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Digital Transformation of Inland Terminals

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Abstract. Small and medium-sized (SME) logistics hubs are characterized by a variety of customer relationships, different services offered, and diverse organizational interfaces. Increased requirements for workflows that run smoothly, at best digitally, are often met by using individual IT systems at hubs like inland intermodal terminals. In this context, the development and introduction of systems are rarely characterized by a uniform strategy, but by short-term requirements and interim solutions. This paper aims to develop an IT reference model for SME inland terminals. The focus is on supporting the independent and structured further development of processes and IT landscapes by the terminals. The paper is based on a project, which was carried out in exchange with experts and involved parties as well as based on a literature analysis to highlight SME- and branch-specific issues. Modeling the current situation creates a basis for identifying weaknesses and target landscapes. Reference process models assist with the systematic mapping and analysis of IT and process landscapes and hold opportunities to identify potentials to increase productivity, reduce costs and avoid redundancies. It consists of many process models, tools, and recommendations for action, which together comprise a "help for self-help" approach. Implications for making process models more flexible to respond to external demands were considered.

Keywords. Digitalization, inland Terminals, SME

1. Introduction

Increased requirements regarding the digital transformation at intermodal terminals, especially for SMEs, are often met by using individual IT systems. Such isolated applications can be e.g. storage management systems, order control systems for vehicles and cranes, or systems for handling truck arrivals at the gates. Here, the development and introduction of (sub-)systems are often characterized by short-term requirements and interim solutions. In IT, the integration of various hardware and software components used in an organization plays a very important role. This is because there is usually not one product that can solve all the challenges in a company in one fell swoop. Thus, the challenges faced by inland terminal operators are not new. However, due to the number of digitalization projects, which has steadily increased in recent years, the effort required for integration is increasing for the projects to deliver their hoped-for benefits.

The analysis of the IT and process landscape as well as the identification of improvement potentials thus hold opportunities to increase productivity, reduce costs, avoid redundancies, reduce manual and create automated interfaces and improve user-friendliness. However, there are various challenges facing SMEs when it comes to digitalization. For example, in addition to a lack of digital infrastructure and

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cybersecurity issues, the shortage of skilled workers, both within the company and in the labor market, are major factors to consider [1].

This project review paper outlines an IT reference process model with its process models, tools, and recommended actions. Together, these form an innovative approach to the digital transformation of SME terminals. A reference process model supports the user in a structured and descriptive manner to examine the existing IT and process landscape and to derive optimization potentials as well as solution approaches.

By conducting in-depth literature research and interviews with stakeholders, this research aims at the following two objectives. First, the development of a reference process model should include an approach to independently assess the level of digitalization of the terminal. Secondly, the paper aims at the development and future-oriented improvement of the terminals stated specific IT infrastructure.

The structure of the paper is as follows. Section 2 gives a glance at the theoretical background. At first, the state of the art of inland terminals and their related IT landscapes are depicted in general. Then, the application of IT landscapes and the means of visualization are examined. Subsequently, the research question underlying this work is presented, which is dealt with using the methodology outlined below. Section 3 contains the rudimentary mode of operation of the developed reference process model. This is followed by an overview of the challenges in digital transformation for SME inland terminals. Finally, an outlook is given on which elements an advanced system and agile transformation can comprise. The conclusions and recommendations for future research can be found in Section 4.

2. Theoretical Background

Inland terminals are nodes or interfaces in national and international logistics chains. Therefore, they provide the environment and the equipment for handling loading units between different modes of transport. Terminals include functional areas such as storage areas for loading units (e.g. containers) and the areas for each of the connected transport modes [2]. In addition to the transfer between modes, various value-added services, e.g. buffering, holding empty containers, and repair can be offered [3]. Depending on the modality of the terminal (bi- or trimodal), different operational areas can be found for loading and unloading the corresponding means of transport. The equipment used at the terminals ranges from large cranes which span across the various modes of transport (see Figure 1) to reach stackers.

