information models and knowledge in the company are insufficiently maintained and rarely updated. At the same time, two thirds of those companies are committed to an established continuous improvement process. As a result, the level of knowledge modeled in the company and the actual situation of the processes differ. It is very important to maintain changes to workflows in information models in a timely manner, but only about 40 % of the companies provide timely maintenance for their information models. The majority of those involved consider the advantages of consistently maintained information models in the areas of real-time error detection, congestion management or weak points in process chains to be important. Problems in these areas can only be solved if processes in the company are modeled and correspond to the actual situation. However, only one company has indicated that it uses a standardized modeling language to map its business processes. However, modeled processes are the starting point for optimizing processes and avoiding errors (Becker et al., 2012). In addition, well-structured processes can reduce manual workflows and the resulting media disruptions, thereby creating greater transparency and leading to a more flexible reaction to changes.

Another insight of the questionnaire was that employees have insufficient access to information models in the company, if they exist. Around half of the companies surveyed stated that they regularly train their employees. These shortcomings lead to a higher probability of errors in the processes. In order to be able to detect errors in processes, a modeled process is necessary, but regular process assessments (certifications) are also useful (Schmelzer and Sesselmann, 2013). According to the results of the questionnaire, evaluations of the processes never take place or only take place irregularly, which makes it difficult to identify deviations between the processes described and the actual situation in the companies.

Based on the results of the questionnaire, the structured interview guide as presented in the chapter *Structure of the empirical study* was developed. This served as the basis for the expert interviews in the companies. The results from the second and the third part of the structured interview guide are presented in the chapter *Variability modeling in picking processes*. The expert interviews on the subject of knowledge management in the four SME showed that knowledge is predominantly documented in text form via work instructions and made available to employees either via the intranet or in printed form at the workplace. Furthermore, structured documentation of the picking processes was found in two out of four companies. In one company it was the requirement of the certification institution and in the other a necessity to train new employees. In the latter there are considerations to realize the knowledge about Wiki-based knowledge management system. Another result of the

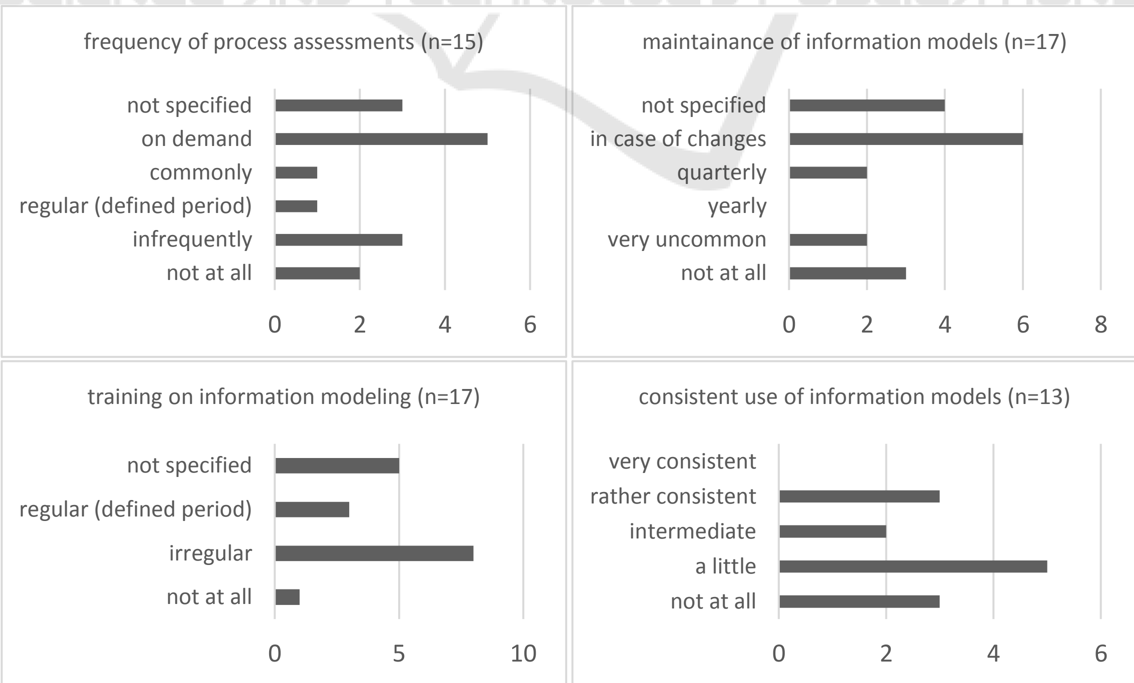

Figure 2: Results from the questionnaire.

questionnaire is that employees generally have a deeper knowledge of the work processes as documented in information models. In addition, knowledge is unevenly distributed across several employees within the same department. The reasons for the incomplete preparation of knowledge in the companies are: Added value from knowledge management for the company is not recognized, information modelling is not recognized as a value-adding activity, expenditure for the survey of complex processes cannot be mapped with the available resources in SME. Complex processes result from several influencing factors in the picking process, which means that there are several different variants of the same process. In order to enable companies to maintain their business processes in information models due to their limited resources, it is proposed to combine the different variants of one process into a single adaptive process model.

