Modeling of Intralogistic Processes for the Implementation of Warehouse Management Systems

Markus Rabe and Felix Stadler
Department IT in Production and Logistics, TU Dortmund University, Leonhard-Euler-Str. 5, 44227 Dortmund, Germany

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Abstract: Due to the growing complexity of intralogistics systems, the use of warehouse management systems (WMS) is becoming increasingly attractive for companies. As an often business-critical management system of internal material flows, however, their implementation or change is complex and carries risks. Especially the insufficient knowledge of companies about their own processes leads to a high capacity and cost burden due to the time-consuming involvement of their own experts and, often, also contracted WMS consultants. In this context, models and modeling methods are gaining additional importance. But, particularly in intralogistics, with its special demands and characteristics, there is a lack of methodological support for mapping and transferring process knowledge appropriate for the WMS implementation. The consequences, besides a low level of acceptance among the affected employees, are project aborts and production downtimes. This paper discusses experiences from industrial practice during the implementation of WMS and takes the position that a supporting method is urgently required in this context. Therefore, we propose the development of a modeling language for mapping intralogistic processes in line with the requirements for the implementation of WMS as well as procedural method components that support the generation and transmission of the process knowledge.

1 INTRODUCTION

Intralogistic systems are confronted with increasing complexity (Motschenbacher & Felch, 2020). To master this complexity, process standardization, automation, and the use of data processing systems are gaining additional importance. In intralogistic systems, warehouse management systems (WMS) play an important role by controlling, monitoring, and optimizing the internal material flow and storage systems for the economic operation of a company (ten Hompel & Schmidt, 2010).

As the complete flow of materials of a company is influenced by WMS, the implementation or change of such a system is often complex and fraught with risk. A main problem, according to the Fraunhofer IML study from 2018, is the insufficient knowledge of the companies about their own intralogistic processes and its deficient transfer between the involved parties (Fraunhofer IML, 2018). This market study for WMS shows that with 76% the lack of process knowledge on the customer side and with 40% the miscommunication of the requirements are main reasons for in-deficit WMS implementations (Fraunhofer IML, 2018).

Thus, in many cases, the process knowledge is developed for the first time during the implementation of a new system, leading to the expensive involvement of both the company experts and the external WMS consultants, who are often hired to compensate the lack of WMS knowledge. This leads to a high impact in terms of capacity and cost on the company side, which puts a strain on the success of the project. Amplified by inadequate and misleading communication between the stakeholders, this can result, according to Hartel (2019), not only in a lack of acceptance of the WMS among the employees, but also in project aborts and production downtimes.

To prevent this, the use of models and modeling methods can be a solution approach by supporting the development, documentation, and communication of process knowledge (Becker et al., 2017). For intralogistic processes and the implementation of WMS, however, a deficit in the methodological support was evident while accompanying various WMS implementations and can be considered contributory to the results of the Fraunhofer study. This deficiency led to serious problems during and after the implementation of the WMS.

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In order to solve this, in this paper examples and essential requirements for the modeling of intralogistic processes regarding the implementation of WMS are discussed and characteristics of a prospective supporting method are proposed.

Thus, the remainder of the paper is organized as follows: Section 2 begins by introducing characteristics of a WMS implementation. In particular, the challenges that arise and the interaction of the parties involved are discussed, here, in the context of modeling. Following on from this, the second part of the section gives indications for the weak methodological support and derives implications from the experiences of the WMS implementations that were accompanied. Based on this, the third section explains the position on how WMS implementations could benefit from methodological support and outlines two main aspects of this. In the last section, conclusions and a possible research plan are established to follow up and evaluate the position. The considerations made are, thereby, illustrated by impulses from industrial applications.

