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Developing a method that supports growth in maturity of intralogistics within SMEs

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BRICK LOG Logisch in Logistiek

UNIVERSITY OF TWENTE.

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Industrial Engineering and Management
4 April 2022

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Preface

This is the final version of my master thesis entitled: Developing a method that supports growth in maturity of intralogistics within small and medium-sized enterprises. This thesis concludes my seven-year student life at the University of Twente in Enschede. During the first 4.5 years, I completed a bachelor Industrial Engineering and Management, followed by a two-year master Industrial Engineering and Management, with the track Production and Logistics Management and a specialization in Supply Chain and Logistics Management.

I was allowed to write my thesis during the first half of the study year 2021-2022 at the company Bricklog in Apeldoorn. Within the Bricklog team, I was warmly welcomed, and I was allowed to join various non-work-related activities. In addition to a good relationship with my colleagues, there was also room for personal development and creativity. I learned to work with Power BI and Microsoft SQL. In consultation with my supervisor at Bricklog, I was able to form my thesis according to my interests. I would like to thank the colleagues within Bricklog for the past months.

From the University of Twente, I would like to thank my first supervisor Maria Iacob and my second supervisor Sebastian Piest for supervising my thesis. Additionally, I would like to thank Hubert Benneker, my supervisor from Bricklog, for sharing practical knowledge and guiding the work surrounding my thesis. Hubert soon realized that I was sticking to an academic method, which is different from the working method: “Keep it *** sane and simple”. It took some (physical) fighting before I understood what Hubert was referring to, but it resulted in a quote that I will never forget.

In the past seven years, I also got to do a lot of things besides studying. I have found a group of friends at the student association A.S.V. Taste and became a member of the independent fraternity Χάος. In addition, I have been able to experience many beautiful moments with my group of friends, study friends, family, and my girlfriend. I would like to thank them all for their support during my graduation and the remaining six years of my studies. Despite more downs than ups in the first years of study, I am very proud of the result of the concluding years.

Kind regards,

Martijn Ma

4 April 2022

Executive summary

This research was initiated by Bricklog with the request for a generic model that can be applied to medium-sized companies in the transport and logistics sector to assess the current state of a company and support this company to grow in the field of intralogistics. The research was set up in collaboration with the customer Customer XX, who was curious about the possibilities of implementing self-driving robots within their warehouse. Customer XX facilitated a case study that was used during the development of the model for Bricklog.

The design science research strategy has been applied to this research. Figure 1 shows the two iterations of the design science research methodology that have been performed. The first iteration is initiated from a client-initiated perspective and the second iteration from an objective-centred solution perspective. In total, eight different steps were completed. First of all, the core problem of this research has been identified. Subsequently, the researcher focused on the case study, in which an exploratory research strategy was applied. This strategy has led to the development of a Power BI report that has been implemented and validated by the customer. After the validation, the research changed from a client-initiated perspective to an objective-centred solution perspective to link practice with the literature. A systematic literature review was executed, the results of which were combined with the results of the case study. The developed artefact resulted from this combination, which has been validated using an expert panel. Based on this validation, several points for improvement have been found that should be investigated in the future. The final step of the research is a colloquium.

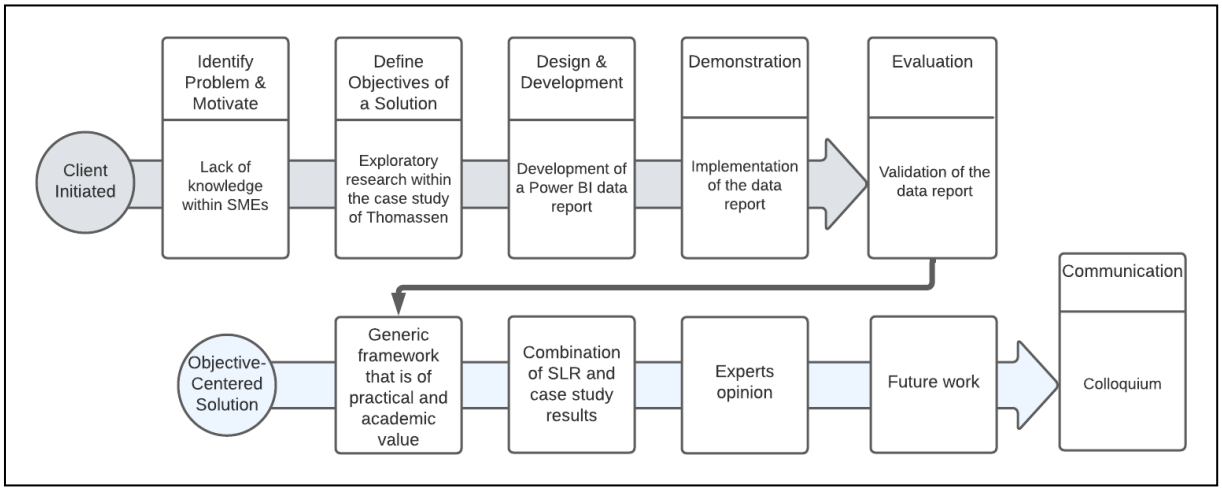

Figure 1, The executed iterations of the DSRM

The research is based on four research questions. The first question was used to identify the core problem, the second to conduct a systematic literature review, the third to develop the artefact and the fourth to validate the artefact.

RQ 1. What is the current state of SME Transport towards the developments of Industry 4.0 regarding intralogistics?

RQ 2. What are available maturity models that focus on intralogistics of SMEs transport?

RQ 3. How should we design a method that can be applied within SMES transport that provides insight into the current state of maturity and supports growth in maturity, focused on Logistics 4.0?

RQ 4. How can the developed method be used in practice?

The first research question is answered by the background information. The background information consists of six sections in which the sector in which Bricklog is active and the history of this sector is described, the application and history of self-driving robots are examined, the importance of people is highlighted through change management, and the different functions of a warehouse are examined. The core problem of this research is:

Within SME transport, there is a lack of knowledge about the developments of Industry 4.0 regarding intralogistics.

After identifying the core problem of the research, an exploratory research strategy was applied to the case study. During the analysis of the current working method within Customer XX's warehouse, it was concluded that they are not yet ready for the implementation of self-driving robots. The exploratory research strategy has led to the development of a Power BI data report that has been implemented and validated by the customer.

A systematic literature review was conducted to answer research question two. The systematic literature review concluded that maturity models that focus on Logistics 4.0 are in line with the subject of this research. Six different models have been found for Logistics 4.0, one of which also focuses on SMEs. Due to the limited availability, year of publication, substantiation for developing the model, and the similarities between the model and the problem of this research, it was decided to apply the model of Facchini, Olésków-Szłapka, Ranieri, and Urbinati (2020).

Research question three was answered with the development of the method titled: "A method that can be applied within SMEs in the transport and logistics sector that provides insight into the current state of maturity and supports growth in maturity, focused on Logistics 4.0." The developed method combines the data report with a maturity model and consists of three phases. The maturity model is used to provide insights into the readiness for change and awareness of the current state of the company from the point of view of the employees and the consultants. The data report is used to substantiate the results of the consultant and to guide the customer in improving their processes.

The method has been validated by an expert panel, which answered research question four. According to the experts, the method is generically applicable, clear, logical, and easy to understand. The main improvement in the model is an extra process step at the end of phase two. This step should ensure that employees' perceptions of the customer are aligned with the perception of the consultant. Figure 2 shows the final model.

The research is of practical value through the development of the data report and theoretical value through the development of the method. The literature shows that maturity models only serve the purpose of gaining insights into the status quo of companies. The developed method also helps companies to grow in maturity after the current state of a company has been determined. The exploratory research strategy has led to the development of the data report, which shows insights that were previously unknown within the company. This data report contains several innovative elements that add value to a company.

Bricklog is advised to conduct further research into generalizing the data model. When the data model can be built up and consists only of generic elements, a report can be developed for each customer as soon as the data is accessible to Bricklog. Moreover, Bricklog is advised to use the developed method to realize improvements in intralogistics for all new customers with related issues. The last recommendation is, to keep improving the developed method. Let every customer journey be a learning moment and adjust the model where necessary. The experiences gained in each customer journey will contribute to the improvement of the method.

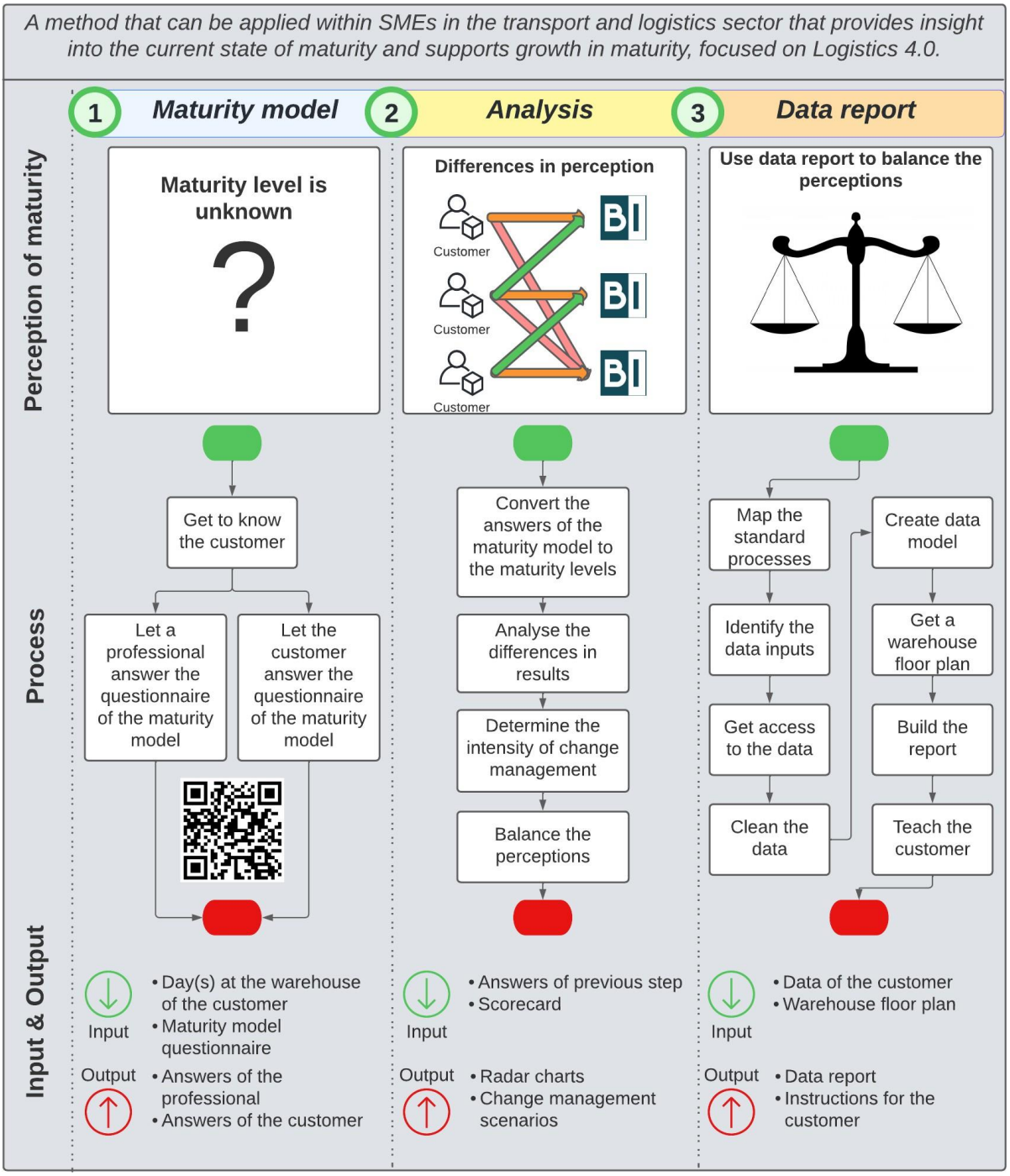

Figure 2, The final model of the developed method

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List of Abbreviations

Abbreviation	Meaning
MSc	Master of Sciences
BMS	Behavioural Management & Social Sciences
IEBIS	Industrial Engineering and Business Information Systems
IEM	Industrial Engineering and Management
PLM	Production and Logistics Management
DSRM	Design science research methodology
BPMN	Business process model and notation
SMEs	Small and medium-sized enterprises
WMS(s)	Warehouse management system(s)
RQ	Research questions
SMEs Transport	Small and medium-sized enterprises within the transport and logistics sector
CMM(I)	Capability Maturity Model (Integration)
IoT	Internet of Things
CPSs	Cyber-physical systems

1 Introduction

Section 1.1 addresses the organizations involved in this research, Section 1.2 addresses the background information of the research, and Section 1.3 describes the research design.

1.1 Organisational Context

The next two paragraphs introduce the main involved organizations in this research. The business structure, product, service, target market, mission, and location are stated (Gregory, 2020). It concerns Bricklog, the company that commissioned the graduation research, and Customer XX, the customer of Bricklog which facilitates the case study for the research. Chapter 2 explains the case study in detail.

1.1.1 Bricklog

The private limited company Bricklog Holding B.V., better known as Bricklog, originated in May 2015. Bricklog operates within the transport and logistics sector and has made a name for itself by providing services within digitization and sustainability. They work on a project basis with their customers and ensure that Bricklog's involvement goes beyond an advisory role. Bricklog is in Apeldoorn and has grown to 20+ full-time employees and offers internships and graduation projects for five students every six months.

Bricklog arose from the passion of two founders to allow small and medium-sized enterprises (SMEs) within the industry to compete with large multinationals. A combination of more than 25 years of experience in the branch, using resources from other industries, curiosity, and a vision for improvement is what allows Bricklog to realise improvement and growth. Within the projects, they develop and strengthen the connection between people, technology, knowledge, and the environment (Bricklog, 2021).

Bricklog started the research to develop a generic method for the sector that provides insight into the current state of a company and helps this company to grow in the field of intralogistics.

1.1.2 Customer XX

The customer of interest is the private limited company Customer XX. Customer XX is a family haulage company that originated in 1939 and is located in Location XY. They focus on the transport of goods by road and temporary storage of these goods, which makes them third-party logistics. In over 80 years, the family company has grown to a business with over 120 employees, 180 trailers, and 90 tractors (Customer XX Transport, 2021). They strive for the best care for and sustainable relations with their customers by offering their reliability and productive and committed employees.