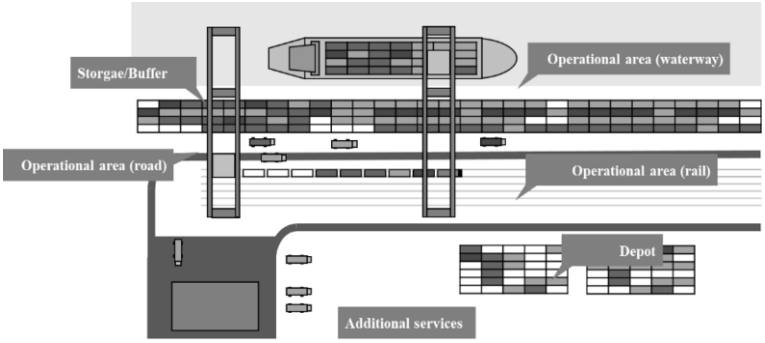

Figure 1. Layout of a terminal.

Section 2 discusses the state of the art in the digital transformation of inland terminals, derives research objectives, and describes the methodology of this paper. Since there is no uniform definition of digitalization and digitization, a reference is made to Lange and Grafelmann [4], which examine the topic of digitalization in maritime logistics with a focus on seaports including terminals. Accordingly, digitization refers exclusively to the availability of digital data. It can be seen as the basis for digitalization [5]. Digitalization can be described as a resulting condition from converting analog data into digital language, which then can improve interactions in business and create value for the wider economy and society [6]. Generally, it can be stated that SME terminals often have a lower degree of digitalization and automation than large terminals [4].

2.1. State of the Art

Multiple companies can be involved in various roles at a cargo handling terminal. Associated partners, including rail operators and freight forwarders, can be users of IT systems. The diversity and complexity of process landscapes at terminals result from the variety of tasks and actors involved. In recent years, several comprehensive systems have been developed to control, monitor, and manage processes in terminals. While large terminals tend to use one terminal-wide Terminal Operating System (TOS), SMEs tend to use separate IT applications for different application cases that have grown over time. Compared to general ERP systems, TOS are specialized for terminal requirements. They aim to include the terminal administrative and operational tasks in one system [7]. Lee and Meng [8] pointed out trends concerning TOS (technological and market-related) and emphasized that the evaluation of TOS requires high costs and a lot of time. Moreover, those systems are not considered a viable option for many SMEs due to the wide functional scope, the adaptation effort, the acquisition costs, customization, maintenance, and ongoing development.

SMEs often use a multitude of IT applications, whereof some were developed intra-company. Multiple individual solutions increase the complexity of the IT landscape and data redundancies and errors due to missing or inaccurate information become more likely [9] and can result in missing flexibility in the event of changing circumstances in the operation. Currently, some processes rely on human-software or software-human interfaces, whereby errors (e.g. during information input at self-service devices for driving personnel on arrival at the terminal) cannot be ruled out.

In addition, some processes are even exclusively paper-based or carried out without suitable IT support, which leads to inefficient and error-prone media disruptions. Ruile [10] highlights that although the primary activities of terminals appear simple (loading, unloading, and buffering), the coordination of resources (including staff and equipment) continuously increases complexity. Landscapes of IT and business processes should therefore be developed in the sense of forward-looking digitalization to establish agility regarding changing conditions and demands for digital interfaces to participants in the supply chain. Terminals are characterized by medium to long-term business relationships with various companies in the fields of freight forwarding, railroad companies, and personnel service providers. Moreover, SME terminals can be dependent on new customers or partners, with requirements that can be difficult to implement. In many cases, communication between the terminal and the business partners takes place via (unstructured) email, telephone, or via the system software of the business partners [9]. While the amount of processes and IT applications in SMEs is often considerably smaller

than in larger enterprises, the diverse landscape and the multitude of IT interfaces lead to a high level of complexity [11].