2 EXPERIENCES ON IMPLEMENTING WMS

The implementation of a WMS as a far-reaching and business-critical management system is afflicted with risk and influenced by various framework conditions (Fraunhofer IML, 2018). In addition to the complexity of the underlying intralogistic processes as a major expense driver, the implementation of a WMS is also influenced by the type of software migration. Depending on the objectives of the WMS implementation (e.g., regarding the degree of individualization), the planned effort, and the possibility of adapting the existing processes, there are several types of migration to choose from (Coyle et al., 2017). The most common form for WMS implementations is customizing a standard WMS software system (2018: 77 %) (Fraunhofer IML, 2018). Here, the standard software is adapted to the scope of functions and structures required by the WMS customer within the framework of predefined configuration and parameterization options (Mertens et al., 2017). For this purpose, the customization process of the software requires a comparison of the customer's processes with the functional scope of the standard software. (Hesseler & Görtz, 2014). To do so, the customizing process has to be accompanied by several coordinating, iterative, and creative conceptual activities performed by the persons involved that aim at converging the customer and software processes. Thus, the course of these activities significantly determines the scope, time, and cost of the implementation of a WMS (ten Hompel & Schmidt, 2010).

In this alignment process with its diverse transformation tasks, various barriers can arise and lead to problems in the customization of standard software. In WMS implementation, a lack of process knowledge and its insufficient transfer is a main problem.

This leads to a resulting need for subsequent development and transfer of process knowledge by the involved persons, which ties up both the cost-intensive WMS experts and the experts on the company side (Hartel, 2019). Besides the ensuing frustration of the participants during and after the implementation of a WMS due to this, as well as the time-consuming and cost-intensive rework, this can jeopardize the intended operation of the WMS.

These deficits were also reflected during the implementation of a WMS for a medium-sized machine manufacturing company, which was characterized by misunderstandings between the WMS consultants and the company experts resulting in frustration on both sides. There, for almost half a year, the experts from both domains discussed and debated without being able to agree on a common picture. Based on the insufficient documentation, the deficient transfer of process knowledge and the lack of experience of the WMS consultants in the specific industry sector, process aspects were unnecessarily discussed repeatedly, and specifications were regularly revised.

Subsequent investigations revealed that this was caused by several reasons. One aspect, for example, was that the process knowledge was spread across several departments and among several experts and not properly consolidated. This led to the WMS experts sporadically obtaining the relevant information from the respective company experts and formulating their own WMS concept. This concept, however, was not comprehensible for the company experts due to the technical terms and, in their eyes, inappropriate visualization (as an EPC model). But, intimidated by the complexity of the models, the company experts endorsed the proposals of the WMS consultants with little reflection. The results were undiscovered uncertainties on both sides. The situation escalated when the company experts noticed in the late tests that business-critical side processes were unknown to the WMS experts.

Besides a general culture problem in the project, a structured overview and appropriate documentation of the processes in a comfortable language for the company experts was lacking, as was an organized transfer of knowledge. The consequences for the project were significantly higher costs and runtime due to the necessary rework.

A similar situation emerged for another WMS implementation that was accompanied. Here, the unstructured and deficient coordination between the WMS consultants and the project team almost led to a duplication of the project duration compared to the original plan. This was causally induced, for example, by the fact that the same process sections were repeatedly discussed in isolation over a period of months, instead of going through the process in a structured manner, for example top-down and line forward. As there was also no commonly accepted and transparent documentation of the processes, a consistent overall picture among the participants was lacking. For the company experts, there was no assurance that the WMS experts had understood and paid attention to their concerns and process demands.

Due to the resulting perceived cost pressure on the management, the implementation was carried out even though concerns of the company experts remained. The result was a production shutdown of nearly two weeks and an adjustment of the system for four months during ongoing operation with reduced production output.

Solution approaches to avoid this can be the enabling of preparatory work on the company side and, above all, methodological support of the project participants in the generation, documentation, and transfer of process knowledge for a structured collaboration of the domains involved (Groß and Pfenning, 2017).

Here, models and modeling methods are gaining importance, which can not only depict complex problems, but also determine their solutions and create a uniform basis for communication (Haberfellner et al., 2019). However, if no suitable method is available or known, companies can only attempt to carry out the modeling based on individual experience or hire cost-intensive external personnel. This can have serious consequences for the quality of WMS implementations and, thus, for the productivity of the company as shown by the accompanied implementations. Particularly in intralogistics, where specialists and managers often have little or no academic background, there is a lack of methodological support for appropriate modeling and transfer of process knowledge to implement WMS.

