Information Modeling of Rule-based Logistic Planning Processes Kanban Loop Planning Supported by a Workflow Engine

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Abstract: This paper discusses the modeling of rule-based logistics planning processes. These are mostly inadequately documented and modeled, especially for small and medium-sized enterprises (SMEs). As a starting point, the ways of representing rule-based logistics planning processes and the modeling languages suitable for the processes are introduced. In addition, it is shown how decision rules can be represented in modeling languages. Based on this, a prototypical representation for the planning of a kanban loop is presented as a technical model. This serves as the basis for a workflow, which is constructed by transforming the domain-oriented model into a technical model. A workflow engine is used to execute and evaluate the technical model.

1 INTRODUCTION

There are a number of logistics planning processes that are necessary to describe the strategic, tactical, and operational activities of a logistics planner. However, there are only a few formally defined planning processes. According to a survey of the needs of logistics planners (SCHUBEL, 2017), they want "reusable, formalized and standardized solutions for logistics process planning". By using standardized process models, important resources can already be saved when planning logistics processes, resulting in more efficient and effective planning processes.

A first formalization was undertaken with the support system of (SCHUBEL, 2017). The implementation of the support system includes a rudimentary visual representation of strategic material supply processes in the EPC (event-driven process chain) modeling language. However, no rule-based logistics planning processes that are suitable for automation are described in (SCHUBEL, 2017). An example of a rule-based logistics planning process is the planning and design of kanban loops (Gorecki and Pautsch, 2014) which are necessary for material supply in production. In addition, the modeling language BPMN (Business Process Model and Notation) (Allweyer, 2015) has established itself as the de facto standard in business process modeling (Kocbek et al., 2015). A comparison between polyglot and pure BPMN modeling stacks has shown that pure BPMN stacks have advantages in the transformation from the domain-oriented to the technical level (Seel, 2014). This transformation is important for implementing processes on a workflow engine and will be described below, both as a domain-oriented and technical model. The representation of rule-based logistics planning processes and their execution can therefore be identified as a research gap. From this the following research questions arise:

RQ1 How can rule-based logistics planning processes be represented?

RQ2 How can rule-based logistics planning processes be supported by a workflow engine?

The paper is divided into six sections: after the introductory section with the research questions, the research methodology used is presented in section two. Section three explains the current state of scientific knowledge on the ways of representing logistics planning processes. It also explains ways of representing decision rules that are necessary for the automated representation of rule-based logistics planning processes. Based on the kanban loop rule-based logistics planning process, a workflow engine based on the BPMN 2.0 modeling language is used in section four and we explain the steps necessary to move from a

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domain-oriented to a technical level and thus again to the executable model. In section five, the modeled process is executed on a workflow engine to evaluate the process. In the last section, the advantages of the model presented for logistics planning are summarized.

2 RESEARCH METHOD

The present article is methodologically guided by the Design Science Research (DSR) according to (Hevner and Chatterjee, 2010). The starting point is a practical problem in production logistics – more precisely, in the automation of rule-based logistics planning processes, such as the planning and design of a kanban loop. In accordance with the DSR, an artefact is constructed for this purpose. This is presented in this paper as a process model. This artefact is developed as a domain-oriented model for the documentation of the process and then transferred into a technical model. The technical model is a workflow that is executed on a workflow engine. The constructed artifacts are evaluated in accordance with the DSR in section five, which describes the execution on a workflow engine and the complete integration of the rules described in this paper. In addition, the artifact is checked for plausibility with experts from production logistics (logistics planners) and for applicability within companies. It is important to note that the implementation represents a generic process via the domain and is not tailored to the interfaces of individual companies.