For Customer XX, the research started with the question of what the possibilities are for the implementation of self-driving robots in the warehouse.

1.2 Background Information

The background information consists of six sections. The first two sections focus on the sector in which Bricklog is active and the history of this sector. Next, the application and history of self-driving robots are examined. The importance of people, which is fundamental within Bricklog, is highlighted through change management. Finally, the different functions of a warehouse are examined, so that the developed model can be used generically. The last section concludes the background information by answering the first research question.

1.2.1 The Industry

Bricklog focuses on SMEs within the transport and logistics sector as their customers. From now on, reference will be made to SMEs within this sector as 'SMEs transport'. The transport and logistics sector has grown since the 'logistics revolution' during the 1950s which has a direct connection with globalization (Mariotti, 2014). In the years after the Second World War, connection to the internet and the rest of the world became more accessible. Allen (1997) stated that "The advocacy of transport deregulations" around the 1960s, which allowed companies to compete, led to smarter and cost-effective methods of transport. There was also a shift to a customer-oriented economy; the customer demanded more customization of products and shorter delivery times. These are just some of the causes that have shaped the transportation and logistics industry as we know it today. But what is meant when we talk about logistics and transport? Logistics is "that part of Supply Chain Management that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption to meet customers' requirements" (Facchini et al., 2020). Transport is part of logistics and stands for all movement of goods by air, sea, road, and rail (Mariotti, 2014). The final term SMEs, are businesses that have a staff headcount below 250 and their turnover is beneath 250 million euros or the balance sheet total is beneath 43 million euros (European Commission, 2021).

Today we are dealing with the 4th industrial revolution, which is called Industry 4.0. Industry 4.0 is "a common synonym for digitalization, especially in the manufacturing sector" (Krowas & Riedel, 2019). **"**The principle of the I4.0 is the implementation of Internet of Things (IoT) and smart manufacturing, work in process products, components and production machine which collects and share data in real-time" (Chaopaisarn & Woschank, 2021). "Industry 4.0 is an idea rather than a specific goal, and the transition to more modern ways of managing logistics flows is an organic process"(Zoubek & Simon, 2021). Industry 4.0 expands on the automation of the past 100 years. Industrial automation can be defined as "the use of control systems and technology to the processes of procurement, material handling, manufacturing, process industry, and quality control with the objective of ensuring minimal human intervention" (Channabasavaraj, 2018). Automation allows processes to be carried out effectively, quickly, and with constant precision over a long period. Industry 4.0 is all about data, connectivity, and advanced automation. (Big) Data is made available so that it can be used for analysis, machine learning, creating a digital twin, etc. Connectivity within the vertical and horizontal business processes is used for improving transparency, the possibility for mass customization, insight into customer demands, etc. Developments in the field of data also ensure that robotics continues to develop. The market share, which is already on the rise, is expected to continue to rise as robots develop themselves through machine and deep learning (Channabasavaraj, 2018). Collaboration with humans and other robotics will continue to improve. Industry 4.0 is often referred to with terms such as artificial intelligence, big data, internet of things, or cloud computing. These techniques are all applied under industry 4.0 and help to minimize interaction by humans. (Tjahjono, Esplugues, Ares, & Pelaez, 2017). "The vision of Industry 4.0 emphasizes the global networks of machines in a smart factory setting capable of autonomously exchanging information and controlling each other" (Tjahjono et al., 2017). The smart factory can be defined as "the environment in which human beings, machines, and resources communicate with each other as naturally as in a social network" (Villa & Taurino, 2019). So, full integration of industry 4.0 means digitization, digitalization, and automation in collaboration with many new technologies.

The developments within corporations and SMEs are different. “It is evident from the research and industrial innovation projects that technologies are being cultivated around large multinational companies and there is not much research available for the development of SMEs in context of digitalization and smart manufacturing” (Grube, Malik, & Bilberg, 2017). The next section discusses the development of Industry 4.0 for SMEs.

1.2.2 Developments in SMEs

The research of CBS (2021) shows that SMEs have a large share of the Dutch market. From 2012 to 2018, the share of SMEs in the Netherlands increased by almost 42%, bringing the total to 1.1 million SMEs. The SMEs, which are 99.9% of all active companies, provide 64% of the total employment in the Netherlands. Nearly 50,000 of these companies are active in storage and transport. HR Praktijk (2020) stated that two-thirds of Dutch SME entrepreneurs realize that digitization is necessary for the growth of the company. However, almost half of the entrepreneurs lack knowledge about the way to digitize for growth. This is based on the research from HR Praktijk (2020) executed in June and November 2020 in the Netherlands in which more than 1200 entrepreneurs participated. Only one-third of the entrepreneurs in transport and logistics seem to find digitization necessary for the growth of the company. The influence of industry 4.0 on digitization and automation within SMEs is questioned in the literature. Sommer (2015) stated that “the smaller SMEs are, the higher the risk that they will become victims instead of beneficiaries of this revolution.” Grube et al. (2017) stated “SMEs are characterized with low volume of production with high mix and hence robotic automation has remained far from SMEs”. However, the new technologies of Industry 4.0 create smarter robots, which results in opportunities for robotic automation within SMEs.

Within SMEs, the manager is often the same person as the founder or CEO of the company (Villa & Taurino, 2019). The managers have implemented their working method that is based on their knowledge and which they feel comfortable with. Digitization and optimization are often neglected, due to a lack of knowledge about the latest developments and changes that these developments entail. At various Bricklog customers, for whom projects have been carried out in recent years, it appears that 'easy' actions for automation are all performed by hand. This is often executed in Microsoft Excel, which is time-consuming for the employee. Within Bricklog it is a common observation that there is a lack of knowledge about the possibilities that Industry 4.0 brings.

1.2.3 Self-driving robots

Ben-Ari and Mondada (2018) defined a robot as “a machine capable of carrying out a complex series of actions automatically, especially one programmable by a computer.” This research focuses on self-driving robots that are used in a logistics environment.

Self-driving robots originated in America around the 1950s, when research was done into the possibilities of making machines do human work. The name for these robots became automated guided vehicles (AGV) around 1980 (Heinz, 2019). These AGVs are robots that transport goods from A to B using a navigation system, sensors, and without human intervention. The first design of the AGV was guided by a track, where bumpers were used as sensors (Ullrich, 2015). The techniques of the AGV have undergone many developments in areas such as control, sensors, data transfer, etc. Various developments are discussed in the following paragraphs.

The navigation technique of the AGVs started with a track-guided system. This track was replaced by different kinds of strips that were glued to the floor so that sensors in the AGV could read and follow these strips. The AGV could perform horizontal movements where goods were placed on the AGV, pulled forward, or lifted by the AGV. When there was a need to change the path of the AGVs, the strips had to be rearranged. This navigation technique is therefore not flexible, and it was not yet possible to perform vertical movements with AGVs.

According to Ullrich (2015), a boost in development was presented around the 1970s. For example, the first onboard computer was introduced, the strip on the floor could transfer data, the batteries on which the AGV runs became more powerful, automatic charging was introduced, and the AGV became more flexible by expanding the possible movements. The number of suppliers in the AGV market

remained limited at this stage. Most developments originated from the technologies used by the AGV, such as sensor technology.

The developments of the AGVs were largely dependent on the car industry in the '80s because the AGVs were mainly used in this industry. The recession in this industry brought a halt to development. Currently, the AGVs were not yet flexible and very expensive. Due to a collaboration between several companies in the automotive industry, an attempt was made to continue the developments. However, this did not reach its potential due to emerging competition from Japan.

After the steady developments in the automotive industry, new sectors, suppliers, and technologies provided the next boost. For example, data was transferred through a wireless network, navigation was no longer depending on wire strips, the speed of movements was increased, and all types of materials could be transported. The increase in suppliers ensured that the possibilities for deploying the AGVs increased, and a standard version could be produced more cheaply. This phase of development, which lasted until about 2010, made the AGV a reliable asset for intralogistics. In addition, the potential of the AGV was absorbed by more and more markets. “Intralogistics comprises the organization, control, execution, and optimization of the intra-company material flow and its accompanying information flow. 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” (Krowas & Riedel, 2019). “Important goals for intra-logistics are the reduction of stored material, faster deliveries, a higher customer satisfaction, and higher efficiency in customer individual production” (Krowas & Riedel, 2019).

Since 2000, the implementations of AGVs have been piling up. They are used for the transport of stock cabinets/pallets/etc., for horizontal/vertical movements, between organizations/within the warehouse/between warehouses/etc., with the use of different algorithms to calculate optimal paths. The possibilities for ways of navigation, data transfer, collaboration with people, battery charging, and integration with systems continued to expand in these implementation projects.

Industry 4.0 has also contributed to the development of the AGV. “Automation is the key focus in manufacturing and logistics sector as a part of Industry 4.0 and Supply Chain 4.0 initiatives for continuous growth and sustainability. Robotics is an important aspect of this automation” (Research and Markets, 2021). According to Mehami, Nawi, and Zhong (2018), Industry 4.0 provided higher customization and lower production costs through smart design. In addition, the rise of the Internet of Things meant that devices were connected and could exchange data. This increased the implementation possibilities. Different types of AGVs are shown in Figure 3.

An important topic in the implementation of AGVs is safety for the cooperation between humans and robots. First, aisles were divided into areas for workers and AGVs. As the sensors on the AGV developed, the sensors could be used for safety in a dynamic working environment. It started with physical bumpers. Nowadays, camera systems are used to map the environment of the AGV. As soon as a person comes too close to the AGV, it stops.

Due to all the innovations, many different types of AGVs have been developed. The differences between the types are determined by, among other things, flexibility, efficiency, safety, and costs. In addition to the AGV, the second line of self-driving robots has been developed. “Autonomous mobile robots (AMRs) are one of the latest and most innovative automation solutions on the market” (Robotics, 2018). The AMR distinguishes itself from the AGV by its flexibility and navigation technologies. The AMR is not linked to a track system but can drive around freely in a dynamic working environment where humans and robots are present. The technologies in the AMR ensure that obstacles can be avoided by calculating new paths and the AMR learns from its environment while performing its tasks. The latter is made possible by the new technologies from Industry 4.0, such as artificial intelligence.

Further details of all recent developments and various implementation projects are not mentioned in this research. What all self-driving robots have in common is the importance that they must be fully system controlled to function.

Additional information: A = AGV used by Autostore; B = AGV that is used for the transport of containers in the port of Rotterdam; C = AGV that is often used for movements within a warehouse; D = AGV that moves stock cabinets and is used by Amazon.

Figure 3, Different types of AGVs (Connors, 2014; Elementlogic, 2019; Indiamart; Pikist)

1.2.4 Change Management

Development, innovations, and changes within the work processes or structure of a company, are in conjunction with change management. The literature contains many papers about methods, theories, and disciplines regarding the concept of change management. The concept can be described as: “It's a structured approach that ensures changes are implemented thoroughly and smoothly – and have the desired impact” (Mindtools). Bricklog believes that advancements in technology within the company or other business processes are only successful with the human being as the main focus. Since Bricklog's customer portfolio consists of SMEs, it often happens that the CEO and operational process manager is the same person. It is therefore not possible to implement changes through a top to bottom management structure. Because the case study focuses on the customer Customer XX, there is an element of change management that influences the research. During the case study and the presentation of the research results, there should be clear communication so that the initiative of the research, the plan of the research, and the implementation/results of the research are clear to all parties involved. This thesis will explain when a conscious choice is made based on change management.

1.2.5 Warehouses

To broaden the scope of the research, various functions, names, and methods of a warehouse are mentioned.

Bricklog's customer portfolio includes customers with different types of warehouses. For the research, a case study is carried out at Customer XX whose warehouse belongs to the category of transit warehouses. At transit warehouses, the products are stored for a short period and transported unprocessed to a customer. Warehouses can be categorized in different ways. Warehouses can be classified based on function. In addition to the transit warehouse, there are warehouses with the function of order picking, distribution, stocking and production, and consolidation (Mecalux, 2021). An order-picking warehouse serves the purpose of making the order picking process run efficiently. Distribution warehouses are used to quickly supply certain regions by storing products with a high turnover rate. Stocking and production warehouses store products that will then be used or processed in a production process. The stock of these products ensures that the production processes are not interrupted due to low supply. The last function, consolidation, serves the purpose of storing inventory by regions or zip codes. The transport of different products is combined so that fewer trucks must drive within a region.

Bricklog's customers have warehouses that are not always named according to the function, but by the method that determines the policy within the warehouse. The most common warehouses are the hubs, order picking, and stock warehouses. Hubs are often used by a network of carriers to distribute the products more efficiently within regions of the Netherlands. Within the hub, all shipments are received and distributed by region. A hub functions as a consolidation warehouse and is also referred to as a cross-docking warehouse in practice. Order picking is self-explanatory and stock warehouses are the common name for transit warehouses. A warehouse does not always have to serve just one function.

1.2.6 Conclusion

The first research question is answered by the background information:

RQ 1. What is the current state of SME Transport towards the developments of Industry 4.0 regarding intralogistics?

The current state of SMEs regarding developments of Industry 4.0 is, among others, shaped by the knowledge within the company, the available technologies, and the management structure. Innovations are mainly implemented and modified within corporations. As a result, the SMEs do not remain informed of the developments, which creates a gap between the corporations and SMEs. The structure within an SME, in which the CEO and the operational manager is the same person, contributes to the lack of knowledge within the organization. The latest technologies, emerging from Industry 4.0, have made various innovations available to SMEs. These innovations are mainly aimed at automation processes through connectivity and data. The current backlog of SMEs means that digitization must be realized before advanced technologies such as an AGV can be implemented. The research of HR Praktijk (2020) shows that a large part of SMEs are aware of the added value of digitization, but do not have the knowledge to realize this.

1.3 Research Design

The research design is a framework that combines different data collection methods and analysis techniques to answer the research question (Fraenkel & Wallen, 2006). The study is designed according to the design science research methodology (DSRM), which consists of six steps (Peffers, Tuunanen, Rothenberger, & Chatterjee, 2007). In the following paragraphs, multiple terms are used to explain the structure of the framework. To become familiar with these terms, the quotes of Fraenkel and Wallen (2006) are given below:

- "*Case study* - An in-depth investigation of an individual, group, or institution to determine the variables, and relationship among the variables, influencing the current behaviour or status of the subject of the study."
- "*Literature review* - The systematic identification, location, and analysis of documents containing information related to a research problem."
- "*Validity* - The degree to which correct inferences can be made based on results from an instrument; ; depends not only on the instrument itself but also on the instrumentation process and the characteristics of the group studied."