This is reflected by the fact, that hardly any of the managers in the implementations we accompanied had applicable experience with modeling languages, and it was visibly difficult for the experts to identify and prove their documented statements. The modeling languages used (such as BPMN 2.0 or EPC) were often perceived as unnecessarily complicated with too many elements on one hand and on the other hand not designed to map the relevant data of intralogistic processes (such as the different conveyors, packaging, and storage equipment relevant for WMS implementation). Also, a lack of orientation in the process model was complained due to the missing intralogistic structural elements in the models (such as areas), which they were used to. Other languages that seemed more accessible to them (such as value stream design), on the other hand, were too unspecific for the WMS experts.

This became also apparent in almost all WMS implementations we accompanied, where, as a likely consequence of this deficit, no, only rudimentary or severely outdated process documentation existed prior to the implementation. Since no standard was accepted by the intralogistic personnel, the few models available were often in different modeling languages and different information levels were used. The more standardized modeling languages such as BPMN 2.0 or EPC were used by, if at all, those with an IT background, but even there they were reduced to fewer model elements due to the deemed excessive complexity of the languages. However, intralogistics personnel often considered these models to be unsuitable and were unable to accept them, as they failed to depict essential process elements from their perspective. Figure 1 illustrates this, showing a small section of an intralogistic process modeled with EPC.

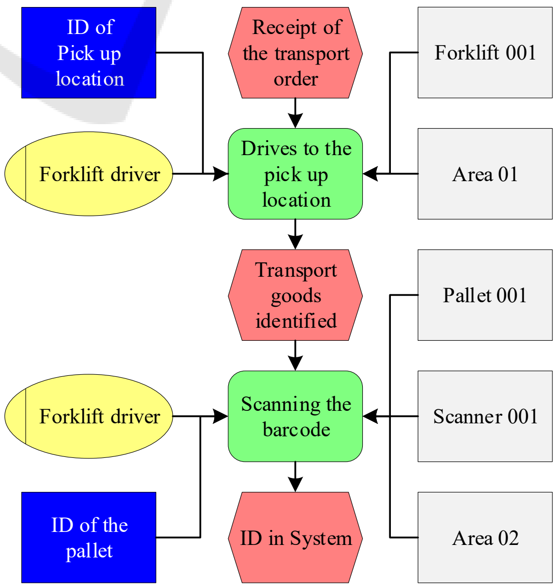

Figure 1: Intralogistic process visualized with EPC.

The process has been extended by operating resources, which are shaded in gray. The logistic areas, which are of particular importance for the intralogistic personnel, were exposed on the right. Relevant for the intralogistic stakeholders are mainly the activities (green) and the resources used (gray and yellow).

Overall, in all cases observed and in line with the results of the Fraunhofer study (2018), the lack of methodological support for modeling intralogistic processes seems to lead to insufficient creation, documentation, and thus communication of the process knowledge between the participants.

3 METHODOLOGICAL SUPPORT AS A SOLUTION

A promising approach to improve this situation can be to provide methodological support for both problem fields. On the one hand, the appropriate documentation of the process knowledge should be supported, and on the other hand, there should be a determined procedure for the structured elaboration, communication, and transformation of process knowledge among the experts involved.

A wholesome methodological concept that fulfills these requirements in the context of modeling intralogistic processes for the implementation of WMS could not be identified. Therefore, the position is taken that a new or significantly evolved method is needed to support companies during their implementation of a WMS regarding the modeling of the relevant processes. This method should comprise a language aspect for the mapping of the process knowledge according to the requirements and a process aspect for the structured elaboration and transfer of the process knowledge.

3.1 Language Aspect

The modeling language should be appropriate to depict the characteristics of intralogistic processes pertinent to the implementation of WMS. Logistical areas, for example, form the basis of the WMS stock structure and can provide intralogistics personnel with the required orientation in the model (Sachan & Jain, 2020). Thus, these process elements should have a higher-ranked status in intralogistic models and could be used, for example, as structuring elements. Figure 2 shows a proposal in which the process as a sequence of activities is visually structured by areas.

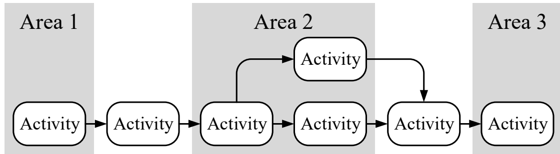

Figure 2: Process structuring using logistical areas.