3 REPRESENTATION OF RULE-BASED LOGISTICS PLANNING PROCESSES

Production logistics describes the area of responsibility in logistics that deals with the optimal design of the value stream from the receipt of goods (acceptance of the necessary production factors) to the issue of goods (handing over the finished products to distribution) (Plümer and Steinfatt, 2016). Planning is a structured information-processing process to achieve business goals (Plümer and Steinfatt, 2016). Business objectives are necessary as input variables for economic planning. The planning takes place under consideration of the principle of rationality. The fundamental problem in planning is the unpredictability of events (Plümer and Steinfatt, 2016). Logistics planners try to protect themselves against this uncertainty through their experience and by considering buffers. It follows that it is necessary to design logistics planning processes dynamically, as customer demands are constantly changing and fluctuating in volatile markets. This affects material supply processes in particular. The planning for this must be constantly revised in order to keep it up to date. The effort for this is considerable, especially because the planning processes in many companies are still carried out manually (Helmke, 2019). Rule-based planning processes in particular are suitable for automation, as they follow decision rules. So-called workflow management systems (WfMS) or business process management systems (BPMS) are mostly used to automate processes. Most of the terms are used synonymously, though there are slight differences (Allweyer, 2015). The central element of these systems is the so-called workflow engine (Freund and Rücker, 2017), which is used to execute and monitor the modeled process.

Logistics planning processes are inadequately formalized (Schubel et al., 2015). SCHUBEL ET AL. carried out a systematic literature analysis on the subject of "information models for production and logistics planning". They found that small and medium-sized enterprises (SME) in particular have a need for action in the systematic presentation of their logistics processes. Especially the logistics planning processes have a considerable potential, since the effectiveness and efficiency of planning projects can be supported by modeled processes (Schubel et al., 2015).

According to (Liebetruth, 2016b), it is necessary to model processes realistically as a first step. When modeled by technical experts, certain steps can be omitted or even combined in order to prevent the process from becoming too complex (Liebetruth, 2019). A representation of the real process is a model and its depiction is called modeling. The aim of modeling is to map actual processes or target processes of operational processes precisely and formally correctly (Gadatsch, 2017). The consistency of the presentation form is particularly important in order to keep the transformation effort between the domain-oriented and the technical model low and avoid content-wise differences between the two model levels. The domain-oriented model is implemented by an expert in the department. They have the best understanding of the process as well as implicit and explicit knowledge relevant to the implementation of the process. The preservation of expert knowledge in particular is a major advantage for companies (Liebetruth, 2016). If the processes are not represented, knowledge is lost during employee turnover and relocation, which leads to higher training costs for new employees. With the processes described, knowledge transfer for employees can be made more efficient. When restructuring business processes, it can be helpful in decision-making if the actual processes are known so that the consequences of change initiatives can be better assessed. In addition, they are necessary to generate transparency in the processes and to successfully pass certifications and audits. Moreover, they ensure the efficient development of business processes and are helpful in the digitization of processes. Digitization means shaping the change from analog to digital business processes. This includes the automation of manual decision-making processes, the use of existing data for decision-making, the use of data and the resulting information to develop new business models and simulate various scenarios (Liebetruth, 2016)

There are numerous ways of modeling processes. As already mentioned at the beginning, the representation of logistics planning processes is inadequate and is criticized by experts (Schubel, 2017). This leads to inefficient processes and ties up qualified and specialized staff resources. In the case of SMEs, it was found in collaboration with the cooperation partners that – in contrast to large companies – they do not have one person working as logistics planner, but that the tasks are shared by other employees (Schubel, 2017). For this reason in particular, it is important for small and medium-sized enterprises to conserve and make more efficient use of their already scarce staff resources in the specialist departments through documented and modeled processes (Federal Ministry for Economic Affairs and Energy, 2018).

When choosing the right modeling system, it is important to consider beforehand which goal will be pursued (Gadatsch, 2017; Liebetruth, 2016). Modeling content must therefore not only be error-free, but also represented target group-oriented (Gadatsch, 2017). LIEBETRUTH distinguishes between three target groups with different requirements for the representation of processes:(1) the upper management (strategy), for which a general representation of the processes as a value chain and a subdivision into core and support processes is sufficient (Porter, 1986); (2) process managers, who are responsible for the performance and quality of the individual processes and are therefore interested in the representation of individual process models, sub-processes and even individual work steps; (3) the lower management and executors, who monitor the implementation of the individual work steps and are thus interested in detailed information on the processes, such as work instructions and documents (Liebetruth, 2016). Those responsible for logistics planning processes are among the last two target groups.