In the literature and practice, there are many different approaches to visualizing complex landscapes. The fundamental basis for the visualization of the IT landscape is the documentation of the enterprise architecture. Enterprise architecture management (EAM) includes repeatedly describing as well as updating EA to comprehend its complexity and cope with its transformations. In the context of EAM, the application landscape, which includes the IT systems and their relationship with business processes, is captured and documented in a holistic manner. Large companies in particular have been dealing with the subject of IT management and their strategic development for quite a while. For SMEs, the application of a comprehensive EAM tends not to be feasible due to limited human and financial resources and experience. To achieve a target and future-oriented management, an easy and cost-effective process model is needed as a guideline. This should include guidance on how to visualize the IT architecture. One way of representing IT landscapes is through software cartography using software maps which are based on the layer principle. The different layers may include information about organizational units, application systems, interconnections, and operational or economic measures. Reference is made to the comprehensive works of Lankes et al. [12] and Ernst et al. [13] on software cartography. There are different kinds of software maps. For example, cluster maps use logical clusters such as organizational units, functional areas, or geographic locations as a base map and assign relevant IT applications to these units. Subsequently, connections and key figures can be mapped. For the software cartography of intermodal terminals, functional areas (e.g. gate, storage, depot) can be used as a basic map [9].

Besides, different guides, recommendations for action and maturity models, or "readiness checks" exist for assessing how digitalized a company is. These were developed because SMEs in particular have problems with the implementation of digitalization projects [14,15]. For example, it is important to examine how and to what extent data is used and processed. While some companies are just starting to process data, other organizations have the resources and capabilities to develop new business areas based on data. For this reason, e.g. the Data Maturity Model has been developed [16].

Due to the growing complexity, increasing demands on quality management, but also savings of company resources as well as for planning security during the implementation of projects, process models are increasingly used. These so-called process models serve as a guide for the realization of (software) projects. In general, they comprise process and activity descriptions and support the executing groups during the process. Nowadays, these models provide the basis for planning as well as controlling large software and system developments [17]. They make the structure of projects tangible, comparable, and assessable and are thus an essential criterion for the successful execution of projects [18].

To the authors' knowledge, a comprehensive reference process model for digital transformation does not yet exist for SME intermodal terminals.

2.2. Objectives

Compared to train transport, trucks emit about 6.5 times the amount, and compared to inland vessels more than 3.5 times the amount of CO2 per ton kilometer [19]. However, transshipment at the terminals also causes disadvantages that limit the competitiveness of intermodal transports. Transshipment operations may extend transport times and lead

to higher costs. As a result, the potential of intermodal transport cannot yet be sufficiently exploited today. Optimization of the processes through forward-looking digitalization can help to remedy this situation.

This work aims to outline a reference process model which provides an approach for the independent assessment of the state of digitalization and the further development of the terminal-specific IT infrastructure. This allows SMEs to better adapt to customer requirements and bring their productivity and quality closer to that of large terminals, significantly increasing their competitiveness. Furthermore, the documentation of the business and IT landscape as a planning and analysis tool facilitates the connection of the terminals to existing or new interfaces to other companies. Considering the special requirements and possibilities of SME inland terminals, the handling or expansion of IT management processes and tools can be made more straightforward for these companies.

2.3. Methodology

In this paper, a combination of qualitative approaches has been conducted. An unstructured literature review was used for the development of the reference process model. This served to form the theoretical basis for obtaining different approaches to the representation of enterprise architecture and processes. In a subsequent step, the focus was placed on software cartography. This turned out to be a suitable means for visualizing company-specific IT infrastructure and thus for analyzing enterprise architecture. In a third step, areas of application of IT systems in the core areas of inland terminals were highlighted to identify potential for improvement. Process mapping at two terminals as well as workshops and several interviews with experts from the logistics and IT sectors were conducted to find out the needs of SMEs in the inland terminal sector regarding the digitalization of their business processes. Due to the small number of interview partners, it was not feasible to conduct a reliable statistical analysis. The interviews provided important insights into the situation of digitalization in the companies. In the approach that follows, it is assumed that approaches to solving specific problems can be generalized. The interviews conducted with terminal operators as well as consulting companies in the IT sector were semi-structured. Two companies surveyed were inland terminal SMEs, two larger terminals were also considered as examples of best practices and two others can be assigned to the roll-on roll-off (RoRo) business.

3. Approach

In the following, the reference process model is explained and findings from the research conducted and, in particular, insights from interviews are presented.