The DSRM is a methodology consisting of six steps. Peffers et al. (2007) describe design sciences as sciences that "creates and evaluates IT artefacts intended to solve identified organization problems". An artefact is for example a model, social innovation, method, etc. The artefact must be designed in such a way that it serves human purposes. The methodology allows modification in the sequence of the steps. Figure 4 shows the six steps of the DSRM which are briefly explained below.

1. Problem identification and motivation: In this phase, the problem must be identified, and the value of a solution must be highlighted.
2. Define the objectives for a solution: The objective must be described from the problem description. This can be explained qualitatively or quantitatively.
3. Design and development: In this phase, the artefact is designed. A correctly designed research artefact exists when the knowledge gained through the research has been used during the design process.
4. Demonstration: Demonstrate that the artefact functions as intended, through a case study for example.
5. Evaluation: During the evaluation, the designed artefact is tested through various forms of analysis and checked whether it meets the problem and objective of the research. From this phase, it is possible to go back to phase three.
6. Communication: In the last phase the artefact is presented to the stakeholders within the research and other relevant audience.

Figure 5 shows the two iterations of the DSRM that were executed in this research. The first iteration is from a client-initiated perspective and the second iteration is from an objective-centred solution perspective. This is comparable to a bottom-up approach, in which there is a shift of focus from a small-scale to a larger one. "Bottom-up allows technologists and managers to learn as they go. Success is more likely when the problems are encountered in small size rather than trying to manage a large, complex scope from the beginning" (Gernaey, Huusom, & Gani, 2015). In total, eight different steps were completed. First of all, the core problem of this research has been identified. Subsequently, the focus was on the case study, in which an exploratory research strategy was applied. Exploratory research is defined as research used to investigate a problem that is not clearly defined. It is conducted to have a better understanding of the existing problem, but will not provide conclusive results. For such research, a researcher starts with a general idea and uses this research as a medium to identify issues, that can be the focus for future research" (QuestionsPro, 2022). The exploratory research strategy has led to the development of a Power BI report that has been implemented and validated by the customer. After the validation, the research changed from a client-initiated perspective to an objective-centred solution perspective to link practice with the literature. This combination is important for the development of a generally applicable model. A systematic literature review was

executed, the results of which were combined with the results of the case study. The developed artefact resulted from this combination, which has been validated using an expert panel. Based on this validation, several points for improvement have been found that can be investigated in the future. The final step of the research is a colloquium.

The following paragraphs describe the problem statement, research objective, research questions, and thesis outline.

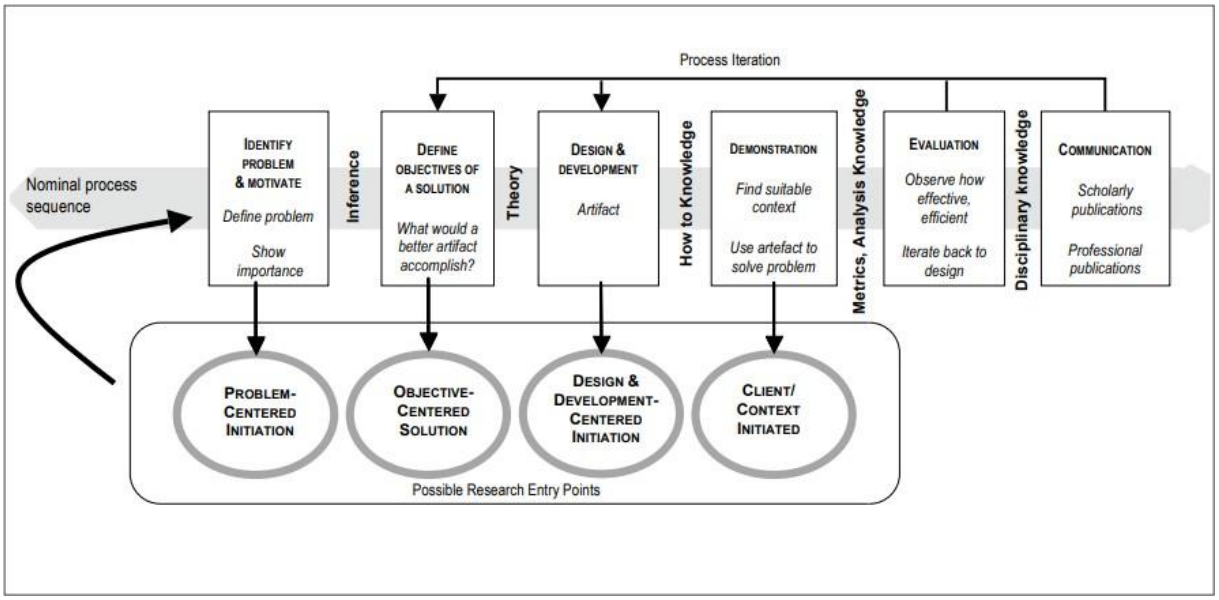

Figure 4, Design science research methodology framework (Peffers et al., 2007)

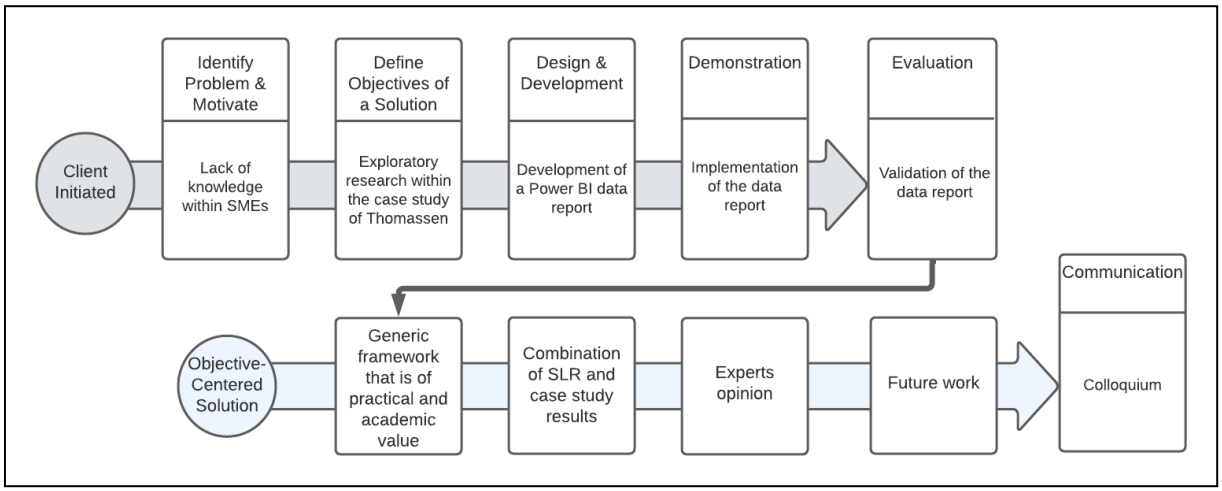

Figure 5, Double iteration of the DSRM

1.3.1 Problem Statement

The first step of the DSRM is to identify the core problem. It has been noted, both within Bricklog and from literature, that SME transport are lagging in the field of digitization and automation. The developments of industry 4.0 are in full swing and more and more smart factories are emerging. The lack of knowledge about the developments of industry 4.0 has ensured that most SMEs lag in this area in comparison with corporations. The research focuses on the developments of the 4th industrial revolution regarding intralogistics within SMEs. Now, SMEs are often not prepared for new technologies in their current working method. To prepare the SME transport for this integration, it is necessary to map the different maturity levels within intralogistics. With these levels, it can be investigated what the current state of the SMEs is and in which area(s) they can improve. The core problem of this research:

Within SME transport, there is a lack of knowledge about the developments of Industry 4.0 regarding intralogistics.

1.3.2 Research Objectives

This research was initiated by Bricklog. The question from Bricklog has already been mentioned in the introduction. Since they are the 'customer' of this research, the main objective of this research is:

The research objective is to design a method that can be applied within SMEs in the transport and logistics sector that provides insight into the current state of maturity and supports growth in maturity, focused on intralogistics.

1.3.3 Research Questions

The structure of the research is determined by four research questions. First, the current state of SMEs Transport and the developments of recent years are discussed. This information forms the background information and is used, among other things, during the problem identification.

RQ 1. What is the current state of SME Transport towards the developments of Industry 4.0 regarding intralogistics?

The exploratory research strategy has been applied within the case study. In an exploratory research strategy, the researcher must be able to adjust his goals through the experiences and knowledge he gains. Therefore, no research question was formulated for the case study. The second research question was formulated to guide the literature review. The goal is to find an existing maturity model that matches the subject of this research. In addition, the review provides a broad theoretical background of important aspects of a maturity model.

RQ 2. What are available maturity models that focus on intralogistics of SMEs transport?

The artefact that is developed during this research is a method that consists of the combined knowledge of the case study and the maturity model. The development of this artefact is done based on the following research questions:

RQ 3. How should we design a method that can be applied within SMES transport that provides insight into the current state of maturity and supports growth in maturity, focused on Logistics 4.0?

The fourth research question is used for the validation of the artefact. The artefact is validated by experts working within Bricklog. The validation of the artefact is based on research question four:

RQ 4. How can the developed method be used in practice?

1.3.4 Thesis Outline

The thesis consists of six chapters. Chapter 1 introduces the companies that initiated the research, the background information, and the research design. Chapter 2 contains all information about the case study. In chapter 3 the link with the literature is made within this research. The steps followed for the systematic literature review are described. Chapter 4 describes the development of the artefact and chapter 5 validates this artefact. Chapter 6 contains an overview of the answers to all research questions, the contribution to theory and practice, limitations, recommendations, and future work. The research will be concluded through a colloquium for stakeholders and the interested public.

2 Casus of Customer XX B.V.

Section 2.1 gives an introduction about Customer XX, the warehouse, and the customer portfolio, Section 0 addresses the methods applied, Section 0 addresses the results, Section 0 describes the validation of the report and Section 2.5 is a summary of this chapter. All steps in the case study have been taken under an exploratory research strategy. The knowledge of Bricklog experts was used for this. The case study includes steps 2, 3, 4, and 5 of the first iteration of the DSRM.

2.1 Current Situation

The current situation is divided into three sections. An explanation is given about the warehouse in Location XX, the internal process is explained, and the available data is discussed.

Besides the main service of transporting products, Customer XX stores products for their customers. Customer XX's head office is in Location XY and the warehouse of almost 25 thousand square meters is in Location XX. This warehouse mainly stores products on pallets. The customer pays for the product handling (put in storage and retrieve from storage) and rent per pallet per week.

Customer XX has been a Bricklog customer for several years. Over time, several projects have been completed within Customer XX: the layout of the warehouse was modified, a new warehouse management system has been implemented, communication flow within management has been set up, insight into stock management has been created, and a basic procedure for inbound and outbound is established. Results of these projects include trip, fleet, and static warehouse reports created by Bricklog employees based on the available data within Customer XX. The warehouse report contains information about inventory quantities, free space, and occupancy in the warehouse. Different aspects of the projects are used within this case study.

2.1.1 The warehouse in Location XX

Figure 6 shows the warehouse of Customer XX. Figure 7 shows a sketch of the layout of the halls. For a more detailed floor plan of the halls, see Appendix A.

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Figure 6, Outside view of the warehouse in Location XX

The warehouse consists of ten halls of approximately 2500 square meters each. The front halls each have six loading docks for trucks at the front. The main purpose of the warehouse is the bulk storage of pallets. In addition to the pallets, paper rolls are stored in Location XX. The process of storing these paper rolls is outside the scope of this research, due to the low volume. Halls 1 and 2 are partly used for the storage of these paper rolls and supplemented with bulk storage. Halls 5 and 6 contain racks that are used for the storage of residual pallets. The other halls are used for bulk storage of pallets.

This figure is not visible for confidential reasons

Figure 7, Sketch of the warehouse in Location XY

The block stacking technique is applied to the storage of these pallets, which is shown in Figure 8. If the occupation of the warehouse allows, one article is stored per stock location.

Customer XX's warehouse is largely filled with the products of two customers: Customer A and Customer B. Customer A's products enter through hall 9 and are stored next to hall 9 in halls 8 and 10. Customer B's products enter through halls 3, 5, and 7 and are stored next to these halls in halls 4, 6, and 8. These racks in halls 5 and 6 are used to store leftover pallets and products with less than four pallets, which applies to both customers. In practice, however, these racks are almost entirely used for Customer B. The bulk storage locations in halls 1 and 2 are filled with products of various customers that all work in small volumes. The product types and agreements with the customers in halls 1 and 2 differ, resulting in different processes. It was therefore decided to focus on the internal processes of Customer A and B.

Figure 8, Block stacking technique

2.1.2 Internal processes

Two warehouse management systems (WMS) are running within Customer XX. "A warehouse management system consists of software and processes that allow organizations to control and administer warehouse operations from the time goods or materials enter a warehouse until they move out" (O'Donnell, 2020). Customer B implemented their own WMS at Customer XX. For Customer A, the WMS called 'In&Out' is implemented. Both systems require different inputs at different stages in the process. The data input, which is done by scanning a barcode on a pallet, is therefore generated at different moments in the internal process. To gain insight into the available data, the internal process has been mapped. The information was gained through conversations with employees and cooperation in the warehouse. The internal process is visualized in Figure 9 using the standard business process model and notation (BPMN, 2021). The process is explained for Customer A.