(Gadatsch, 2017) has compared numerous modeling systematics. In an empirical study conducted by the Zurich University of Applied Sciences in 2011 asking “Which notations are used in your organization for the documentation of business process models?” the results were as follows: (N=186; multiple answers were possible): simple, non-formalized flowcharts (63 %), BPMN 2.0 (49 %), EPC (47 %) and, to a lesser extent, IT-related UML (Unified Modeling Language) (20 %). A further interesting question was: “In which departments are BPM methods applied in your organization?” 32 of the companies (N=191) stated logistics. This functional area was ranked seventh behind IT, consulting/provision of services, procurement/purchasing, finance/controlling, production and sales/distribution. At the same time, 47 of the companies stated that the greatest benefit was seen in logistics (Minonne, 2011). A particular challenge in the presentation of processes in logistics and purchasing lies in the strong link between physical and administrative or IT processes (Liebetruth, 2016). Both BPMN 2.0 and EPC offer a means to map physical and administrative processes. According to (Allweyer, 2015), EPC is still frequently used as notation in the field of business process modeling. EPC is mainly established in German-speaking countries, but has disadvantages in automation. EPC should no longer be preferred for process modeling in the context of process automation (Freund and Rücker, 2017). In addition, there is a clear trend towards modeling business processes in BPMN 2.0.

The BPMN 2.0 modeling language is well-suited where existing processes are to be documented and modeled in a domain-oriented way and where the main focus is the technical modeling and execution of the models (Gadatsch, 2017; Liebetruth, 2016). One notation introduced by the Object Management Group (OMG) for modeling decision rules in business process management is the Decision Model and Notation (DMN) (Freund and Rücker, 2017). Describing the principle of decision logic of the process as business rules has existed for a long time (Endl, 2004). There are some software solutions on the market like Drools or IBM Websphere ILOG JRules. However, the use of the two standards DMN and BPMN makes it possible to map and integrate the decision logic directly via a workflow management system. An advantage is thereby the combinability with BPMN, which will be further improved in the BPMN 2.1 specification. In addition, the implementation of an automated decision making process is possible, which can present the requirements for the department as well as the IT in an understandable way. BPMN 2.0 thus offers three major advantages over EPC which are important for the representation of rule-based logistics planning processes. First, it is designed to be usable by logistics experts and skilled personnel without IT knowledge. Secondly, it offers a way of making modeled processes executable (Liebetruth, 2016). Thirdly, BPMN 2.0 is supported by DNM, which is relevant for the presentation of the rules. Thus, EPC is not suitable for the representation of rule-based logistics planning processes.

As already mentioned at the beginning, the material supply processes are most strongly affected by the fast pace. The strongly fluctuating markets require a waste-free, synchronized and short-cycle supply of production to avoid bottlenecks in material supply. An example of a rule-based logistics planning process in production logistics is the planning and calculation of the kanban loop. So far, these logistics planning processes have been insufficiently represented by models in standard modeling languages. Planning the kanban loops is very time-consuming and is carried out manually in many companies. However, this principle is potentially error-prone. Basically, the procedure is based on the principle of processing decision rules that have a direct influence on the design of the kanban loop. Decision rules can be documented in the implicit knowledge of employees, in the program code or in formally written down rules.