6 VARIABILITY MODELING IN PICKING PROCESSES

Using the reference picking process according to Günthner et al., an actual state analysis of the existing picking processes in the four SME was conducted. This chapter deals with the results from the picking process and information modeling from the expert interviews.

During the analysis, it became apparent that the documentation of work processes in the company is scarce and employees have only limited access to it. In cases where documentation exists in text form, deviations can partly be determined by process changes between the time of the process documentation and the actual situation in the company. Various variants of the picking processes were identified, which differ only in partial steps. Factors influencing the process included a sorted and unsorted picking list, order-related and order-neutral picking, and technology-supported picking confirmation. The influencing factors mentioned in Figure 3 in BPMN 2.0 determine the variants of the picking process (**RQ2**). These were collected in cooperation with the technical experts of the companies. The different variation steps are marked in red in the information model.

Variant 1 is a classic order-neutral picking process using a sorted picking list, without any technological support during goods withdrawal. The withdrawal is confirmed at the end of the process by posting all items in the ERP system (Enterprise Resource Planning). Variant 2 differs from Variant 1 in using an unsorted pick list. Therefore, the additional process step "Search next storage location"

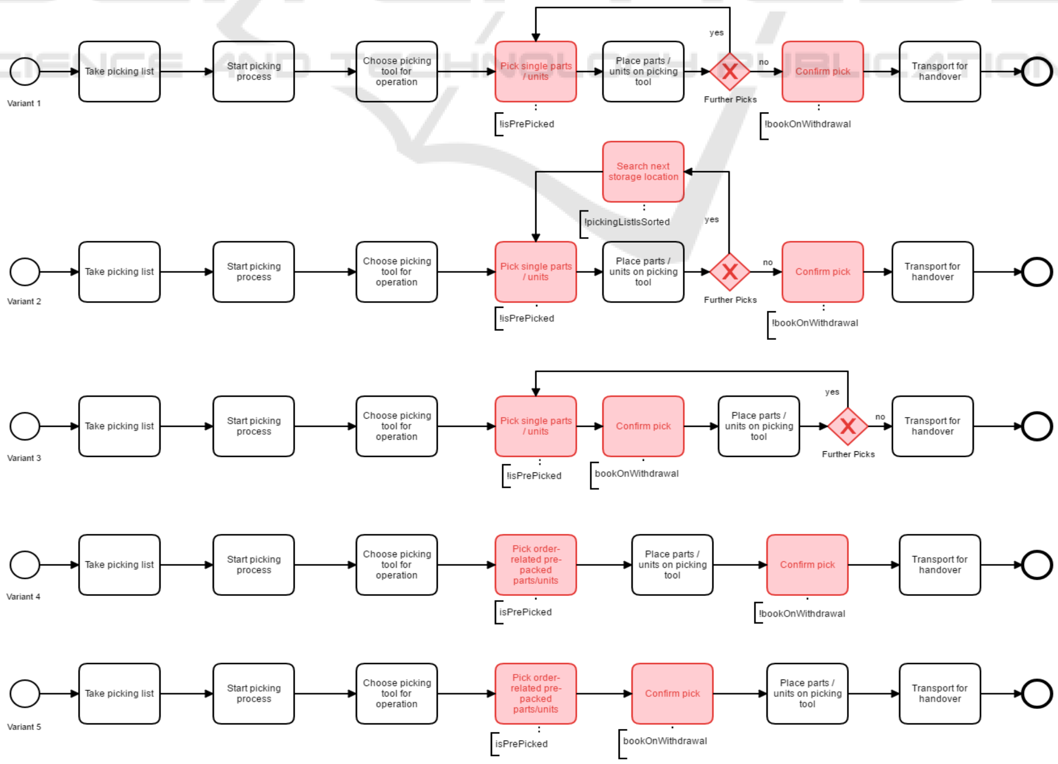

Figure 3: Overview of the collected picking process variants.