The internal process for Customer A starts when the pallets are already in the warehouse. The loading and unloading of the trucks are done by the truck drivers themselves, which is a process that does not belong to Customer XX. The drivers place the pallets on the loading/unloading area, from now on called the loading field, at the front of the front halls. The pallets that come in contain barcodes that have been added by the customer of origin. The scanners used by the employees on the floor cannot always read these barcodes. When this happens, new barcodes have to be added to the pallets, which is an extra process step. With a usable barcode on the pallet, the pallets are picked up with a forklift or pallet truck by one of the employees. The barcodes are scanned, and the employee is shown which stock locations contain the same products The employee must check physically if the used locations are fully occupied because this is not shown by the system. Where possible, the stock locations are replenished, otherwise, a new stock location can be chosen. The replenishment is done based on the first in first out (FIFO) principle. The locations are not always replenished when there are empty locations available. The employees rather choose a new location because replenishing with a combination of FIFO and block stacking is a time-consuming activity. The location where the pallets are placed is scanned so the location of the pallets is known in the WMS. The pallets are in storage until they are needed for a shipment. They scan the pallets when they collect them from the stock location and when it is placed on the loading field. Finally, a check scan takes place at the loading field when all pallets of a shipment are collected. The light blue activities in Figure 9 are the five scan moments.

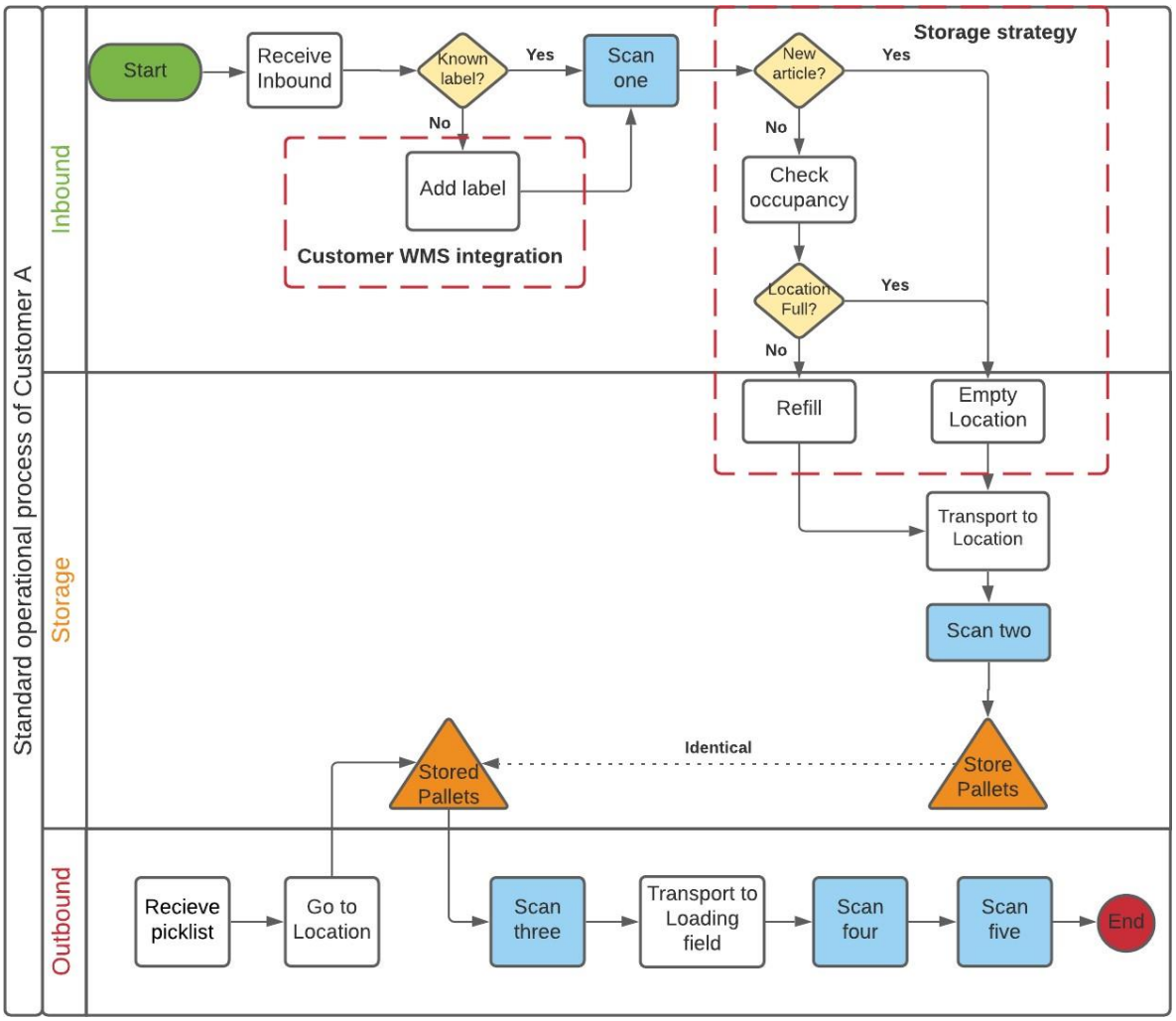

Figure 9, BPMN for the operational process of Customer A

After analysing the standard process, several elements immediately stand out:

1. The research was initiated by the demand for the implementation of self-driving robots within the Customer XX warehouse. The most basic requirement for self-driving robots is complete control via a system. Since the employees on the floor make decisions themselves in the current work method, it has been concluded that Customer XX is not yet ready for the implementation of self-driving robots.
2. The two outlined red squares in Figure 9 show a particularity in the internal process. The first is called ‘customer WMS integration’, which is caused by Customer A's In&Out not being connected to the WMS of the customer where the pallet originated from. The labels attached to the pallets cannot always be read during scanning, so new labels must be added. Printing and pasting two new barcodes on each pallet are time-consuming activities for the employees. This step can be skipped if there is a connection between the customer's WMS and In&Out.
3. The second particularity in the internal process can be found in the second red square ‘storage strategy’. When scanning the incoming pallet, it is shown where similar products are stored. However, it is not shown whether the stock locations are full, or which empty stock location is strategic to choose. The employee must now check all locations for total occupancy. If the information about the occupancy rate of all stock locations was integrated with the system, an employee immediately know where the pallets should be stored. This eliminates the control process of the occupancy rate of all stock locations, which is also a time-consuming activity.
4. In the internal process, there are three possible moments when a new stock location must be chosen by an employee. This happens when the current stock locations of a certain pallet are filled, the employee chooses to skip replenishing the stock locations, or when it concerns a new product that needs to be put into storage. Choosing this new location happens randomly and often depends on the location where the employee is currently located. If an employee transports a pallet on a forklift while checking the occupancy of the stock locations with similar products, he may need to check a stock location in the back of the rear hall. If the location is fully occupied, and more pallets of the same product need to be stored, he can choose any empty location. If he would choose an empty location near the loading fields, the pallet of the same product will be stored scattered across the warehouse.

The approach to map the standard process of Customer A is also performed at Customer B. There are several differences between the two processes. In the process of Customer B, Customer XX employees must load and unload the trucks themselves. So, the internal process has a different start and endpoint. Additionally, the WMS of Customer B requires different input moments (scanning a barcode). It soon became clear that Customer B has no information about the internal transport of the pallets because the WMS system does not request input during transport. Moreover, the WMS is managed by Customer B self instead of being managed by Customer XX. As a result, there is only information about the arrival of the products and which products must be picked for a shipment and not about the storage location of the products. It is possible that this information can be seen in the WMS of the customer, but not in the part of the WMS that is integrated within Customer XX. Customer XX would like to gain more insights into the internal process of Customer B. To realize this, the process of Customer B will be integrated with In&Out. This is an ongoing project which is being carried out by a collaboration between Bricklog and Customer XX employees. In this process, the internal process of Customer B is set up in the same way as that of Customer A. Since the process of Customer B is made equivalent to the process of Customer A, it has been decided to focus on Customer A in this case study. After the integration of In&Out for the process of Customer B, the results of this case study will apply to Customer B. In theory, the results of the case study should apply to a process that is set up the same. In practice, there are always differences, which means that modifications must be applied. The two main differences between the processes of Customer A and B, even when both are integrated with In&Out, are the quality of the pallets and the use of halls 5 and 6. The products of Customer A are often oversized compared to the pallet size. Customer B's pallets, on the other hand, are always packed accurately within the dimensions of the pallet. This makes these pallets more stackable, and always storable on the racks. These differences should be considered when the insights gained in this case study are also to be examined for Customer B’s process.

2.1.3 Data of the internal processes

The scans in the process create data that ends up in In&Out. For each scan moment, it is explained which data ends up in the WMS. Since January 2021, the process, as it is now depicted, has been implemented at Customer XX. The corresponding data is therefore from January onwards.

Within Customer A’s process, there are five scan moments, which collect data about: the product number, pallet number, location in the warehouse, timestamp of the scan, customer of origin, etc. Scan moment one is the beginning of the internal process of a pallet when it is placed on the loading field. Scan moment two occurs when the pallet is stored in a stock location. Within In&Out these two scan moments are combined and have the same timestamp. As a result, there is no insight into the duration of the internal transport from the loading field to the stock location. The same occurs with scans three and four, where the pallet is transported from a stock location to the loading field. All scans are labelled as 'movement' in In&Out, this also applies to scan moment five. Scan moment five is a check for confirmation that all pallets for the shipment are collected. The pallets remain at the loading field, so there is no physical movement of the pallet. When all pallets for a shipment are collected and scanned, the location of the loading field changes to a dock number. This change of location takes place in the WMS, but the pallets are physically stationary. The scan was initiated in the process to confirm that the pallets left the warehouse physically and should be performed when a pallet is loaded into the truck. The scan for confirmation changed to a check scan but is still labelled as ‘movement’ in In&Out.

2.2 Methods

Bricklog has a central data server where, in addition to other customers, Customer XX's data from their WMS is shared. This only applies to the data of Customer A. This data was loaded, processed, and analysed using Power BI and MySQL (Microsoft, 2021).

With the standard process and the associated data mapped out, it is time to clean the data. From In&Out there are two important tables retrieved in the central server. The data resulting from the scan moments can be found in the 'Mutation table'. The Mutation table contains information about the history of the internal transport for each pallet. This means that each pallet contains a unique code so that it can be followed in its path through all scans. The second table (Stock table) contains all information about the current stock quantities in the warehouse. The latter is a static table that is refreshed once a day. The mutation table is a dynamic table that is updated with every scan. Only the Mutation table required cleaning of the data. The following steps have been performed in Microsoft Power BI and MySQL to the Mutation table to clean the data:

- Unnecessary columns have been filtered out. These are empty columns, columns with the same value, or columns that have no added value.
- Data lines with missing location data have been filtered out. The information about locations is crucial in tracking internal transport.
- During the implementation in January, all pallets have been scanned in and out of the system several times. These scan actions are labelled as inbound and outbound; However, the pallets have not been moved. It has therefore been concluded that the data can be used from February 2021 onwards.
- Scan moment five in the standard process has been filtered out of the data. The pallets are physically stationary even though the data resulting from scan 5 is labelled as 'movement'.
- Every mutation of a pallet is linked to two scans, which results in two data lines in the Mutation table. The information of each mutation has been brought back to one data line where the start and end locations are combined.
- Data from other customers besides Customer A that could be found in In&Out has been filtered out.
- Several corrections, data lines labelled as 'corrections', were made to the data in In&Out throughout the year. The number of corrections to the total data was less than 0.1%. These corrections have been filtered out.

The data has been cleaned and is divided between the Mutation table and the current Stock table. Both tables are used for the insights created in the report. It is important to consider the difference in the type of the table. The dynamic table and static table can both be used in the report but must be used interchangeably. In addition to these two tables, help and reference tables have been added that were drawn up in previous projects carried out at Customer XX. This concerns the location tables, in which all stock locations with associated halls are listed. A date table, in which all format options for dates, including holidays, are listed. The data from the Stock table is stored with each update in a 'stock_history' table, which is also added. This table makes it possible, since the implementation of this system, to view the stock level of the warehouse for each day. The other tables in the report affect the classification of the products and the interactive heatmap that can be found in the report. The next section provides more information about the heatmap. To combine the data in the tables, relationships must be established between the tables, creating a data model. These relationships depend on primary and foreign keys, for example, the location name in the location table (Franklin, 2018). The unique keys allow one-to-one and one-to-many relations to be established between the tables. This makes it possible to combine the data from the different tables. The data model created in the report can be found in Figure 10.

Figure 10, Power BI report – Data model

2.2.1 The heatmap

An interactive heatmap is created in the report. This heatmap is a visualization of the part of the warehouse that is used by Customer A. The heatmap has the effect that the data insights are displayed recognizably and simply for the employees within Customer XX. If changes to the operational process are made based on this report, it is easier to substantiate what the effect of the changes is for the employees.

Each stock location of the warehouse is visualised and can be connected to the data in the other tables. This gives the possibility to visualize, for example, mutations from a certain location or the stock level per day. All mutations from one of the loading fields during the second half of 2021 are shown in Figure 11. The stock level of January 26th, 2022, can be found in Figure 12. The legend in the figures is in Dutch because both figures come directly from the report.