There are two options for modeling in a standard modeling language. Decision logic can be integrated into the model as scripts or external files in programming languages such as Java or C++ can be connected to the model. The disadvantage of linking to external files is obvious, as logistics planners usually do not have in-depth programming knowledge. In addition, the logistics planner can no longer view the process knowledge in the program code. External systems can be linked to the process model by web service calls through the code either in the models themselves or in associated files. With the introduction by the OMG of DMN as the official standard for decision rules, a way to define deterministic decision logics for processes, which can also be maintained by business users was created. An overview of the decision rules used in the BPMN model (Figure 2) is shown in the DMN decision table (Figure 1). This is linked to the BPMN model and can be used to extract decision logics from the model and present it in an easily understandable form.

kanban_replenishment_time

U	Input +	Output +
	FormField_Kanbanart FormField_Kanbanart	Wiederbeschaffungszeit_Kanban
	string	long
1	'Value_KanbanE'	FormField_Information_Transmission+ FormField_Post_Production+FormField_Transport
2	'Value_KanbanB'	(FormField_Information_Transmission+ FormField_Post_Production+FormField_Transport) * 2
3	'Value_KanbanK'	(FormField_Information_Transmission+ FormField_Post_Production+FormField_Transport) * 2

Figure 1: Decision rules in the DMN-Model.

4 WORKFLOW IMPLEMENTATION

In general, business processes are modeled based on logically linked activities and can be automated using a workflow engine. Workflows are automated process operations in which, in addition to the processes, predefined rules as well as the interacting participants and systems are defined. When modeling executable processes, the transition from domain-oriented to technical models is the focus. Modeled processes are basically semi-formal, represented in flow diagrams, not directly executable and serve primarily for the documentation and visualization of processes. Executable workflows, on the other hand, must be exact and allow a clear interpretation of the process and the interaction. For this purpose, information sources and sinks must be defined in the process, and this includes ERP systems or other inventory management systems in which the relevant information for processes is stored: lot sizes, packaging units and consumptions. Ideally, these systems provide interfaces through which they can be accessed from outside. If interfaces do not exist, they must be defined additionally, otherwise automated data exchange cannot be ensured. The modeling language BPMN 2.0 is suitable for the automation of business processes. The following section describes how the exemplary implementation of a workflow was carried out using the rule-based "kanban loop" logistics planning process. Therefore we describe the domain-oriented model, the technical model and the necessary steps to get from the domain-oriented to the technical model.

In the modeling of information models, a general distinction is made between a domain-oriented model and a technical model (Freund and Rücker, 2017). The domain-oriented model contains more organizational structures and forms a basic framework for the documentation of the process. A technical model, on the other hand, extends the domain-oriented model with information that is required as a workflow at the execution time. For this purpose, the individual steps of the domain-oriented model must be broken down into transactional tasks which are implemented by individual components.

Figure 2 shows the model of a rule-based logistics planning process: the kanban loop. Its description in the literature is limited to the interpretation and calculation of the number of kanban. Kanban in Japanese stands for sign or card, but it is far more than that. It stands for the production control element that transforms a push system into a pull system (Gorecki and Pautsch, 2014). Here, each kanban stands for a real stock keeping unit and triggers the replenishment process when it is removed. This means that the number of kanban limits the actual inventory. Therefore, the planning of kanban loops is an important logistics planning process, ensuring the material supply of production. Individual planning process steps have been described in the literature (Becker, 2018; Gadatsch, 2017; Liebetruth, 2016). However, no kanban loops with the planning process steps needed have yet been modeled. This was developed in collaboration with the partners of the "Intelligent Production Logistics Competence Network" project, e.g. a company for agriculture textile products or a company for conductors and other technical experts. At the beginning, a first process draft based on the knowledge from practice and literature was prepared. This process was then subjected to a plausibility check by partners and other experts from logistics planning. The domain-oriented model was modeled in BPMN 2.0 and continuously further developed with the knowledge and experience of the technical experts. The model contains the steps for calculating the number of kanban as well as the upstream and downstream process steps that are necessary for the design and introduction of the kanban loop. In the following, these three focal points of the process are referred to as process building blocks. The upstream planning process steps (upstream process building block) include executing an ABC/XYZ analysis to check the kanban capability of the component, determining the source and sink, checking the lot size with the packaging unit, and determining the kanban type. The ABC/XYZ analysis divides the components according to consumption value (high, medium and low) and prediction accuracy (high, medium and low). Components with the properties AX, AY, BX, CX, BY and CY are suitable for consumption control and thus for kanban loops. An ABC/XYZ analysis is a valuable aid for the logistics planner, but not the only criterion as to whether there is kanban capability or not. Other criteria may include component size and technological limitations of the source and sink. Therefore, after performing the analysis, the logistics planner can still decide whether to cancel the process even after kanban capability has been determined, or to continue the process even though the component BX, CX, BY or CY is not assigned. There are three loop options in production logistics: warehouse to supermarket, supermarket to production and production to production. The decision for the loop option influences the selection of the kanban type, lot size and replenishment lead time. The next process step is to check the ratio of the lot size to the packaging unit. The packaging unit is the number of components in the container. In the extreme case, the packaging unit must be adapted to the container. In Figure 2 the kanban loop process was terminated for this scenario. In order to concentrate Figure 2 on the essentials, a process termination was chosen. The selection of the kanban type influences the calculation. The kanban types to be selected are:

