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Planning Guideline and Maturity Model for Intra-logistics 4.0 in SME

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Abstract. Logistics systems have a key function to meet competition criteria like delivery time, punctuality or flexibility. Industry 4.0 technologies are considered as an important key to master increasing requirements like individualization, shorter product lifecycles or global competition. However, bringing the complex structures and processes of a logistics system to a higher level of maturity is not an easy endeavor. The actions to be planned and implemented need to be rooted in the overall digitalization strategy of the company. Furthermore, they need to be interlinked with the development of other corporate functions like production, quality or planning and they need to be based on current capabilities. To support such a systematic development process, maturity models seem to be the method of choice, and there is already a considerable amount of such models available. As those models are mainly focused on the company as a whole or specifically on production systems, we identified the need for a specific support for logistics. Therefore, in this paper we describe the relevant background as well as the components of a maturity model for an Intralogistics 4.0.

Keywords: Maturity model · Industry 4.0 · Intralogistics

1 Introduction

One of the most important trends of our time is digitalization, which goes along with long-lasting changes in a lot of areas. A common synonym for digitalization, especially in the manufacturing sector, is Industry 4.0, which will lead to disruptive changes, providing opportunities but also challenges for business models, production technology, and work organization [12]. Mastering this (r)evolution is considered as the key for the future sustainability of an (industrial) enterprise. Industry 4.0 technologies will form the basis for increased transparency and improved safety and security in supply chains [18] as well as for sustainable manufacturing [15].

Nowadays, logistics systems need to fulfil high requirements. The trend of customer-individual production leads to the need for quick-response and efficient processes despite small lot sizes. Beside other approaches like lean logistics etc. Industry 4.0 technologies are considered as an important key to master those challenges.

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However, there is no “off-the-shelf” solution for a “Logistics 4.0”. It rather needs to be tailored to the special needs of a company or a supply chain. And it needs to be viewed from a holistic perspective and should not be restricted to single technologies. Therefore, a systematic guideline for the design of company-specific solutions is more than desirable.

Especially for small and medium sized enterprises (SME) it is not easy to deal with those topics, due to a general lack of resources, deficits in strategic thinking, and an individual infrastructure which limits adaptability. A recent observable trend to solve these shortcomings was to provide SME with maturity or readiness models, which were meant to allow an easier access to the topic [17]. However, many solutions are at a rather general level or are focussed mainly on production systems, which does not really help to derive concrete decisions for particular functions like logistics.

Therefore, we identified the need for developing a planning guideline with a maturity model especially for intralogistics. This should serve as a basis for a structured and comprehensible evaluation of the current system, its processes and capabilities as well as for the derivations of concrete actions for further evolution.

2 Theoretical Background

2.1 Intralogistics

Intralogistics comprises the organization, control, execution and optimization of the intra-company material flow and its accompanying information flow [18]. The objective of intralogistics is to supply the right part or the right tool, in the right quantity and quality, at the right time, at the right place, with minimal costs. Operative functions of logistics are transportation, handling, storage and commissioning [6, 7].

In logistics a huge amount of data should already be available that just need to be exploited [10]. In this context the terms Logistics 4.0 and Smart Logistics emerged. Logistics 4.0 refers to the combination of logistics with the innovations and applications from Cyber-Physical Systems [2]. The hereby intended optimization shall be supported by intelligent systems, embedded in software and databases from which relevant information is provided and shared though Internet of Things (IoT) systems, in order to achieve a major automation degree [2].

2.2 Industry 4.0

Central paradigms of Industry 4.0 are a horizontal integration throughout value adding networks, a vertical integration and networked production systems as well as an integrated engineering along the whole value chain [12, 15].

Industry 4.0 is based on the acquisition of data and their intelligent usage. The vision is a real-time feedback in whatever processes for their active control and manipulation. This leads to a paradigm shift which describes the switch from solid production structures to autonomous, self-organizing, intelligent systems. The basis for Industry 4.0 form new sensor technology for data acquisition, mechatronic components which are enriched with intelligent functions, a comprehensive interlinking of those components for data distribution and exchange, modern information technology for information processing, and human-machine interactions [16].

2.3 Maturity Models

As the digital transformation of a company should not be an occasional process, a roadmap is needed, which in turn should be based on a thorough analysis of the current status and capabilities [5]. A prominent approach to support this process is provided by maturity models, which serve for the evaluation of the quality of a company's processes, often against some specific target state [11, 14]. A maturity model usually consists of the following components [1]: maturity levels, maturity dimensions and indicators, weights for indicators and/or dimensions, and a maturity level – parameter – matrix.

There are frameworks or procedures as a sound methodological basis for designing maturity models, see for instance [3, 4]. Moreover, a quite considerable amount of maturity models has been published in the context of Industry 4.0, Smart Manufacturing, or Smart Services [5, 8, 9, 11, 13, 14]. However, many of those address mainly a technical perspective or don't refer to particular functions. So far, we haven't found any maturity model that is particularly focussed on logistics.