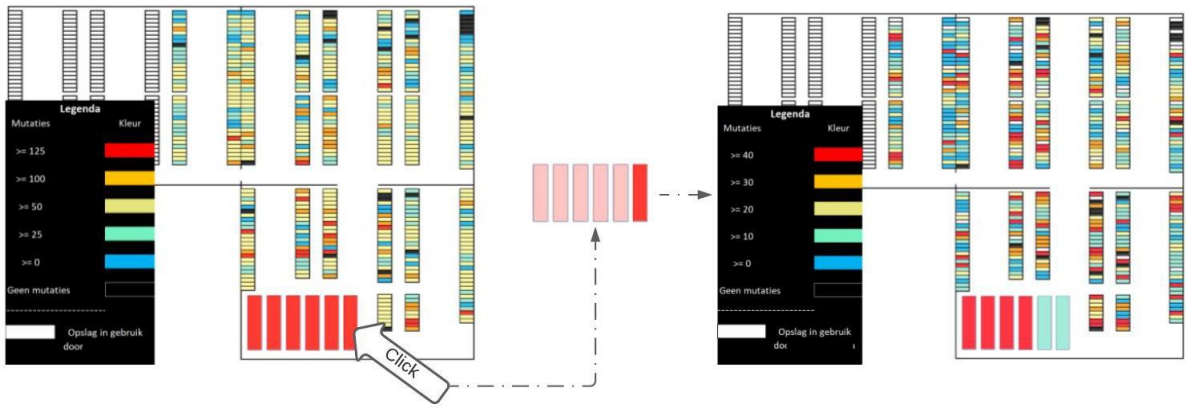

Figure 11, Power BI report – interactive heatmap explained

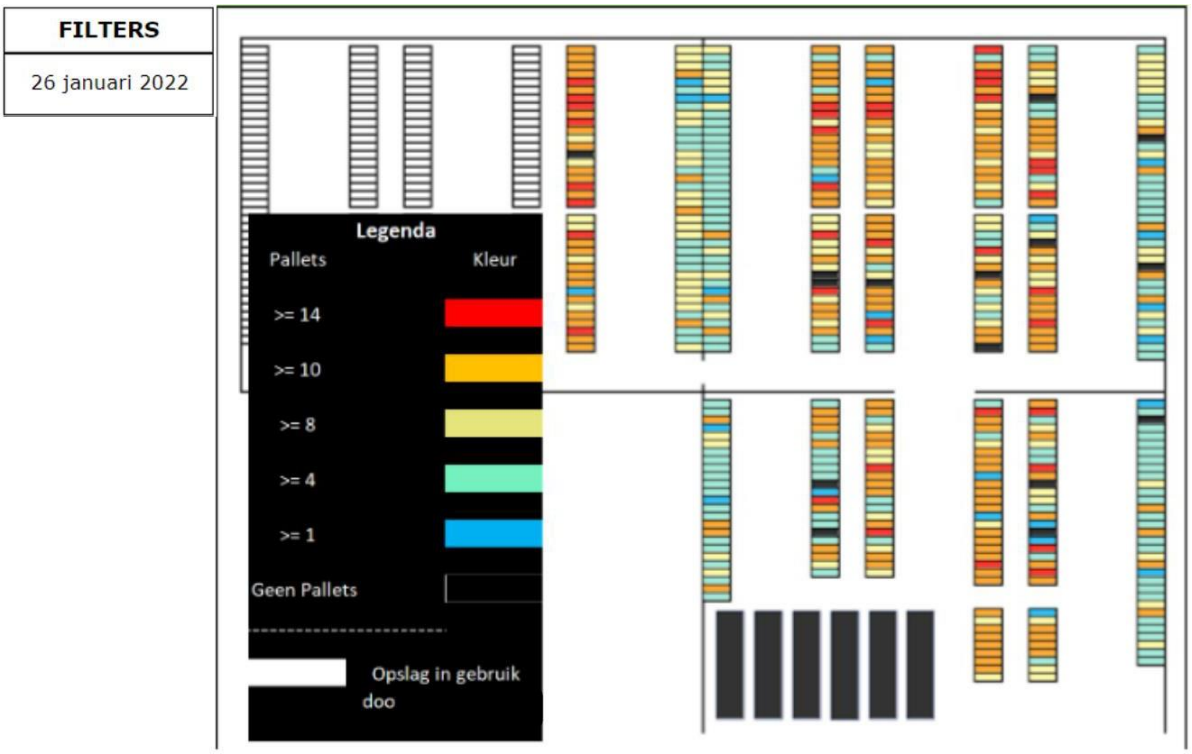

Figure 12, Power BI report – Warehouse occupancy Jan 26th, 2022

2.2.2 The data report

The report consists of five pages from which various insights can be obtained. This report is accessible to the employees of Customer XX using the 'Portal' (Bricklog's online environment for its customers). The report is automatically refreshed at midnight, so it is up to date with the latest data. During one of the earlier projects that Bricklog carried out in collaboration with Customer XX, a static warehouse report was created. This report contains information about the total occupancy rate of the warehouse, where a distinction is made between the different pallet types. Since this information is already known within Customer XX, it has not been included in this report. The design of all pages can be found in Appendix B. For each page, a brief explanation is given of the information obtainable:

'Voorraad Info' - The first page is based on the data from the Stock history table and Stock table. From February 2021 it can be visualized per day how all pallets were stored in the warehouse. The empty locations, number of articles, number of pallets, the number of locations per article, and the number of articles per location can be seen per day. Moreover, it is possible to find the stock locations based on the article number. The locations in the heatmap can be selected so the tables on the page display the associated information for that location. The last filter on the page is based on the classification of the articles. Employees of Customer XX are in the process of creating a full lead time classification for all products. A draft version of this classification has been added to the report. Based on this classification filter, all stock locations with articles of, for example, the classification 'A' can be displayed. See Figure 13 for the distribution of these articles.

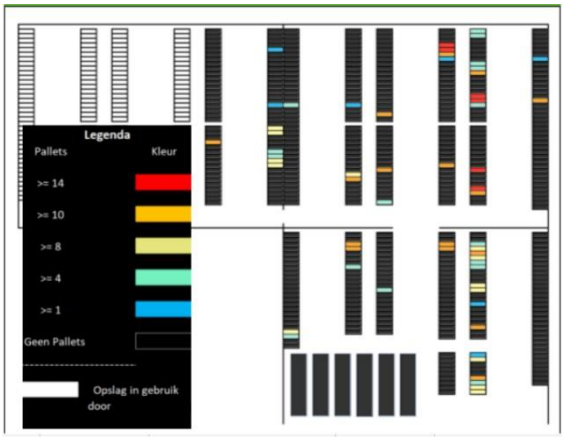

Figure 13, Power BI report – Distribution of articles with the classification 'A'

'Mutatie Geschiedenis' - This page is dedicated to all mutations that have taken place in the warehouse. The page has several filters that can be used: a date, product, and location filter. The total number of transactions, based on the selected filters, is displayed on a card. In addition, there are two tables, one showing the number of locations without any mutations and the other showing all the mutations. At the bottom of the page are two interactive heatmaps of the warehouse. When a location on the left heatmap is selected, the location is considered the start location of a mutation of a pallet (Figure 11). The right heatmap then shows all the end locations of these mutations. De table with all mutations also responds to the selected locations in the heatmap, so that only the corresponding mutations are displayed.

'Flow Per Pallet' - The third page can be used to visualize the flow of a pallet. Through a pallet ID filter, every pallet that has been in the warehouse can be selected. The locations where the pallet was stored have been visualized in the heatmap and the flow of the pallet is displayed by locations and halls (Figure 14). The number of mutations, the number of visits per location, and the order of the mutations are shown for the selected pallet.

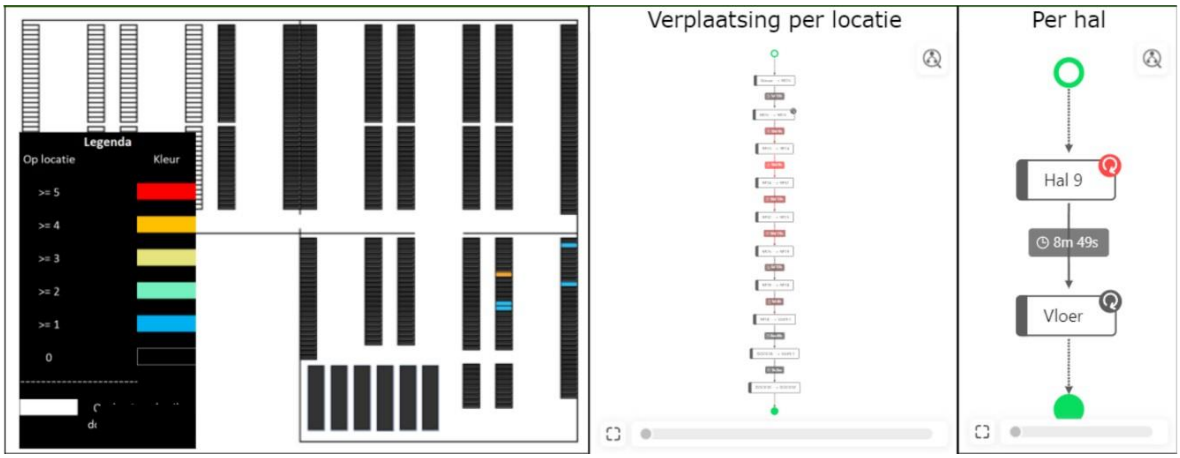

Figure 14, Power BI report – Flow of a pallet

'Verplaatsingen en Classificatie' - The penultimate page contains information about the distribution of the number of mutations of the pallets. From this, it can be concluded that most pallets have two mutations, once to the stock location and once back to the loading field. However, there are also pallets with more than 15 mutations. When selecting the number of mutations, all associated pallet IDs are displayed. These pallet IDs could be used in the filter of the previous page for more detailed information. Additionally, there is an overview of all articles with the draft of the classification. This table shows the classification of each article and which articles are not classified yet.

'Overige Info' - The last page offers space for new insights that can be added to the report. For now, it is shown how the number of mutations is divided over the halls and the total number of pallets in the warehouse since February 2021. The latter comes from the static warehouse report created in an earlier project.

2.3 Results

Based on the insights obtained in the report, different statements can be made about the operational process for Customer A. The statements are described in no order. The statements described can be seen as possible improvements to the operational process. In the next chapter, the theoretical basis is laid, which is then linked to the findings in this case study.

- It can be confirmed that choosing a new location for storing pallets happens randomly. When the article filter on page one is used to select one article, the heatmap shows that the pallets of the article are scattered across the warehouse.
- The first page shows that multiple stock locations contain pallets of multiple articles, while there are still locations empty.
- Looking at the number of mutations within one corridor, it is noticeable that this occurs frequently. From this, it can be concluded that pallets are often moved because they are placed in front of a pallet of another article. This is shown when a stock location is selected in the heatmap on the second page.
- Pallets of one article are spread over several stock locations, while not all locations in use for this article are full. The table with the number of locations per article is shown on the first page.
- Stock locations in hall 9 are filled with leftover pallets of multiple items. While hall 9 contains the stock locations closest to the loading fields. This is also shown on the first page.
- The classification of all articles is a project that has recently started within Customer XX. The current layout shows that the articles of all classifications are scattered around the warehouse. It can be seen on the first page that hall 9 contains a lot of articles with the classification ‘C’. In addition, there are several articles in storage that have not yet been classified.
- Selecting the data from quarters 3 and 4 of 2021 on the second page shows that locations in hall 9 have no mutations. This means that these locations have been empty or full for six months.
- The middle corridor in halls 9 and 10 are used more often than the side corridors in hall 9. The distance between the side corridor of hall 9 to the loading fields is smaller than the middle corridor at the back of hall 10 to the loading fields. This is shown on the interactive heatmap on the second page.
- When a pallet has more than two mutations, they are not paid for by the customer. They only pay for two mutations, putting pallets in storage, and retrieving them from storage. The table with the number of mutations for every pallet is shown on the fourth page.
- Page five shows that of all mutations in 2022 more pallets are moved from the loading fields to hall 10 than to hall 9.

All results in the report have been discussed with the contact person within Customer XX. The report was also validated in collaboration, which is discussed in the next section.

2.4 Validation of the report

Communication with a Customer XX employee was established during the design and validation of the data used in the report. Among others, the draft version of the classification was added to the report because of this collaboration. For the validation of the data, it was checked whether the current layout of the warehouse was equivalent to the layout according to the report. Through this validation, articles were discovered that were stored in the warehouse but were not registered in the system. These articles were found by checking locations that were supposed to be empty according to the report. This location turned out to contain articles that, according to the employees, had been there for a long time. These articles were added to the system and ended up in the report after the midnight update. Since these articles were not registered in the WMS, the customer did not pay for the storage costs. In addition, it was noted that there are more differences between the warehouse and the report as the day progresses. This is a result of the daily update at midnight. The more mutations that occur in the warehouse after midnight, the more differences there are. If Customer XX wants to manage the employees based on the data in the report, a shorter time interval for the updates should be set up. Furthermore, the statements from the previous section were discussed with the employee when the report was made available. At this point, the results from the report have been discussed without giving a guideline to improve the operational process.

2.5 Summary

Due to the lack of guidance in Customer XX's current work method, it was concluded that the company was not ready for the implementation of self-driving robots. To gain knowledge about the current state of Customer XX, research has been done into the current working method in the warehouse. The results in this chapter were found through exploratory research in which the first iteration of the DSRM was executed.

Customer XX's warehouse consists of ten halls that are mainly used for two customers. Each customer has integrated a different WMS, resulting in differences in available information per customer. From all processes around the warehouse of Customer XX in Location XX, the research focused on the operational processes of Customer A. The standard process has been mapped and linked with the available data. The data has been cleaned and processed in a Power BI report that runs in the online environment of Bricklog. The layout of the warehouse has been incorporated in this report so that the data is easily and recognisably described. All insights that can be obtained from the report were discussed with an employee at Customer XX. The report is accessible by the management of Customer XX. The data has been validated by comparing the data in the report with the pallets in the warehouse. The result of this case study will be supported by literature to provide advice on growth opportunities in the next two chapters.

3 Theoretical Framework

Section 3.1 addresses the design of the systematic literature review, Section 0 describes the planning of the review, Section 0 describes how the review is conducted, Section 0 reports the review, and Section 3.5 is the summary of the systematic literature review. The SLR is part of the second iteration of the DSRM.

3.1 Design

The Systematic Literature Review (SLR) was prepared based on Kitchenham and Charters (2007). This article is a guideline that divides the SLR into planning, executing, and reporting on the review. Figure 15 shows the tasks that the three steps consist of. The guideline is based on experience from experts in a variety of disciplines, multiple textbooks, and articles covering the topic of systematic reviews and experiences within two universities in England. In Keele (2007), the SLR is described as: "A systematic literature review (often referred to as a systematic review) is a means of identifying, evaluating and interpreting all available research relevant to a particular research question, or topic area, or phenomenon of interest."