K-kanban: Classic kanban in which a card (K) is attached to the container and is given to the operative logistician when the last component is removed, thus triggering the order for the next lot size.

B-kanban: This type also has a card, but this is not removed when the last component is removed; instead, the entire container (B) is returned with the card to the source as empties, thus triggering the order.

E-kanban: The logic is identical to that of the K-kanban but the card is not returned. Instead a signal that the last component was removed is sent back to the source electronically.

The information flow of the order is shorter than with K-kanban and B-kanban. The "physical transmission" by card or container is eliminated and replaced by an electronic transmission. Once the upstream process building block has been completed, the actual process steps for calculating the number of kanban start. The kanban formula is described in detail in the literature and is as follows (Burrows, 2015; Klevers, 2009):

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Number of kanban = (replenishment lead
time * average consumption
rate)/packaging unit * safety factor +
safety stock
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As already mentioned, the replenishment lead time depends on the kanban type and is made up of three parts: transport time, post-production time and transmission or waiting time. The transport time is the time between source and sink and depends on the transport medium, transport cycles and handling times. The post-production time depends on the lot size in the case of the production-production cycle option. It is omitted in the possible cycles warehouse-supermarket and supermarket-production. The transmission and waiting time depends on the selected kanban type. The average consumption is calculated from past values and therefore involves some uncertainty. This uncertainty is addressed using the safety factor. In case of strongly fluctuating consumption, the maximum consumption is often used in the formula. In practice, this information is retrieved either from the ERP system (Enterprise Resource Planning System) or from databases. During plausibility checks of the kanban loop rule-based logistics planning process, it was often pointed out that some information is not available in the ERP system, for instance the packaging unit, which in some cases was not maintained as a master data record. This is particularly true for small and medium-sized enterprises. In addition, it was pointed out that implicit knowledge and the experience of logistics planners play an essential role in whether the number of kanban was calculated correctly. In the process described, there are still two variants of the triggering of an order. Variant 1 (V1) describes the triggering of an order by a signalling point, also known as collective or signal kanban. Here, kanban are bundled according to a defined limit before the order is triggered. Another variant (V2) describes how an order is triggered with each kanban. The decision is made in cooperation with operative logisticians and production planners. It depends on the local conditions and a high consumption rate. After the successful calculation of the kanban loop, the third and last process building block – the so-called downstream process steps – starts. They describe the steps required to implement a kanban loop. For the implementation, the kanban must first be generated. The type depends on the kanban type selected at the beginning. With K-kanban and B-kanban, the kanban must be attached to the containers and the containers must be brought into the cycle. With E-kanban, it is not absolutely necessary to print out the kanban. However, it is necessary to check the type of data transmission. The decisive factor is whether technological support already exists or whether technologies have to be procured before the implementation of the kanban loop. Finally, the operative logistician (e.g. tugger train driver) must be informed. In practice, a further process for checking the transport capacities between source and sink must also be started here. This process was not take into consideration here because of the concentration on the kanban loop. So far, the domain-oriented part of the entire kanban control cycle rule-based logistics planning process has been described. Next, the steps necessary to move from a domain-oriented model to a technical one will be described, since the former model is not yet suitable for execution on a workflow