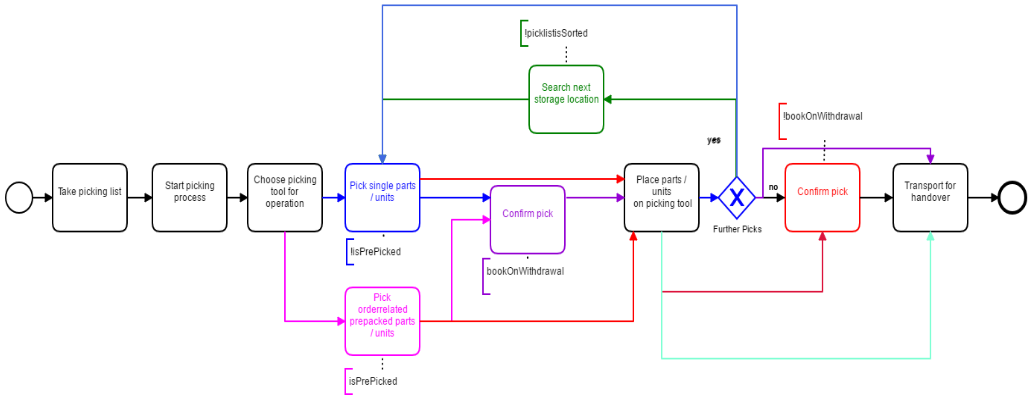

Figure 4: Adaptive Information model, which includes all variants from Figure 2.

is included. Variant 3 describes a process that provides technological support for the picking confirmation. Withdrawal is acknowledged in real time by using technologies pick-by or barcode scanning technologies. The fourth variant describes an order-related picking process in which the goods for an order have already been pre-packed. The fifth variant describes the order-related picking process, which, like variant 3, is supported by a technology for picking confirmation. The variants presented are only an excerpt of the situation found in the four SME. Further variants were found when using different picking aids and in hybrid approaches to order-related and order-neutral picking lists. The modelling and description of all further variants would go beyond the scope of the article and would not show any further insights for solving the above-mentioned problem.

It is clear to see that an increased effort is involved in the maintenance of information models if a company has to maintain all these variants in separate information models. When process changes occur to the same parts of the picking process (shown black in Figure 3), all affected information models must be modified. Inconsistencies can occur if certain information models have been forgotten. If companies are certified, these inconsistencies can lead to deviations in the certification assessment and inconsistencies should therefore be avoided.

To solve this problem, it is proposed to combine the five variants in an adaptive information model. Using the configuration terms, which are annotated to the elements of the model, any original variant can be generated by an algorithm. This algorithm was implemented in a software tool and can be accessed via an online repository (Bitbucket, 2018; Hilpoltsteiner et al., 2018). Figure 4 shows the constructed adaptive information model, which represents an artifact of the Design Science process. The adaptive model was enriched with configuration terms, which were added to the individual elements and edges. A configuration term as used in the model is shown below. The configuration term gets interpreted by the software tool and returns the result of the expression. Only elements with the Boolean result true remain in the model. In the current solution this leads to redundancy regarding to edges.

```
[pickingListIsSorted] == false &&
[isPrePicked] == false
```

Altogether three configuration variables were used in the adaptive information model. They can be displayed and maintained in a separate overview. Using an additional function of the software tool, all elements can be colored which have an identical configuration term. As a rule, the variants can already be identified by this. This approach poses problems, when several variants dependent on each other. For example, the process step "Place parts / units on picking tool" causes problems because it can be achieved by both incoming process steps with different variants.

7 EVALUATION

The aim of the design science process is to create artifacts that solve a practical problem (Hevner and Chatterjee, 2010). One of the core activities of the Design Science process is the evaluation of the created artifact to prove and justify its usefulness (Peffers et al., 2007). To demonstrate the usefulness of the designed artifact it is examined whether all originally determined variants are present in the adaptive information model and can be generated using configuration terms. As a first indicator for the correctness of the adaptive information model, the number of colors

Table 1: Matrix including the used configuration variables and their relation to the process variants.

	isPrePicked	bookOnWithdrawal	pickingListIsSorted
Variant 1	false	false	true
Variant 2	false	false	false
Variant 3	false	true	true
Variant 4	true	false	true || false
Variant 5	true	true	true || false

can be checked. Elements that occur in all variants are displayed in black. As already mentioned in the previous chapter, problems occur when coloring the elements as soon as the configuration terms differ. The reason for this problem is that common process steps can follow two different variants. Therefore, the subsequent configuration term of the process step differs from both the first and second incoming variants. The mere check of the correctness of the information model based on the number of colors can therefore not be guaranteed in this case. However, the approach would work well with completely independent process variants. On the software side this behavior can be further optimized. The variable assignments for the individual variants are defined in Table 1. The individual variants of the adaptive information model are written down vertically. By assigning variable values to variants, one can test whether the individual information model variants can be generated from the adaptive information model. The values are inserted into the evaluation interface of the software tool.