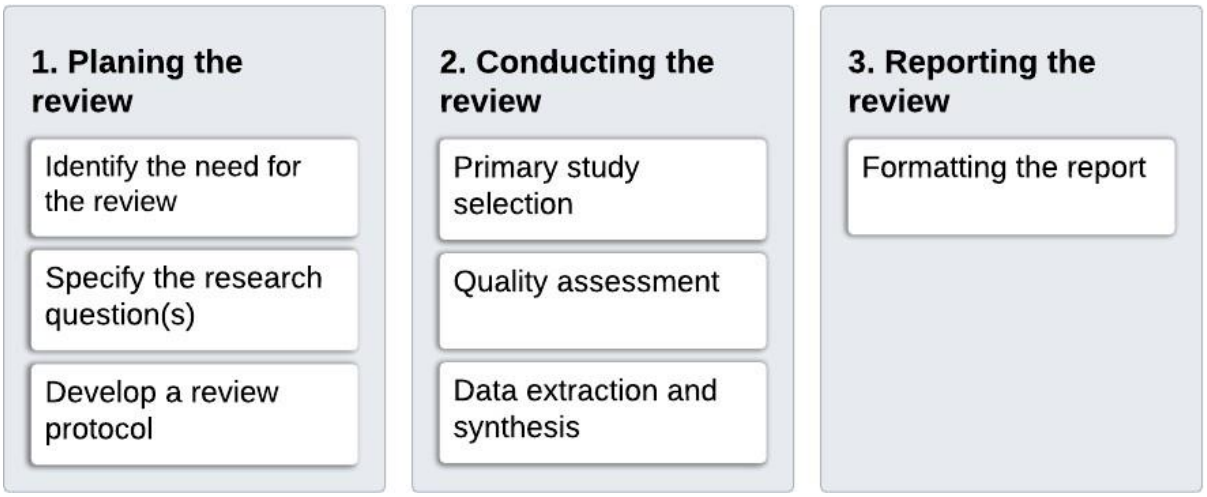

Figure 15, SLR – Guideline

3.2 Planning

The SLR is conducted to substantiate and process the findings from the case study with theoretical knowledge. Additionally, the applicability of the research is increased by drawing more general conclusions based on the theoretical framework as opposed to conclusions from the case study. Finally, the SLR ensures that the research is of theoretical value by providing insight into the contribution of the research to the literature.

The SLR is used to combine the research initiative and the results of the case study. The results from the case study are various optimization possibilities within Customer XX's operational processes. The SLR should provide insight into which process optimization within the case study provides the best growth opportunity. For this purpose, a specific search is made for maturity models. A maturity model is: “A business tool that facilitates change or improvement by providing a framework based on certain performance parameters designed to assess the current capabilities of an organization as well as provide a path for improvement” (Cruz-Cunha, 2013). “In the context of Industry 4.0, maturity models are especially important, as they contribute to the dissemination of the concept and provide companies with a broader understanding and implementation proposals to deal with this revolution” (Amaral, Jorge, & Peças, 2019). To make the combination between the results of the case study and the initiative of the research, the SLR is guided by the following research question:

RQ 2. What are available maturity models that focus on intralogistics of SMEs transport?

A protocol has been drawn up to guarantee the quality of the literature review. The digital library Scopus is used to find relevant papers. In addition, Google Scholar and FindUT are used to gain access to the literature, when the papers are not publicly accessible in Scopus. Four keywords were selected from the research question which forms the start of the search string used in the digital library. For each keyword, the synonyms, related words, and abbreviations have been drafted. The addition of the synonyms and abbreviations of all keywords ensures that no important papers are skipped by using alternative words. During the search, the operator “AND” is used between the keywords and the operator “OR” between the synonyms. The keywords, abbreviations, and synonyms can be found in Table 1.

The keywords in Table 1 originate from a research question that has been reformulated. The original research question was: What are available maturity models that support the integration of robots in operational processes of SMEs transport? In addition to the time limit, the result of the SLR answers both research questions, therefore the SLR has not been completely redone.

Table 2 shows the number of papers found in Scopus through the combination of the different keywords. The first keyword is used within all search strings because it is the most important keyword within the SLR. Research question one showed that SMEs lag in the implementation of Industry 4.0 related processes. This not only results in less practical examples but also less available literature. For this reason, it was decided to remove keyword two from the search string, resulting in 74 papers. These 74 papers form the basis of the literature research.

Table 1, SLR – Keywords, synonyms, and abbreviations

ID	Keyword	Synonyms and abbreviations
1	Maturity model	"Maturity model*" OR "Readiness Model*" OR “Maturity”
2	SMEs	"SMEs" OR "Small and mid-size enterprises" OR "Small and mid-size businesses" OR "Small and mid-size companies" OR "Small and medium-sized enterprises" OR "Small and medium-sized businesses" OR "Small and medium-sized companies" OR "SME"
3	Transport and logistics sector	"Transport and logistics sector" OR "Transport sector" OR "Logistics sector" OR "Transport and Logistics industry" OR "Haulage industry" OR “Logistics” OR “Transport” OR “Warehouse”
4	Robotization in the field of internal transport	"Robotization" OR "Internal transport" OR "Internal movement" OR "Robotics" OR "AGV" OR "Automated guided vehicles" OR "AMR" OR "Autonomous mobile robots" OR "automation" OR “Industry 4.0”

Table 2, SLR – Criteria combinations

Criteria combination	Number of papers
1 & 2 & 3 & 4	7
1 & 3 & 4	74
1 & 2 & 4	91
1 & 2 & 3	27
1 & 2	697
1 & 3	3780
1 & 4	1550

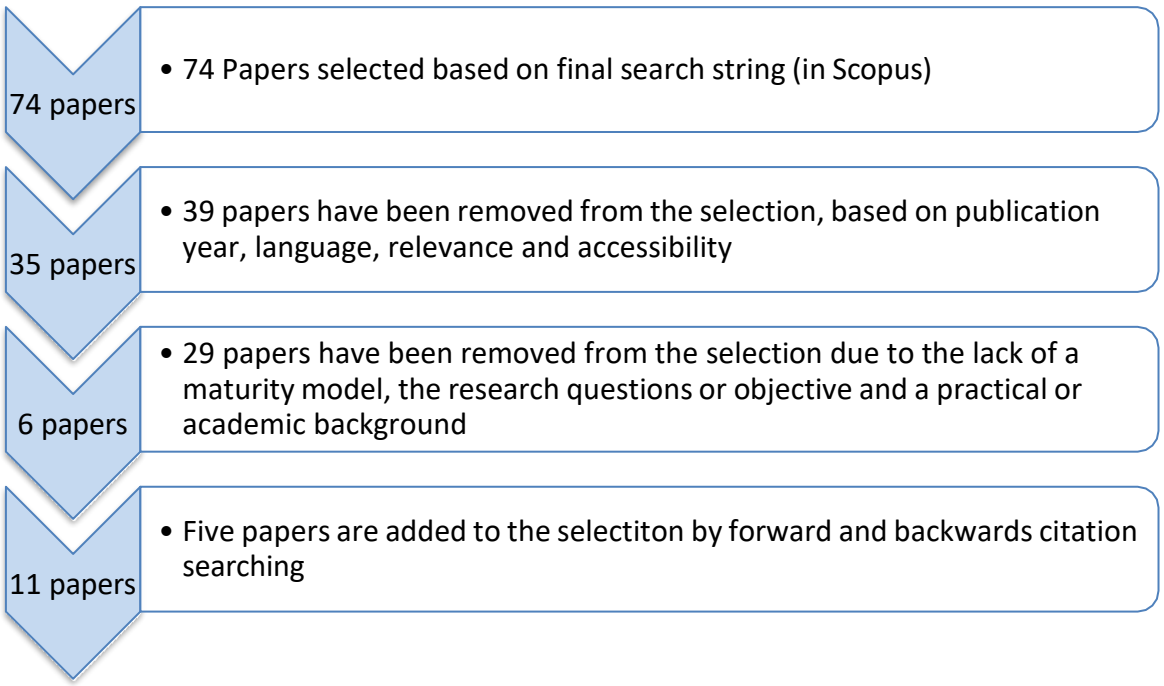

Figure 16, SLR - An overview of the selection procedure

3.3 Conducting the review

The papers are selected based on the three criteria in Table 3. The language of the papers should be English or Dutch. Moreover, only papers that were published after 2000 are selected. Finally, the papers must be freely accessible within the chosen digital libraries. The selection of papers is narrowed down to 35 papers by these criteria.

Table 3, SLR – phase one, including and excluding criteria

Inclusion Criteria	Exclusion Criteria
The paper is published in Dutch or English	Paper is published after the year 2000
	The full text of the paper is accessible

3.3.1 Quality assessment

The step-by-step plan of Wolfswinkel, Furtmueller, and Wilderom (2013) was applied to the selection of papers after the first phase of the criteria analysis, to select the final sample of papers. When multiple search engines are used, double-selected papers must be filtered out. Then, based on the title and abstract, papers are filtered out that do not meet the criteria in Table 4. The research question(s) or objective(s) should be clearly stated, and the research should address a maturity model. The papers are excluded from the research when they are not practical or academically substantiated. After filtering out papers, backward and forward-searching is applied to identify all relevant papers in literature. In University of Wisconsin (2022), backward and forward citation searching is compared to an ongoing conversation. Literature develops based on the literature available at the time of writing. The papers refer to articles that have been used as a source. Search engines such as SCOPUS make it possible to see in which papers a paper has been used or which references a paper has. Based on the titles of these references, four papers were added to the selection. The papers selected by forward and backwards searching must go through all steps of the SLR. Figure 16 shows all steps taken in the selection procedure. Table 5 contains the eleven papers, which form the final sample. For each paper it is stated if the paper states its research questions or objective, the number of models used, and what the background information is based on.

Table 4, SLR – phase two, including and excluding criteria

Inclusion Criteria	Exclusion Criteria
The paper supports answering the research questions so it should address a maturity model	The research is not practical or academically substantiated
The research question(s) or objective(s) are clearly stated	

3.3.1 Data extraction and synthesis

Several aspects are important for the data extraction of the papers. The research question is answered by selecting an appropriate model from the literature so that it can be applied to the case study. The model must be available in the literature, this applies to the dimensions, levels, indicators, weights, questionnaires, etc. that are used. Since several papers from the final sample are reviews of existing maturity models, all mentioned maturity models in the papers are stated in Appendix X. For each model, the number of dimensions and levels are stated where possible. The times that the papers name the same model is stated as well. In total 39 models have been mentioned in the final papers.

Table 5, SLR - Final papers

Reference	RQ/Objective	Maturity model	Background
(Amaral et al., 2019)	Objectives	9 models	Literature review
(Angreani, Vijaya, & Wicaksono, 2020)	RQ and objectives	17 models	SLR
(Chaopaisarn & Woschank, 2021)	Objectives	5 models	Literature review
(Da Silva, Barbalho, Adam, Heine, & Schmitt, 2019)	Objective	11 models	Bibliometric study
(A. De Carolis, M. Macchi, E. Negri, & S. Terzi, 2017)	RQ and objectives	1 model	Literature review and Questionnaire
(Facchini et al., 2020)	Objective	Not mentioned	Literature review
(Krowas & Riedel, 2019)	Objective	7 models	Literature review
(S. Mittal, Khan, Romero, & Wuest, 2018)	RQ and objectives	15 models	SLR
(J. Oleśków-Szłapka & Stachowiak, 2019)	Objective	5 models	Literature review and field experience
(Zoubek & Simon, 2020)	Objective	20+ models	Literature review
(Zoubek & Simon, 2021)	Objective	36 models	Literature review and field experience

3.4 Report

The content of the eleven papers differs from the development of a maturity model, a review of maturity models, the design of a methodology for developing a maturity model, and a maturity model assessment. The information from these papers is divided into sections: history of maturity models, maturity models in general, maturity models for SMEs, and the final model selection. The research question is answered in the summary.

3.4.1 History of maturity models

In 2013, the literature already stated that "ignoring changes in a globalized world often results in losing opportunities or failing to respond to threats" (Facchini et al., 2020). Maturity models are used to facilitate these changes, as stated in the description of a maturity model. The foundation for these models was already laid in 1986. "In the Capability Maturity Model (CMM), a methodology created in 1986 to improve organizational processes and capabilities in managing the development, acquisition, and maintenance of software products and services, the maturity concept is classified as the necessary path to achieve the improvement of organizational processes, within a set of areas, called levels of maturity" (Da Silva et al., 2019). In 2006 this CMM has expanded: "the Software Engineering Institute expanded the CMM concept to add hardware integration giving form to CMMI as a guideline for process integration and product improvement. The original proposal of CMMI encompasses four bodies of knowledge: systems engineering, software engineering, integrated product and process development, and supplier sourcing"(Da Silva et al., 2019). "The CMMI is a process based on behavioural models that support the organizations to streamline process improvement and encourage efficient behaviours to decrease risks in product and service development"(Facchini et al., 2020).

The 39 models consist of different dimensions and levels. The names of these dimensions and levels differ per model. The number of dimensions varies from 3 to 10 and often includes the departments that the model focuses on within the company. In addition, there are several levels, which are often five. "There is a close relation between these steps and the ones presented in the capability maturity models (CMM), presented more than twenty-five years ago. CMM has 5 different levels: Initial, Repeatable, Defined, Managed, and Optimized. So, these levels thus seem to be the basis for most Industry 4.0 models presented in the table below" (Amaral et al., 2019).

In the literature a maturity model is referred to in different terms, however, there is a contradiction in the use of synonyms. "In the Industry 4.0 context, several terms are used to express the model, such as readiness assessment model, roadmap, framework, and maturity index" (Angreani et al., 2020). Chaopaisarn and Woschank (2021) and S. Mittal et al. (2018) both have different descriptions for the terms described by Angreani et al. (2020) as synonyms. Industry 4.0 originated in Germany in 2011. Figure 17 shows the number of publications from the year 2000 to 2018 on the topic of maturity models. According to Anderl et al. (2015) Germany has the largest share, showing that maturity models and industry 4.0 are closely connected.

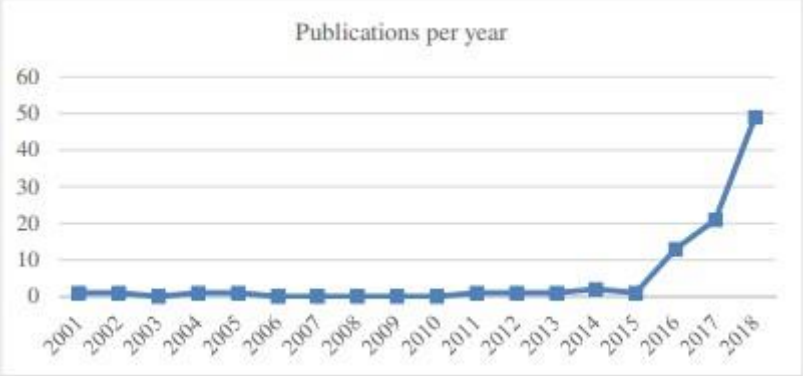

Figure 17, "Number of publications per year containing the terms" (Da Silva et al., 2019).