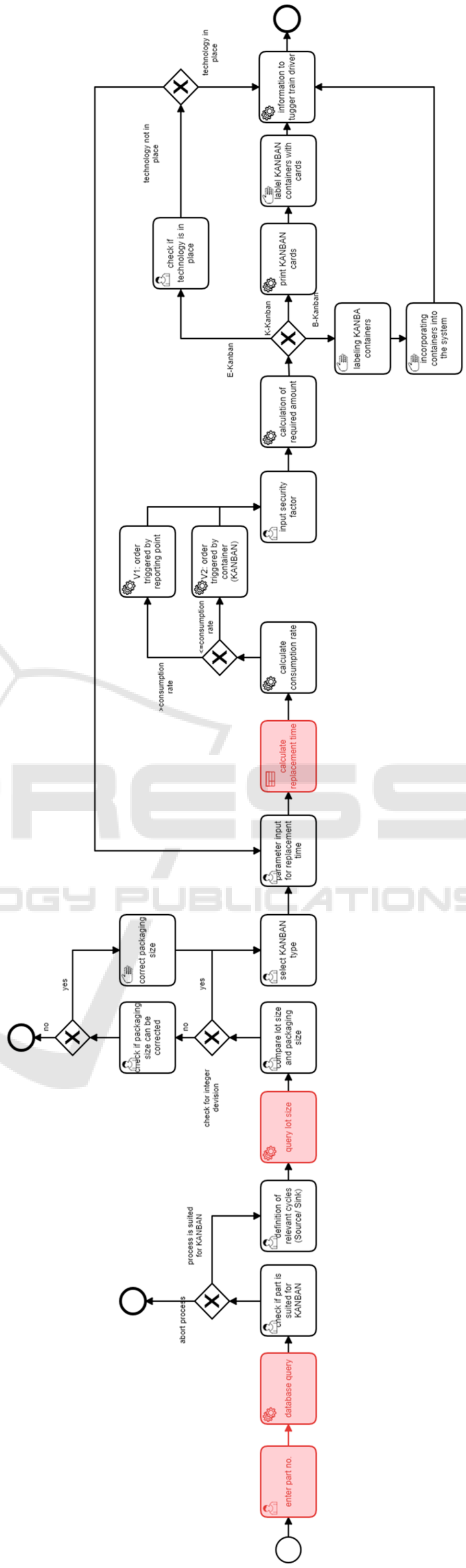

Figure 2: The technical model.

engine. A technical model, which is also called a workflow, “is a formally described, completely or partially automated business process” (Gadatsch, 2017). Compared to the domain-oriented model, the technical model contains additional information such as error handling, responsibilities, but also interface call-ups to other systems.

As shown in Figure 2 all tasks in the model, which are relevant for automation, contain an icon that defines their type. This determines which properties a task has. Service tasks (represented by a cogwheel) offer the ability to store scripts, whereas user tasks (represented by a human as icon) offer input options. In Figure 2 the differences to the domain-oriented model are marked in red. Due to the lack of space one can find the domain-oriented model online (https://github.com/DanielHilpoltsteiner/KMIS_2019_Paper_Appendix). All changes in the technical model serve to refine the process flow and better allocate tasks to the system or user. At the beginning, the technical model was supplemented by the information that has to be entered by the user at the start of the process. For this purpose, the task “enter part no.” was inserted at the beginning of the process as a user task, in which the user must enter the article number in an input screen. In addition, the service task “database query” was added, which specifies that information on the article number must be retrieved from an external system so that it is available later in the process. At the same time, scripts were stored and variables defined in the aforementioned tasks in order to be able to use the values in the workflow engine at execution time. The same procedure was used to check the lot size for the packaging unit, since here too the information must be obtained from an external system. The “calculate replacement time” task was challenging during the transformation because process logic has to be entered here. This was solved by defining the calculations in the DMN table “KanbanReplenishmentTime” from Figure 1. To perform this work, the task was defined as a business rule task and DMN used as the implementation detail. It would also have been possible to implement this via embedded scripts or an external program code. However, both approaches would have the disadvantage that the business rules could not be maintained by the business experts themselves, since most of them have no experience in programming. In the case of external file links, it must be ensured that this is known to a workflow engine at the time of execution and is in the correct directory. When the task is executed, information is exchanged between the engine and the script using the input and output parameters of the task.