As most existing modeling approaches cannot map these and other process characteristics (such as a large number of operating resources) appropriately, different method concepts are adapted and different process content is depicted, depending on the individual experience of the modeler. According to Becker et al. (2012) failures in this process lead to inconsistencies, a lack of information or over-information, and higher modeling efforts, as well as a low acceptance of the models.

On the other hand, the language should also support a flexible and low-effort adaptation of models during the customizing iterations. Therefore, simple but stringent syntactic rules should be supported by the language. As a result, a consistent modeling language, with a notation for the concrete syntax, a language-based metamodel for the specification of the abstract syntax, and semantic as well as pragmatic descriptions should be developed.

Here, it should be examined whether an existing language can be sufficiently adapted or whether a new language needs to be developed. However, the language should be less formalized and aim to make the company experts feel comfortable using it. In the first step, therefore, the language does not need to be automatable or machine-readable, but simply accepted by the company experts and understood by the WMS experts.

In addition, principles from Gestalt psychology (Fitzek, 2014) should be considered in the design of the notation. These ensure the purpose-oriented perception of the models as well as the low-complexity design of the models and model elements by means of Gestalt laws (Desolneux et al., 2008). However, in the Gestalt-psychological examination of existing methodological modeling concepts, it was found that these aspects are often neglected. Yet, they contribute to its perception and interpretation, especially in the case of more comprehensive models.

It became apparent in the WMS implementations we accompanied that a modeling language adapted to the specific requirements of intralogistic processes and to the needs of the employees involved encountered great acceptance. By also applying the principles of Gestalt psychology to the design of the notation, the perceived complexity of the models could be significantly reduced. An example of this is the common visualization of a few but essential process attributes in the main model. This simplified the required understanding of the process models considerably and made it possible to reduce the number of different models. Figure 3 demonstrates this by taking the process section shown in Figure 1 and mapping it in an alternative way, more appropriate to the intralogistic requirements.

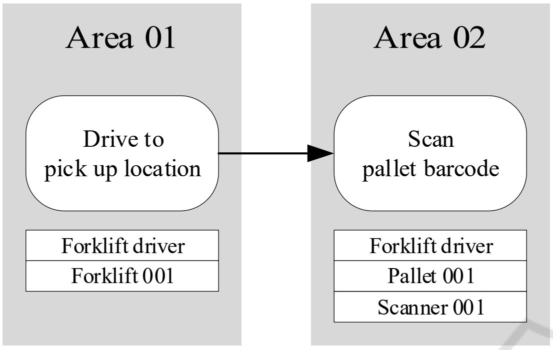

Figure 3: Proposal of an alternative process visualization.

3.2 Process Aspect

Furthermore, the processes for the elaboration, documentation and transfer of the process knowledge should be supported by the method with appropriate procedural components. For this purpose, the procedural support should be considered comprehensively and on several levels. Here, process-related components should be developed that provide support and orientation for the persons involved at the operational, tactical, and strategic levels of modeling.

For example – alongside a higher-level procedural model for describing the development, structuring and transfer of process knowledge in general – more specific activities for the structured modeling of individual complex intralogistics processes should also be determined as well as concrete operational steps, how model elements are set. To illustrate this, the following are some suggested questions to be answered at each procedural level.

At the strategic modeling level, for example, the following questions should be answered:

- How does the process structure to be modeled look like and how are the processes delimited from each other (e.g., processes are structured hierarchically according to a top-down approach and delimited based on physical buffers or areas)?

- How can preliminary work be realized, and how can the intralogistics personnel build up their own understanding of the process (e.g., by two modeling cycles: one to support domain-oriented modeling for low-cost preparatory work on the company side and one to support WMS-oriented modeling for adapting the business unit models to WMS requirements with the involvement of cost-intensive consultants)? Figure 4 shows a possible approach of a simple phase model, which takes this into account.

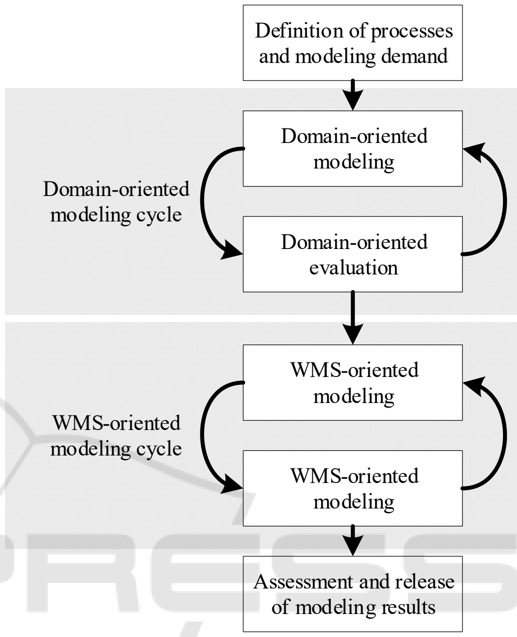

Figure 4: Proposal for a phase model.