To support the creation of a coordinated overall IT system, a simple and cost-effective process model is required. To the authors' knowledge, there is no approach, especially in the German-speaking countries that specifically addresses the introduction of reference process models in SME terminals. The innovation of the presented model lies in particular in the simplicity of the manageability and execution. It can be used by SMEs as a guide to carry out the necessary steps independently in a reasonable amount of time. Figure 2 shows the generic reference process model, which comprises a total of five sub-models for this purpose.

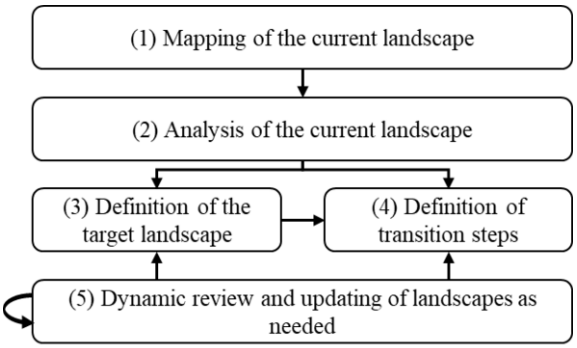

Figure 2. Generic reference process model.

As a basis for the model, the focus should initially be on the survey phase of the company processes. For this purpose, the use of easy-to-handle or already known tools for process visualization as well as a modeling method (e.g. as swimlane diagrams) is suggested. This preparation of the business processes is essential to locate the associated applications in terms of software cartography. Cluster maps support the evaluation of the current landscapes and can be adapted to the terminal-specific functional areas by showing and hiding different clusters and information content by layers, depending on the needs of the terminals.

This procedure supports the subsequent determination of a target landscape considering terminal-specific concerns and with the help of the different (maturity) models on the subject of digitalization. In this way, the company-specific need for action is determined, categorized and a potential target landscape is created. In terms of determining requirements and defining transformation steps, it is important to note how the transition steps (which can be adaptations of existing IT systems, further developments, and new investments, either in-house developments or external procurement) should be prioritized. A step-by-step merging of different operating systems into a uniform system can be envisaged, whereby accompanying systems are optimized first and then the core applications. At the same time, operational requirements should be reacted to and thus, if necessary, modules should be treated with higher priority.

These target landscapes and transition steps must be continuously reviewed to identify updates as needed. Last but not least, the COVID-19 pandemic has impressively shown how necessary it is to make business processes more resilient. Schnelle et al. [20] demonstrate how digitalization can play a part in this. The results of their study show that transparency and the exchange of data are more limited in SMEs than in large-scale enterprises. At the same time, this also means that, according to the assessment of the current state of digitalization in the companies, there is still potential for increasing transparency and the use of data. As a result, the process models must also be designed with a high degree of flexibility and agility. Adjustments in the organization, especially by defining and assigning new roles, create new potential for IT management and also increase the company's ability to respond.

Benefits are generated through the application of the reference model in that the SMEs independently document the business and IT processes and identify the potential for optimization. The application of the model also leads to the expectation of increased agility, flexibility, and strategic controllability of the application landscape of SMEs. In the future, it will be necessary to further optimize the reference process model and the procedure for its application. The process mapping and exchange with the practice allow

the following insights regarding the challenges in system integration for SME inland terminals.

Insights into inland terminals. There are often IT solutions that are not (yet) well integrated with other software solutions in use. Repeatedly, employees have to transfer information manually from one software to another. Likewise, cross-company communication takes place in part based on unstructured emails that do not allow for simple automation. In addition, at some terminals, information is initially recorded with pen and paper during the handling processes and only later, if at all, manually entered into the IT systems. Furthermore, digitalization projects for in-house system integration and those for cross-company communication are interdependent. Because as soon as more information is available digitally in reliable quality, this simplifies further projects, including collaborative ones. The importance of the maturity of data should not be underestimated. Here, a rough distinction can be made between unstructured data (e.g., the texts in mails), structured but non-standardized data (e.g., Excel table with free-text annotations), and structured standardized data (e.g., SQL table with numerical values). The last maturity level is the key to reliably functioning partial automation of business processes and thus actually noticeable work relief for employees on site.