3.4.2 Maturity models in general

The reason for using maturity models has been described in many ways in the literature, according to Angreani et al. (2020) it can be used as strategic guidance for the implementation of industry 4.0 related technologies and Amaral et al. (2019) mention the use of the models to measure the competitiveness of the company. “Three application-specific purposes can be identified in literature:

1. Descriptive purpose: maturity models with this purpose, want to assess the as-is situation of the organization/process;
2. Prescriptive purpose: a prescriptive model focuses on the domain relationships to performance and indicates how to approach maturity improvement in order to positively affect business value;
3. Comparative purpose: a comparative model enables benchmarking across companies; in particular, a model of this nature would be able to compare similar practices across organizations in order to benchmark maturity within different industries” (A. De Carolis et al., 2017).

The different applications of the models appear to be disappointing from the analysis of A. De Carolis et al. (2017). Ultimately, all models serve the purpose of mapping the current state and lack guidance for improvement. Not only do maturity models have different purposes, but they also have different backgrounds. A “literature Review, Conceptual Modelling, Qualitative Method, Quantitative Method, Workshop, Case Studies, Analytic Network Processing, Factory Design and Improvement” are used as a basis for developing the models (Anderl et al., 2015).

The different dimensions and levels used in a maturity model have been developed to make the model understandable. These elements have not been developed to focus only on one department of a company, moreover, it is recommended to only focus on the results of a maturity model when it is fully executed. The maturity level is not a dimension of the model, but the outcome of a maturity model (Da Silva et al., 2019). The highest attainable level in a maturity model is not a suitable end goal for all companies. However, there is no information available in literature about the requirements for a company to pursue this end goal.

In addition, Figure 18 shows the most common dimensions used in the models. “The evidence indicates that all of those MMs can be implemented in manufacturing and logistics. Even though every dimension has a specific focus in readiness assessment, the ultimate goal of the improvement steps of them leads to successful implementations of Industry 4.0 in the form of smart manufacture and logistics. This condition affirms that manufacturing and logistics are the core of Industry 4.0” (Angreani et al., 2020). One reason that logistics fall under the core of Industry 4.0 is also due to the available data. “In logistics a huge amount of data should already be available that just need to be exploited” (Krowas & Riedel, 2019).

From the eleven papers, sixteen maturity models have been named and analysed several times. The three most common models are:

1. IMPULS model - (Lichblau et al., 2015)
2. Maturity model for assessing I4.0 - (Schumacher, Erol, & Sihn, 2016)
3. DREAMY model - (Anna De Carolis, Marco Macchi, Elisa Negri, & Sergio Terzi, 2017)

The content and application of the models are summarized in detail in the bibliometric study by Da Silva et al. (2019).

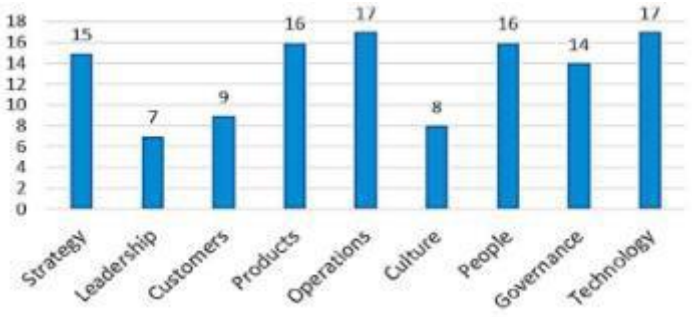

Figure 18, "Trends of dimensions from selected studies" Angreani et al. (2020)

3.4.3 Maturity models for SMEs

SMEs are indicated based on some limits on turnover, employees, and type of business. However, regardless of which area in the world, it concerns more than 90% of the total number of companies in that area. According to Chaopaisarn and Woschank (2021), there is big diversity between all these companies. Amaral et al. (2019) confirm this statement and see a separation between the companies with and without knowledge of Industry 4.0. For companies that do not know themselves, it may be important to engage a collaboration with a company specialized in Industry 4.0. Many maturity models are based on certain basic knowledge so that the lowest level already has a significant entry threshold. According to Chaopaisarn and Woschank (2021) and Da Silva et al. (2019), this threshold is often too high for SMEs, which are still in their infancy regarding Industry 4.0. As with the developments within Industry 4.0, maturity models are first focused on corporations before they are implemented at SMEs. Over the years, models have been created that have an extra beginner's level, so that even companies without knowledge gain insight into the status quo. Amaral et al. (2019) has drawn up a protocol for the development of a maturity model, which is also applicable to SMEs. This protocol consists of five steps and can largely be found in the development of all models in the literature:

1. Research – apply one of the mentioned methods to create a good foundation for the model.
2. Defining – focus specifically on the issues that affect many companies, it is important to compare the same types of companies.
3. Model – choose or develop a model, including a detailed initial step for SMEs.
4. Questionnaire – analysis of maturity based on the model, by an expert.
5. Implementation – a case study for validation of the model and show where the model is of scientific relevance.

3.4.4 Models focusing on Logistics 4.0

It has already been shown that maturity models have developed from application from corporations to SMEs. The next development in maturity models is the change in the focus area, such as a focus from Industry 4.0 to Logistics 4.0. “In the literature authors have found numerous examples of maturity models for business processes, as well as Industry 4.0, nevertheless, there is a gap in the field of Logistics 4.0” (J. Oleśków-Szłapka & Stachowiak, 2019). The term Logistics 4.0 is a branch of Industry 4.0 and was created by the application of Industry 4.0 to intralogistics/internal logistics. “Consistently with existing scientific definitions, Logistics 4.0 represents the logistical system that enables the sustainable satisfaction of individualized customer demands without increasing costs“ (Facchini et al., 2020). “The vision of Logistics 4.0 is a process that seeks to eliminate the human factor and to the greatest extent possible automate the process“ (Zoubek & Simon, 2020). “Logistics 4.0 changes the existing solutions already adopted in traditional logistics, and introduces new enabling technologies, such as the cyber-physical systems (CPSs), which allow us to realize the networking and automation of storage system transportation, and decentralized software control. In other cases, the support of the Internet of Things (IoT) technology allows linking physical objects to enable real-time data visualization in order to automate the logistics flows under either an uncertain or a given demand, and when considering different kind of materials. Again, the implementation of big data in logistics and supply chain operations contributes to improving the visibility, flexibility, and integration of global supply chains and logistics processes, effectively managing demand volatility, and handling cost fluctuations” (Facchini et al., 2020).

As with the synonyms for a maturity model, there is also a contradiction about the synonyms of Logistics 4.0. The paper by J. Oleśków-Szłapka and Stachowiak (2019) focuses on the differences between Logistics 4.0 and smart logistics and calls the application of smart logistics a temporary solution where Logistics 4.0 provides continuous improvements towards digitization and automation. However, Zoubek and Simon (2020) label the terms synonymous.

3.4.5 Final model selection

The focus of the case study is intralogistics at Customer XX. “The future challenges of internal logistics are primarily driven by growing individualization in all areas of the company and increasing customer requirements for logistics services. This creates the need for flexible and adaptable internal logistics systems as well a transparent and continuous exchange of information“ (Zoubek & Simon, 2020). ”Supply chain processes (inbound and outbound logistics) have to adapt to this changing environment, since due to the increasing complexity, it cannot be handled with ordinary planning and control practices” (J. Oleśków-Szłapka & Stachowiak, 2019). The maturity models that focus on Logistics 4.0 support this change in intralogistics. Zoubek, Koubovská, and Šimon (2021) analysed the five models in Table 6 that specify Logistics 4.0.

Table 6, Logistics 4.0 maturity models reviewed by Zoubek et al. (2021).

Model name	Authors	Dimensions
The Framework of Logistics 4.0 Maturity Model	(J. Oleśków-Szłapka & Stachowiak, 2019)	3 – Management. The flow of material (automation and robotization in warehouse and transportation, IoT, 3D printing, 3D scanning, AR). The flow of information (Data-driven services, Big data, RFID).
Intelligent Logistics For Intelligent Production Systems	(M. Krajcovic, P. Grznar, M. Fusko, & R. J. C.-S. l. o. t. U. o. Z. Skokan, 2018)	7 – Shopping logistics. Factory logistics. Warehouses logistics. Distribution logistics. Identification. Supply chain logistics. Logistics way.
Maturity Levels For Logistics 4.0 Based On Nrw's I4.0 MM	(Gajšek, Sternad, & Lerher, 2018)	4 – Purchase logistics. Internal logistics. Distribution logistics. After-sales logistics.
Logistics 4.0 Maturity in Service Industry: Empirical Research Results	(K. Werner-Lewandowska & M. Kosacka-Olejnik, 2019)	General dimension Logistics 4.0
A Maturity Model for Logistics 4.0: An Empirical Analysis and a Roadmap for Future Research	(Facchini et al., 2020)	7 – Knowledge. Strategy and Leadership. Employees. IT Systems. Smart Products. Smart Warehouses. Technologies.

“After reviewing and analysing the readiness models, it can be stated that none of the models comprehensively evaluate a company's readiness within the concept of Industry 4.0 in the field of internal logistics and do not focus specifically on the area. They do not evaluate the overall area of internal logistics, nor its partial activities or even the concept of logistics activities within the company in detail” (Zoubek et al., 2021). As a result of this analysis, they are developing a new model, which has not yet been published. In the analysis of Zoubek et al. (2021) the model of Krowas and Riedel (2019) that focuses on intralogistics within SMEs is missing. The model uses an additional beginner level for the SMEs. The model of Krowas and Riedel (2019) fits well with the question of this research, but the entire model is not available in the literature. This also applies to the model of J. Oleśków-Szłapka and Stachowiak (2019) however the developments from this paper have been further developed in the paper by Facchini et al. (2020). The latter contains a full maturity model focusing on intralogistics, which is substantiated by a literature review, is the most recent model in the analysis of Zoubek et al. (2021), and is one of the selected eleven papers of this SLR. Even though the model does not have an additional beginner's level for SMEs, this model best fits the topic of this research. The application of the model is explained in the next chapter.

3.5 Summary

The second research question is answered by the SLR, which is part of the second iteration of the DSRM.

RQ 1. What are available maturity models that focus on intralogistics of SMEs transport?

In the literature, 39 different maturity models have been found that are discussed in the eleven papers in the SLR. Due to the development of the maturity models, a separation has arisen between models that focus on Industry 4.0 in general and models that focus on a specific area of Industry 4.0. It has been concluded that the models that focus on Logistics 4.0 are more in line with the topic of this research. Six different models have been found for Logistics 4.0, one of which also focuses on SMEs. Due to the limited availability, year of publication, substantiation for developing the model, and the similarities between the model and the problem of this research, it was decided to apply the model of Facchini et al. (2020).

4 Development of the artefact

Section 4.1 explains the maturity model, Section 0 analysis the results of the maturity model, Section 0 describes the development process of the artefact, and Section 4.4 summarizes the chapter. The second step of the second iteration of the DSRM is finalized in this chapter.

4.1 Explaining the maturity model

The maturity model of Facchini et al. (2020) has five levels, three dimensions, seven sub-dimensions that are divided into sixteen items, weights per item, and a questionnaire of 66 questions to map the maturity of a company. The model results in a maturity level for each sub-dimension.

Table 7 shows the three dimensions identified by the authors. These dimensions arose from an analysis of maturity models in literature and the definition of 'logistics'. For each dimension, it is explained which subjects are evaluated by this dimension.

Table 7, "Logistics 4.0 dimensions and areas of evaluation" (Facchini et al., 2020)

Logistics 4.0 Dimensions	Areas of Evaluation
Management	Investments, innovations management, integration of value chains
Flow of material	Degree of automation and robotization in warehouse and transportation, Internet of things, 3D printing, 3D scanning, advanced materials, augmented reality, smart products
Flow of information	Data-driven services, Big data (data capturing and usage), RFID, RTLS (real-time locating systems), IT systems (ERP, WMS, cloud systems).

The levels that are applied in this maturity model arise from the proposed levels of J. Oleśków-Szłapka and Stachowiak (2019). Like the CMMI, the maturity model consists of five levels. Figure 19 provides an overview of each level and explains the status of the company for each dimension in each level. "The first level (i.e., "ignoring") describes a total lack of competencies, knowledge, and adoption of the elements generally adopted by Industry 4.0 and Logistics 4.0, on the contrary, the fifth level (i.e., "integrated") indicates a full integration and complete digitization of the analysed company" (Facchini et al., 2020).

The authors of this maturity model have identified sub-dimensions for each of the three dimensions. These sub-dimensions comprise several items under which the questions of the questionnaire are divided. "On the basis of existing research in the intersection between Logistics 4.0 and Industry 4.0, we assumed that not all items/questions have the same impact in order to evaluate the "maturity" of a company in terms of Logistics 4.0" (Facchini et al., 2020). Table 8 lists all dimensions, sub-dimensions, items, and weights.