Therefore, the gap we identified is a maturity model which allows to analyse and to evaluate the as-is situation of Intralogistics 4.0, and to recognize and to exploit its relevant potentials. Such a model might be a good extension for the evolution of production processes or it might be helpful for companies which base their business model on logistics processes such as logistics service providers.

3 Maturity Model for Intralogistics 4.0

3.1 Requirements and Context

The maturity model should meet the following requirements: It should be able to evaluate the current degree of implementation of Industry 4.0 technology in the logistics sector of the company. It should take a holistic view, especially taking into account socio-technical aspects [16]. It should be modular, so that indicators can be adapted according to the needs of the respective application. The application of the maturity model should be possible without special training and without special expert knowledge [17]. The model should be able to identify dimensions with high potential and it should offer guidance on how to attain a higher level of maturity [17].

The application of the maturity model itself is embedded in a planning guide which consists of five, clearly separated parts, see Fig. 1. Hereby, it is possible to secure interim results and the whole process becomes more transparent for all involved people. We assume that changing logistics to 4.0 is a complex endeavor which needs to be made manageable, especially in the implementation phase. The definition of (internal) projects of manageable size and risks might be a good approach for that. The planning guideline is loosely oriented on problem solving methods, e.g. from Systems Engineering. Snapshots will be avoided and project management principles like the involvement of relevant stakeholders, the definition of objectives and of activities for detailed engineering, implementation and necessary resources, etc. are considered.

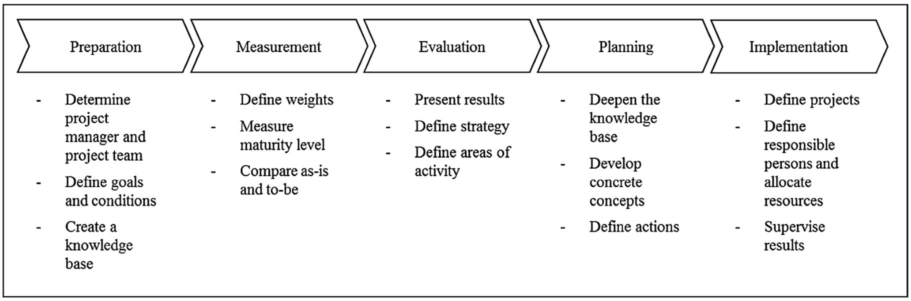

Fig. 1. Steps of the planning guideline

An important component of the planning guideline is a particular maturity model for intralogistics, which meets the specialties of that corporate function.

3.2 Maturity Levels

The maturity levels are based on a phase model, where the particular phases are built on each other but are separated by quality gates. The achievement of one level also implies the achievement of all subjacent levels. In our model a five-level approach was chosen, as this allows a compact demonstration of results and follows other widely accepted models, see Table 1.

3.3 Dimensions and Indicators

Based on literature we defined twelve indicators and categorized them into four dimensions. Hereby, we try to map the intralogistics system in a holistic and socio-technical way. The content-related clustering allows the derivation of recommendations for actions for each dimension.

Data: Intralogistics 4.0 or Smart Logistics is based on data and their intelligent usage. An important precondition is the integration of sensors (and possibly also actors) to be capable to acquire data at all. The transport units need to be identified and localized; at higher levels information processing is needed.

Communication: The exchange of data and information is an essential precondition for the (autonomous) interaction of different entities of the logistics system. Communication can occur between machines (M2M) and between humans and machines (HMI); furthermore, the information exchange throughout the whole logistics systems need to be considered.

Processes: The relevant areas of actions in intra-logistics are the basic working processes transportation, storage and commissioning. Their optimization is the main goal of applying Industry 4.0 technologies.

Table 1. Maturity levels

Level	Description
Level 1 (outsider)	The logistics system does not fulfill any requirement in the context of Industry 4.0 applications. The topic is not known or currently not relevant
Level 2 (beginner)	Industry 4.0 is recognized as relevant and first pilot projects have been realized. However, only a few logistics processes are supported by information technology and the logistics system does no fulfil the requirements on future networking and communication. For further improvement only limited competences are available
Level 3 (advanced)	Industry 4.0 is part of the company's strategy. The implementation of Industry 4.0 technologies in logistics is pursued and controlled as a continuous improvement process. Data are acquired partly-automatically and are used to limited extend. Necessary competencies are available but require upgrading
Level 4 (experienced)	The company acts based on an Industry 4.0 strategy. A sector-specific innovation management supports the implementation of Industry 4.0 technologies. In the logistics sector all software systems are connected by interfaces; important data are acquired automatically. Internal and inter-company information exchange takes place partly system-integrated. The upgrading of Industry 4.0 competencies is part of the company's strategy
Level 5 (expert)	The company has already realized a Industry 4.0 strategy. A company-wide innovation management controls the implementation of respective projects. In intra-logistics there are consistent information and communication technologies, all relevant data are acquired and processed automatically. The transportation and storage system operate autonomously. The company possesses matured competences to develop processes and systems further

Intellectual Capital: This dimension deals with humans, work organization and the company as a whole. The dimension and its indicators aim at a holistic, socio-technical perspective. Flexibility and adaptability are considered as main requirements on logistics systems. Due to the still high portion of manual work humans and the work structured they are embedded in play a decisive role in fulfilling these requirements (Table 2).