Outlook for further steps towards digital transformation. To be well-positioned in the future it becomes clear that desired target processes have no longer any breaks - all sub-systems that record and control the handling of loading units are integrated and the recording of information is taken away from the employees as far as possible or at least simplified by appropriate support. Nowadays, the collection of data can be much better supported with technologies, e.g. by integrating sensors (such as distance meters, light barriers, GPS receivers) or camera systems with integrated image recognition to identify number plates, wagon numbers, or damage. Replacing paper and pen – e.g. when employees directly enter the information into the system with devices like tablets - saves the subsequent transfer from paper into the system as a separate work step and an additional source of error.

Hereafter, various approaches (see Figure 2) of start-ups and solution providers that currently exist are thus clustered and shown to be able to better support handling processes on the IT side. The challenges of system integration and information acquisition will also be addressed.

Digital registration of loading units. The handling of loading units is the core business of a handling facility. From the moment the loading unit arrives on the premises, the operator of the facility is responsible for the condition of the loading unit and should know its location on its premises. To fulfill this duty of care, the loading units are inspected once at the gate (i.e., the truck gate, rail gate, or river gate) to determine their condition, to be able to ward off any unjustified claims for damages in the event of a defective delivery. The digital registration of loading units delivered by trucks is done at the truck gate via the recognition of truck license plates and loading units by OCR. Trucks arrive at the truck gate either to drop off or pick up a loading unit. When a loading unit is about to be picked up, the driver at the gate can be informed of the assigned handover position, which minimizes gantry crane movements. If a loading unit is handed over, the truck gate is the ideal place to check the loading unit for damage and to document it so that unjustified claims for damages can be defended later. It is advisable to have the detection of damage to the loading unit digitally supported.

In terms of efficient planning, early information on loading units also plays an important role. Information about loading units arriving at or leaving a terminal by barge or train is usually known. In the case of a roadside pickup or delivery, there is greater

uncertainty. Whether the trucking companies have to book time slots for the trucks to reduce this uncertainty depends on the operator.

Intra-terminal tracking of loading units. As soon as a loading unit enters the terminal area, it can either be directly transferred to another mode of transport or it is temporarily stored. In the case of temporary storage, the location of the loading unit must be recorded so that it is quickly available for pickup. At some terminals today, the (vague) position of the loading unit is recorded with pen and paper on the site and this list is not submitted until the next visit to the office, e.g. at the end of the shift.

Two general types of intra-terminal tracking can be distinguished: (1) driver-initiated information collection and (2) GPS tracking from own equipment. The first option is to have drivers digitally capture information while operating cargo handling equipment either with permanently integrated hardware such as a simple screen and a few buttons for interaction or tablet applications with touch input. Typically, the next orders are displayed sorted by priority, and selected by the operator. In the procedure described, the position of a loading unit is implicitly recorded via the equipment that last transported this loading unit. The last movements of the loading unit are stored in the order control software. The latter records the GPS position of the equipment as close as possible to the loading unit (e.g., on the spreader), consequently each loading unit can be assigned a GPS track for transport. The last known GPS position then corresponds to the current location of the loading unit. Once GPS tracking has been introduced, further analyses of routes, waiting times, etc. can be made, which can be used as decision-making support. Likewise, the position of a loading unit can be shared with the customer as a confidence-building measure.

Cross-company communication. Intra-terminal processes are highly dependent on supply chain partners. Transshipment processes can be optimized above all if the information on the intended transports and delays is shared early and comprehensively, which can be considered in operational planning at the terminal. Likewise, the supply chain partners would like to be informed by the terminal operator when the desired loading unit(s) can probably be picked up. A digital, possibly even automated, exchange of information creates clarity. Thus, if implemented correctly, digitalization leads to more transparency in the supply chain.