On the tactical level, on the other hand, the following questions are in the focus:

- How are the models constructed (e.g., models are built in three stages: Stage One is the mapping of the basic process structure, in Stage Two, the intralogistics resources are added and in Stage Three other process attributes, such as process times, are supplemented)?

- By which techniques are the model data collected and how are models investigated, validated, and verified (e.g., via observation and additional questioning of the experts)?

Finally, at the operational level, the modeling rules are defined, and practical questions are answered, for example, about the concrete procedure of modeling workshops:

- In which order should the model elements be placed (e.g., first process-external elements as starting points, then the following process element, then the connector between both)?

- How are modeling workshops conducted? (e.g., first structured walk- and talk-through of the entire process, then talk-through line-forward process section by process section; notes are taken directly in the model; moderation by domain-neutral and trained modeler)?

These questions need to be answered in procedural models. Here, it is important that these process-related specifications are aligned with the characteristics of the intralogistics modeling language and the specifics of the WMS implementation process. An example for this is the differentiation in two modeling cycles. The first cycle helps to establish a common understanding of the processes within the company. The focus in the WMS modeling cycle, as the second cycle, is on supporting the customizing interactions among the participants and in building a common understanding of what the processes in the WMS will look like.

With these two aspects, the language aspect, and the procedural aspect, both closely aligned and intertwined, a methodological support for the implementation of WMS would be given and risks occurring there could be reduced.

4 CONCLUSION

Our research indicates that the use of appropriate models and modeling methods for intralogistic processes to initiate WMS has a significant impact on the economic implementation of WMS. Therefore, a method is required that covers both the language and the process aspects of modeling intralogistic processes needed for the implementation of WMS. The overall research goal should be a methodological support for modeling intralogistic processes regarding the implementation of WMS.

Future work and research in this field include the detailed specification of the requirements for a modeling method from both a language and a process point of view. Afterwards, a suitable development process for the method has to be defined, which ensures its high-quality and consistent structure. On this basis, the development of the modeling method can be carried out and evaluated step by step, ideally accompanied by a practical application in the idea of prototyping.

The concrete development of the method should start with the definition of perspectives that need to be taken for an appropriate modeling of the intralogistic processes. Subsequently, the modeling language with its three aspects the syntax, the semantics, and the pragmatics can be built. It can be expected that at least basic aspects of existing process modeling languages can be adopted due to generally valid process characteristics.

For the syntax, a language-based metamodel should be constructed that specifies the language elements and their relationships among each other. Here, a small number of language elements should be aimed for to keep the complexity of the modeling method low for the intralogistics experts from the outset. For this purpose, discoveries from Gestalt psychology should be used. Here, the intralogistics areas should take on a superordinate and process-structuring significance.

Gestalt psychology should also be considered when designing the representational forms of the language elements. This should support an easily perceivable and interpretable shape of the forms.

Overall, the focus should be on supporting the company experts with a suitable modeling language to be able to adequately map their process knowledge and adapt it according to the WMS requirements.

Furthermore, procedural method components also need to be developed, which determine the modeling process and structure the interaction among the involved domains. Here, the main goal should be to support the business experts and convey their modeled process knowledge to the WMS consultants during the customizing process. In particular, preparatory work by the company should be enabled and the target-oriented exchange between the parties simplified. Two modeling cycles should be developed for this purpose: one to support business-unit-oriented modeling and one to support WMS-oriented modeling. Furthermore, the process-related components should cover the operational and tactical as well as the strategic modeling level to support the participants. Next, to support the involved stakeholders, it should be examined to what extent the modeling can be supported by information technology tools. For this, the modeling language should be supported by a modeling tool or a visualization program.

Finally, the methodological construct should be evaluated in practice.

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