During the transformation of the domain-oriented into a technical model, it was also found that the definition of output parameters and variables within the model can only be used to a limited extent with regard to the data types. While information entered in input interfaces contains numbers or truth values, neither of these two data types can be used as the output of a task. This problem is solved by using external scripts and files in which the program code is managed. Even the design of forms within a model is only possible in a rudimentary way and so it makes sense to outsource this functionality to an external program code.

5 EVALUATION

As intended in the DSR according to (Hevner and Chatterjee, 2010), the developed artifact (Figure 2) is evaluated. The domain-oriented model was constructed in cooperation with various technical experts and thus represents a scientifically founded kanban loop that includes factors relevant to practice. The domain-oriented model was increasingly refined in several iterations. The next step was to transform the domain-oriented model into a technical model. As already described, broader requirements apply to this model than to the technical model. It is important that after the transformation the technical correctness is maintained. Therefore, the process was executed on a workflow engine and tested to ensure that it ran correctly and that all elements in the model were reached and processed. For this, the model must be uploaded to the engine. This was done by using a REST (Representational State Transfer) from the modeling environment.

Since digitization affects many SMEs are involved in technology transfer projects, when choosing a workflow engine open source providers and free product versions were consciously considered. Furthermore, the application can be used for further research by third parties. SMEs are often financially limited in their digitization resources. In addition, many companies are only beginning to digitize their processes and can approach the topic slowly by using freely accessible software. The “Community Platform” by Camunda was used as a concrete example of a workflow engine. shows the first interface seen by the user when they start the process. Here, the user must enter the article number for which they want to plan a kanban loop.

The application on the workflow engine was made available to the logistics planner as a technical model for testing the logic. It was noted that during implementation, the interfaces to external systems such as inventory management systems were left out. Exemplary values were chosen and firmly integrated into the DMN (Figure 1) and BPMN models (Figure 2). Requesting the values from external systems is ultimately only an implementation detail. By publishing the model and the decision rules, everyone is free to take this step towards integration within their own systems.

6 CONCLUSION

It has been shown that the challenge lies in bundling implicit and explicit employee knowledge in logistics planning and preparing it for programmers in a way that ensured efficient and effective automation of rule-based logistics planning processes. This helps companies digitize their processes. The BPMN 2.0 modeling language in combination with DMN is able to represent rule-based logistics planning processes. It is equally suitable for employees from specialist departments and for programmers in companies. The processes can be represented completely, sustainably and uniformly in a common notation. DMN also allows rules to be mapped in the processes. The advantages of a transformation from a domain-oriented to a technical model towards an executable process in a workflow engine are obvious. It eliminates the extra time and effort involved in software modeling. Specialist departments can model their processes themselves. The process logic is determined on the basis of the decision rules, and employee knowledge is recorded and documented. Continuous improvements, which are necessary to survive in a volatile market, can be implemented quickly through this approach as resources can be used in a targeted manner. Specialized changes in the process can be carried out by the departments themselves without needing the resources of in-house programmers. Coordination processes between specialist departments and programmers can be made more efficient through a common (modeling) language. The process specifies the process flow in the workflow engine. This means that the process is not determined by the information flow, but rather the reverse: the process defines the information flow.

This procedure will be further elaborated and checked for plausibility within the framework of the "Intelligent Production Logistics Competence Network" project, e.g. a company for agriculture textile products or a company for conductors. The approach offers small and medium-sized enterprises the opportunity to use their technical resources more sustainably. The free licenses of the open source platforms for BPMN and DMN also offer small companies the opportunity to automate their processes and to start out on digital transformation.

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