Optimized terminal control. Based on the information provided by the previously mentioned options, improved operational planning can be carried out. Typically, this aims at a combination of improved service (shorter train, barge, and truck turnaround times), more energy-efficient handling (shorter distances traveled by gantry cranes, and efficient use of terminal-owned equipment for horizontal transport), or increased terminal capacity (intelligent use of space). For example, truck turnaround time can be reduced if the peaks in the truck arrivals are smoothed out. In this regard, a time window booking system represents the key to the predictive arrival management system. Based on the information, the travel distances of the gantry crane can be minimized. This simultaneously saves energy and time for the transfer of loading units between the means of transport. Optimization goals are diverse and can differ between terminals and for individual terminals dynamically in operation. The development of customized solutions is therefore a challenge, also in cooperation with external partners.

4. Discussion

Digitalization not only has an internal impact on companies' business activities and business models by enabling various new forms of collaboration between companies and leading to new corporate relationships with customers and employees but is also a prerequisite for achieving resilience to supply chain vulnerabilities such as the COVID-19 pandemic. Using rail or waterways as environmentally friendly modes of transport as part of intermodal transport is a very important contribution to achieving the sustainability targets since CO_2 emissions required for continuous road transport are saved. However, this paper shows that the digitalization of SME terminals today causes disadvantages that limit the competitiveness with direct transport. Manual or inefficient digital processes can be time-consuming and error-prone, which may lead to longer transport times, customer dissatisfaction, and higher costs. The described model helps terminals to improve themselves and thus to make intermodal transport more efficient and attractive. On the one side, the model is deliberately kept generic with regard to the process models and tools to accommodate the most diverse characteristics of intermodal terminals. Their function as logistical nodes varies and depends in particular on the services offered and other special features such as access to transport modalities, their layout, or the availability of special transport services. On the other side, it contains detailed recommendations for action on possible further steps for the digital transformation of inland terminals (e.g., tracking and gates). These provide a comprehensive overview to enable as many terminals as possible to identify with. The interaction of this generic approach together with the detailed insights enables terminals to develop independently and systematically. The limiting factor of the study was the limited number of participating terminals, especially concerning the heterogeneity of the terminals. Though, not only inland terminal SMEs but also companies with an integrated reference to two or three modes of transport can use the described reference process model. This includes nodes in logistic networks such as freight centers. The current model is a starting point for further, more detailed considerations and adaptations. Due to the ongoing development of digitalization, it is even indispensable that the model is extended and adapted.

5. Conclusion

This paper presents an approach for inland terminals to self-assess and evolve their IT landscape. The methodology consists of both secondary desk research and a survey on various logistic hubs. The survey is based on the results of a workshop and semi-structured interviews conducted with various players in the logistics industry whose activities are related to the inland terminals sector. The research outlines the existing IT landscapes of inland terminals and the resulting requirements for digital transformation. Finally, different alternatives to depict the inland terminals' architecture are exposed and a general reference process model architecture is defined.

The results of the secondary research and interviews led to the following key conclusions. First, this research highlights the need for self-assessment capabilities, as EAM approaches are often not feasible for SMEs. Second, the work identifies the various, very wide-ranging differences in terms of the state of digitalization of inland terminals. Third, it emphasizes the importance of knowledge about the company's processes. Fourth, depending on the maturity level, which is based on the digitalization of internal

operational processes, approaches for adaptation are given. These are the basis for the model and only enable the application of flexibility and resilience.

The results of this research are relevant to both academia and practice. Theoretical considerations on the elementary necessities for building a reference process model are presented. In addition, terminals will benefit from a practical process model. Individual adaptation needs are identified that are reflected in different configurations of each target landscape.

From this initial investigation of aspects related to the development of reference process models at inland terminals, several opportunities for further investigation emerge. For example, there is a lack of efficient data collection and utilization to optimize terminal processes in a future-oriented manner. Though, approaches from fields such as artificial intelligence generally require a reliable database. In addition, the design of the interface to other players in the logistics chain is becoming increasingly relevant as their digitalization and corresponding requirements increase. The process model must be adapted to the corporate structure and corporate culture to work as efficiently as possible. Agility and flexibility in the use of the model are important to be able to adapt to changing conditions. This offers a constant need for improvement.