Table 2. Dimensions and indicators of maturity

Dimension	Indicators		
Data	Integration of sensors and actors	Intelligent transport units	Data exchange
Communication	Machine-to-machine communication	Human-machine interface	Information and communication technology
Processes	Transportation system	Storage system	Commissioning
Intellectual capital	Employees' competences (human capital)	Work design (structural capital)	Innovation culture (relation capital)

By assigning different weights to the dimensions or indicators it is possible to differentiate those according to their importance.

3.4 Maturity Level – Parameter Matrix

This matrix is the central component, because it represents the evaluation basis for the current and also for future state(s). For each indicator ordinal scaled requirements are determined and assigned to the different maturity levels. Hereby, it becomes possible to categorize and to evaluate the current stage of intralogistics with respect to the particular maturity indicators.

For each of the aforementioned dimensions resp. indicators specific requirements for each of the five maturity levels have been defined, see Table 3. The particularities of logistics are especially considered in the "processes" dimension. The parameters for the logistics processes transportation, storage and commissioning cover characteristics from purely manual over mechanical supported, mechanized, automated up to autonomous.

Table 3. Cut-off of the maturity-level – parameter matrix

Dimension	Indicator	Maturity levels				
		Level 1	Level 2	Level 3	Level 4	Level 5
Data	Integration of sensors and actors	No usage of sensors and actors	Sensors and actors are integrated	Logistics systems processes sensor data	Logistics systems interprets data for analyses	Logistics system acts autonomously based on data
	Intelligent transport units	No functionality available	Clear identification and localization possible	Storage of data and conditions possible	Execution of predefined actions	Autonomously acting transport unit
	Data exchange in intra-logistics	No connection to other corporate sectors	Information exchange via e-mail	Consistent data formats and rules for data exchange	Inter-divisional connected data-servers	Completely connected IT-solutions, company-wide

4 Experiences from Practical Application and Conclusion

The planning guideline and especially the maturity model have been applied in a medium sized company (150 employees) that produces ceramic tiles. In the logistics department there are 20 employees who are responsible for commissioning, warehouse management, material supply and transportation. The company so far has started only digitalization projects in production, not in logistics. Current challenges of the company are an increasing cost pressure from the market and higher requirements from the customers regarding the availability and delivery time of final products. The purpose of the use case was to test the developed model exemplarily and to validate its applicability, i.e. its ability to produce useful results in a practical context.

The proposed planning guideline has been applied completely: In the *preparation phase* a project team has been formed, consisting of employees and middle managers in logistics. The planning horizon has been defined as three years. Important goals for intra-logistics are the reduction of stored material, faster deliveries, a higher customer satisfaction, and higher efficiency in customer individual production. In the *measurement phase* data collection has been done with the help of a semi-structured questionnaire. Gaps between the current state and a future state have been identified in all dimensions. However, for the "communication" dimension the gap was evaluated not as big as for the "data", "processes" and "intellectual capital" dimensions. In the *evaluation phase* a thorough analysis led to the conclusion, that the company is at a beginners' level (level 2) in our maturity model. The storage systems was identified as an indicator with a lot of deficiencies in the "processes" dimension. As a consequence, an internal improvement project was defined, which aimed at the seamless identification and localization of every material and part in stock. In the *planning phase* the internal project has been structured in detail with concrete measures like an update and extension of the identification system using RFID, the equipment of transportation means (e.g. forklifts) with readers and interfaces to the internal WiFi, etc. The *implementation* is still in progress.

The application of the developed model showed, that it was possible to evaluate the maturity of intralogistics regarding Industry 4.0 in a given setting without much effort and without extra training of involved people. Dimensions and indicators could be easily understood. The application showed, that there haven't been white spots and also no redundancies. Obviously, the four maturity dimensions with their twelve maturity indicators were able to cover the field of intralogistics in an Industry 4.0 context completely - at least for the pilot company. The defined five maturity levels seemed to be sufficient for discrimination. The results of the maturity evaluation could be easily interpreted, despite involved people did not have any experience with maturity models. Therefore, the (easy and purposeful) applicability of the concept can be concluded.

All in all, we can assume that the developed maturity model can serve as a sound basis for industrial companies to evaluate and to further develop their intralogistics system towards Industry 4.0. The model helps to determine the state-of-the-art for the digital maturity of the logistics system. Areas with a high potential for further development can be identified. As a consequence, companies are able to derive and to implement purposeful strategies and actions which serve their needs. The modular structure of the model allows the user to adapt specific indicators according to the needs of a particular company. It is also possible to extend the model with additional indicators or even dimensions. The weighting of dimensions or indicators further supports the diversification of the model.

It could be shown that the planning guideline with its maturity model have been helpful to systematically analyze and to evaluate the state-of-the-art, to identify the right main points for changes and to generate appropriate ideas for the evolution of intralogistics towards Industry 4.0. Therefore, our solution seems to be a suitable management tool for the improvement of the logistics system, its elements and processes.

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