Figure 5 shows the generated information models from the software tool. On closer inspection, all five generated variants are technically correct. Only their optical appearance differs by the positioning of the elements and the edges, because the absolute positions from the adaptive information model are used. Commercial software already offers possibilities to automatically align elements after changes.

By creating the adaptive information model, the effort for the administration and maintenance of information models could be reduced, because only one information model must be maintained. This will also reduce the risk of inconsistency after changes to variants. However, it should be noted that the introduction of configuration terms in the adaptive information model leads to a higher complexity of the model.

8 CONCLUSION

In this paper the two research questions RQ1 and RQ2 have been answered. The first question dealt with the state of the art of knowledge management in picking processes in SME (**RQ1**).

It was found that knowledge management in SME is insufficiently established in order picking. The rep

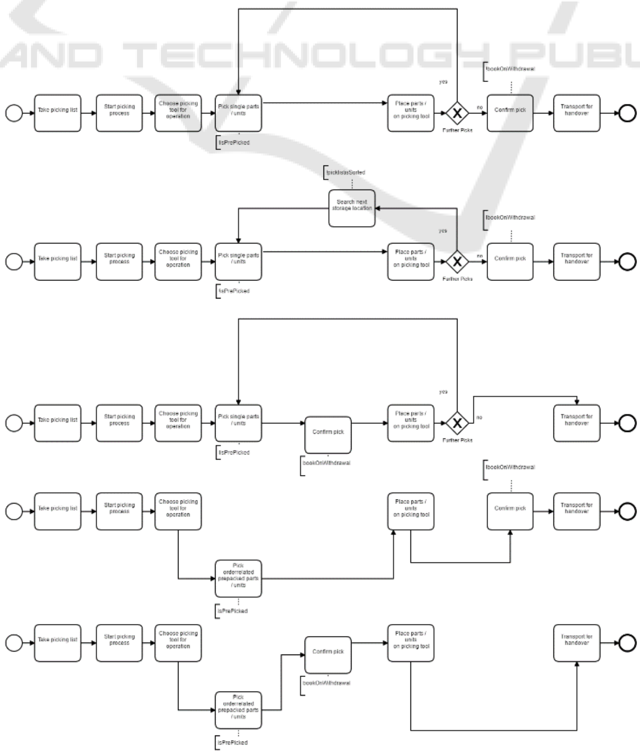

Figure 5: All generated variants from the software tool.

resentation of knowledge in information models is also weak. Furthermore, it was discovered that knowledge is unequally distributed among employeesin the same department and that access to the information models is not guaranteed across the department. The documentation of knowledge and its accessibility is essential to avoid errors. Also errors in the processes themselves or potentials for optimizations can often only be recognized if these have already been documented in advance. The questionnaire and the interviews with experts showed that there is potential for development in SME. Among other things, the modelling of business processes due to variations was considered complex. Especially the documentation of these process variants is important to achieve a holistic representation of the process flows.

As part of the empirical study, expert interviews were conducted in four SME. Various factors have been identified that influence the order picking process in SME. Together with the companies, these variants of the picking processes were documented. With the help of adaptive information modeling, an artifact was created from these process variants as part of the design science process. Using this artifact, the support of knowledge management in SME through information modeling was demonstrated (**RQ2**). Specifically, variants of the picking process were collected and modelled in four SME. Based on the influencing factors, the adaptive information model was extended by configuration terms. Through using element selection by terms, all process variants found in the companies in Figure 3 can be recreated. The correctness of the information model and the software tool that executes the element selection by terms was proven in the evaluation of this paper.

Overall, adaptive information models can support SME in documenting their expert knowledge. Especially in processes with many variation steps, adaptive information modeling enables a more compact option for long-term digitalization of knowledge, which requires less effort in maintenance and management. Above all, the possibility of optimizing processes on the basis of the documented processes has great advantages.

ACKNOWLEDGEMENTS

The technology transfer project "Competence Network Intelligent Production Logistics" is funded by the European Regional Development Fund (ERDF) - Operational Program "Investment in Growth and Employment" Bavaria 2014 - 2020.

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