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References

[1] Abel-Koch J, Al Obaidi L, El Kasmi S, et al. Going Digital: The Challenges Facing European SMEs. European SME Survey; 2019.
[2] Hervás-Peralta M, Poveda-Reyes S, Molero GD, et al. Improving the Performance of Dry and Maritime Ports by Increasing Knowledge about the Most Relevant Functionalities of the Terminal Operating System (TOS). Sustainability. 2019; 11:1648.
[3] Ballis A, Golias J. Comparative evaluation of existing and innovative rail-road freight transport terminals. Transportation Research Part A: Policy and Practice. 2002; 36:593–611.
[4] Lange A-K, Grafelmann M. Digitalization of Maritime Logistics Systems. In: Ilin I, Devezas T, Jahn C, editors Arctic Maritime Logistics; 2022; p. 95–116.
[5] Ritter T, Pedersen CL. Digitization capability and the digitalization of business models in business-to-business firms: Past, present, and future. Industrial Marketing Management. 2020; 86:180–190.
[6] Reis J, Amorim M, Melão N, et al. Digitalization: A Literature Review and Research Agenda. In: International Joint conference on Industrial Engineering and Operations Management. Springer, Cham.2020; p. 443–456.
[7] Jahn C, Zimmermann P, Kuechle J. Terminal Operating Systems 2021. 2021. Stuttgart: Fraunhofer Verlag.
[8] Lee C-Y, Meng Q, editors. Handbook of ocean container transport logistics: Making global supply chains effective. Cham: Springer; 2015. (International Series in Operations Research & Management Science; Volume 220).
[9] Grafelmann M, Zlotos C, Lange A-K, et al. Modelling the IT and Business Process Landscapes at Inland Intermodal Terminals. In: Data Science in Maritime and City Logistics: Data-driven Solutions for Logistics and Sustainability. Proceedings of the Hamburg International Conference of Logistics (HICL); 30:159-179. 2020.
[10] Ruile HV. Efficiency of multi-modal Hinterland Terminals. In: Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria.; 2018.

[11] Aarabi M, Saman M, Wong K, et al. The Effect of Enterprise Architecture for Enterprise Resource Planning in Small and Medium Enterprises: a Review and Research Direction. International Conference on Industrial Engineering and Service Science (IESS). 2011; 2011.
[12] Lankes J, Matthes F, Wittenburg A. Softwarekartographie: Systematische Darstellung von Anwendungslandschaften. In: Wirtschaftsinformatik 2005; 2005; p. 1443–1462.
[13] Ernst AM, Lankes J, Schweda CM, et al. Tool Support for Enterprise Architecture Management - Strengths and Weaknesses. In: 10th IEEE International Enterprise Distributed Object Computing Conference, 2006; 2006.
[14] Bischoff J, Taphorn C, Hegmanns T, et al. Erschließen der der Potenziale der Anwendung von "Industrie 4.0" im Mittelstand: Studie beauftragt vom Bundesministerium für Wirtschaft und Energie (BMWi). Mülheim an der Ruhr; 2015.
[15] Leineweber S, Wienbruch T, Kuhlenkötter B. Konzept zur Unterstützung der Digitalen Transformation von Kleinen und Mittelständischen Unternehmen. In: Matt D, editor KMU 4.0 - digitale Transformation in kleinen und mittelständischen Unternehmen; 2018; p. 20–39.
[16] Palmer K. Building a Data Maturity Model + the 4 Stages of Data Maturity [Internet] [cited 2022 Apr 22]. Available from: https://www.safegraph.com/blog/the-four-stages-of-data-maturity.
[17] Scharch M. Vorgehensmodelle in der Software-Entwicklung. In: Arbeitspapiere WI (4/2016).
[18] Broy M, Kuhrmann M. Einführung in die Softwaretechnik. Springer Berlin/Heidelberg; 2021.
[19] Umweltbundesamt: Emissionsdaten. Available from: https://www.umweltbundesamt.de/themen/verkehr-laerm/emissionsdaten [cited 2022 Jan 22].
[20] Schnelle J, Schöpper H, Kersten W. Corona: Katalysator für Digitalisierung und Transparenz? : Eine Studie über die Auswirkungen der Pandemie. 2021.