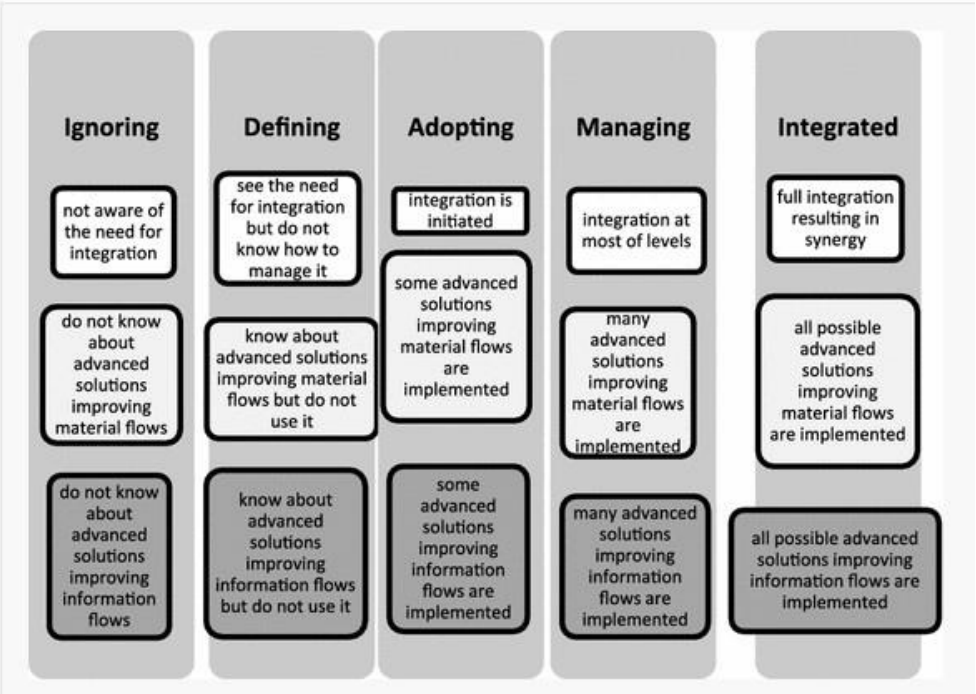

Figure 19, "A maturity model for Logistics 4.0" (J. Oleśków-Szłapka & Stachowiak, 2019)

Table 8, "Macro-dimensions, sub-dimensions, and items/questions of the maturity model" (Facchini et al., 2020)

Dimensions	Sub-dimensions	Items/Questions	Weights
Management	Knowledge	Adoption perception	3
		Development dynamics	3,3
		Competitive position	3,2
	Strategy and Leadership (S&L)	Impacts	3,8
		Obstacles	3,5
Flow of material and information	Employees	Skills	3,4
	IT Systems	Adoption	3,9
	Smart Products	Devices	3,7
	Smart Warehouses	Storage facilities	3,9
		Warehouse equipment	3,8
		Impacts	3,8
		Obstacles	3,5
	Technologies	Knowledge	3,3
		Technology relevance	3,8
		Adopting Position	3,9
		Investments	4

A total of 66 multiple-choice questions were formulated that are answered based on the Likert scale. The "Likert scale was devised to measure 'attitude' in a scientifically accepted and validated manner in 1932. An attitude can be defined as preferential ways of behaving/reacting in a specific circumstance rooted in relatively enduring organization of belief and ideas (around an object, a subject or a concept) acquired through social interactions" (Joshi, Kale, Chandel, Pal, & technology, 2015). Each question has four possible answers, as shown in Table 9. Each answer has a certain score, which is used in the calculation of the result.

Table 9, Likert-scale used in the maturity model

Score / Likert-scale subjects	**1**	**2**	**3**	**4**
Performance	Far below average	Below average	Above average	Far above average
Usability	Not helpful at all	Not very helpful	Very helpful	Extremely helpful
Hindering	Very inhibiting	Enough inhibiting	Very inhibiting	Not inhibiting
Agree	Completely disagree	Disagree	Agree	Completely agree
Presence	Not present	Partly present	Almost fully present	Fully present
Frequency	Never	Almost never	Often	Always
Recognizability	Not known	Somewhat known	Very familiar	Extremely familiar
Probability	Definitely not	Probably not	Probably	Definitely

For each sub-dimension, the weighted average is calculated with the answers to the questionnaire and the weights per sub-dimension. The weighted averages are shown in a radar chart for a clear overview. For each sub-dimension it can then be determined what the maturity level of the company is:

1. Ignoring - a company gets this level when the score in this sub-dimension is equal to one.
2. Defining - a company gets this level when the score in this sub-dimension is greater than one and less than two.
3. Adopting - a company gets this level when the score in this sub-dimension is greater than two and less than three.
4. Managing - a company gets this level when the score in this sub-dimension is greater than three and less than four.
5. Integrated - a company gets this level when the score in this sub-dimension is equal to 4.

4.2 Analysing the results of the maturity model

The maturity model has been tested at Customer XX. The maturity model is used to gain insight into the perception of Customer XX employees about the current state of Customer XX concerning the developments of Logistics 4.0 and the perception in the eyes of a consultant of Bricklog. All questions have been translated into Dutch and processed in Microsoft forms. Three employees of Customer XX completed the questionnaire. These employees did not receive any explanation about the content of Industry 4.0 and Logistics 4.0. The answers of these employees give a clear picture of how they experience the company development and whether there is awareness about Logistics 4.0. In addition, the questionnaire was completed by people who are familiar with Customer XX and who are familiar with Logistics 4.0, from now on called a consultant. The averages of the answers of the consultant and the employees of Customer XX have been calculated and visualized in a radar chart. Figure 20 shows the results of the Management dimension and Figure 21 shows the results of the Flow of material and information dimension. An overview of all dimensions is shown in Figure 22. The left side of all three figures are the results of the employees of Customer XX, and the right side is the results of the consultants.

In the Management dimension, both groups' results are approximately the same on strategy and leadership, giving Customer XX the maturity level 'Adopting'. From this result, it can be concluded that all persons are reasonably aware of the benefits of implementing Logistics 4.0 and know where the barriers lie within the company to apply Logistics 4.0. Within this dimension, however, large differences can be seen in the score of the sub-dimensions Knowledge and Employees. The sub- dimension Employees' score is calculated based on one question. As a result, differences will arise more quickly compared to other dimensions. According to the consultants, there is a lack of initiatives to train and inform employees about the developments of Logistics 4.0. As a result, there is a lack of knowledge among the employees of the company, and the company lags compared to competitors. The score of the employees of Customer XX results in the level 'Adopting' on both sub-dimensions. The consultant's scores result in the maturity level 'Ignoring' on the sub-dimensional Employees and the maturity level 'Defining' on the sub-dimensional Knowledge. These results conclude that there is a difference between the perception of the consultants and the perception of the employees.

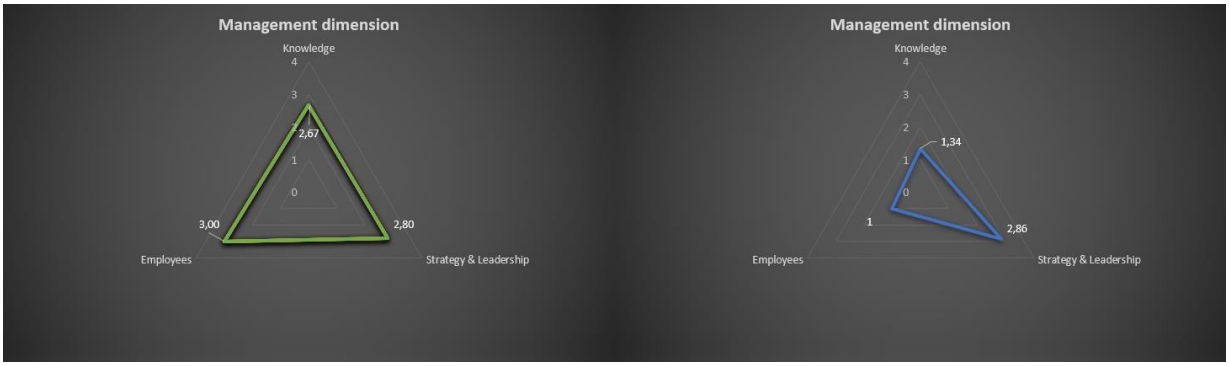

Figure 20, Results sub-dimensions of management

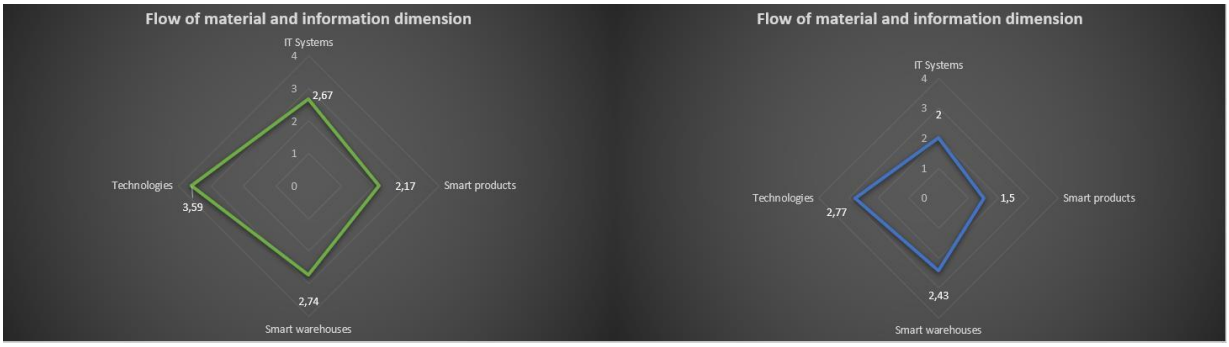

Figure 21, Results sub-dimensions of the flow of material and information

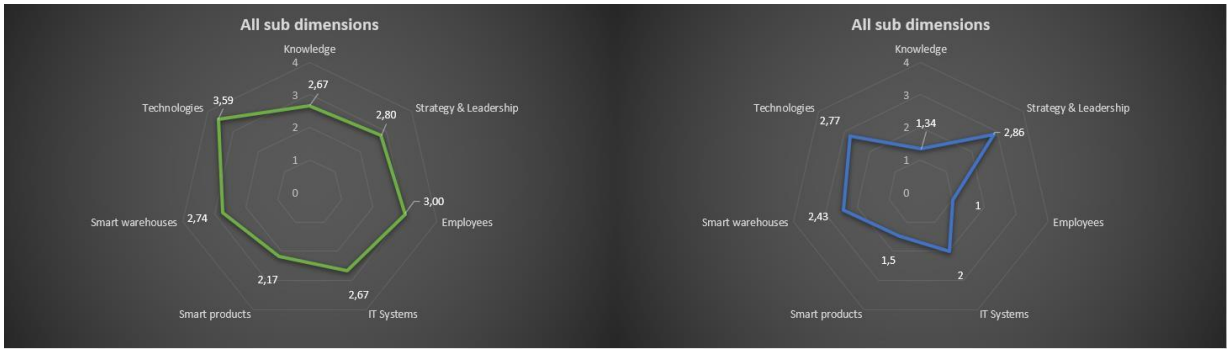

Figure 22, Results for all sub-dimensions

In the Flow of material and information dimension, the scores of the employees are higher than those of the consultants for each sub-dimension. The largest differences can be found in the Technologies, IT Systems, and Smart products sub-dimension. To analyse the differences, the questions of the corresponding sub-dimensions were examined. The consultants, who are familiar with the developments of Logistics 4.0 give a lower score when there is partial integration of, for example, an IT System or Smart product. The knowledge of Logistics 4.0 appears to play a major role in the perception of the developments within the company. Table 10 shows the maturity levels of all sub-dimensions for Customer XX's employees and the consultants.

Table 10, Maturity level per sub-dimension

Sub-dimensions	Customer XX employees	Consultants
Knowledge	Adopting	Defining
Strategy and Leadership	Adopting	Adopting
Employees	Adopting	Ignoring
IT Systems	Adopting	Adopting
Smart products	Defining	Defining
Smart Warehouses	Adopting	Adopting
Technologies	Managing	Adopting

Based on the results of the consultants, it must be examined in which sub-dimensions the most improvement can be made. In Industry 4.0 all processes are linked together. Achieving the highest maturity level within one sub-dimension should not be the company's goal. The company will have to focus on the lowest scoring sub-dimension and thus improve the average maturity of the company. From the results of Customer XX, the focus should be on the Employees and Knowledge sub-dimension.

4.3 Developing the artefact

In this section, the results of the maturity model are combined with the results of the case study. First, both tools are briefly explained. The artefact of this research is a method that is created by combining the process to develop the 'data report' of the case study and the maturity model. This method is being created for Bricklog so that they can use this for future customers. The combination of both tools answers the third research question:

RQ 3. How should we design a method that can be applied within SMES transport that provides insight into the current state of maturity and supports growth in maturity, focused on intralogistics?

4.3.1 Recap of the developed tools

The questionnaire of the maturity model provides insights into the maturity of the company in seven sub-dimensions. By having the questionnaire completed by a consultant and an employee of the customer, an analysis can be made about the differences in the results. The analysis shows the difference in perception about the developments regarding Logistics 4.0 at the company. These differences can have multiple causes, for example, a difference in knowledge about Logistics 4.0 or the company. In the next chapter, several scenarios are described in which the differences in the results are assessed. Differences in the results say something about the willingness to change and the importance of change management.

The data report provides objective information about the working method within a warehouse. This report demonstrates where various processes can be improved. The objective analysis of the processes has been made recognizable to all employees by incorporating the floor plan of the warehouse in the report. This data visualization makes the data less overwhelming and easier to understand.

4.3.2 Combining the tools

The artefact is developed for Bricklog. The developed method shown in Figure 23, titled: “A method that can be applied within SMEs in the transport and logistics sector that provides insight into the current state of maturity and supports growth in maturity, focused on Logistics 4.0.”, consists of three phases. These three phases are divided into three sections: the perception of maturity, the process, and the input and output. The first section provides information about the knowledge of the maturity of the company of the customer, the second section shows the process of all phases, and the third section shows the input and output of the process for all phases. The method can be applied to all customer journeys that have a demand for the development of their internal logistics.

In phase 1, the maturity of the customer is unknown. A Bricklog consultant will visit the customer to become familiar with the operational processes at the customer. Subsequently, the questionnaire of the maturity model, consisting of 66 questions, is completed by the consultant (see the QR code in Figure 23). In addition, the customer is asked to complete this questionnaire. The result of this phase is the answers to the consultant's and customer's questionnaires.

Phase 2 starts with converting the answers to the questionnaire with the scorecard of the maturity model. This provides insight into the maturity of the customer's business across seven different dimensions. The results are displayed on radar charts. The results of the customer and the consultant are then analysed. Various scenarios can arise from the analysis. These scenarios are shown under 'perception of maturity' with the red, orange, and green arrows.

1. A red arrow represents the scenario where the customer's results indicate a higher maturity level than the consultant's results. This occurs when the customer is convinced that the company is performing better and has more knowledge about the possibilities of Logistics 4.0 than the consultant states. Change management is of great importance in this scenario because the customer must be convinced of the consultant's opinion before changes can be implemented.
2. An orange arrow indicates that the consultant and customer scores are equal. Change management will be of less importance because the customer is aware of the current state of the company and the possibilities within Logistics 4.0
3. A green arrow is a scenario that occurs when the customer maturity level is lower than the consultant states. In this scenario, the customer is willing to change making change management even less important.

The result of this phase is the radar charts and the information about the intensity of change management on the different dimensions of the maturity model.

Phase 3 is the development of the data report in Power BI. The standard processes are mapped, the data entry moments are identified, a connection is made with the data, the data is cleaned, the data model is created, the warehouse floor plan is processed and the data report is built. Finally, instruct the customer on how the data report can be used to improve the operational processes.

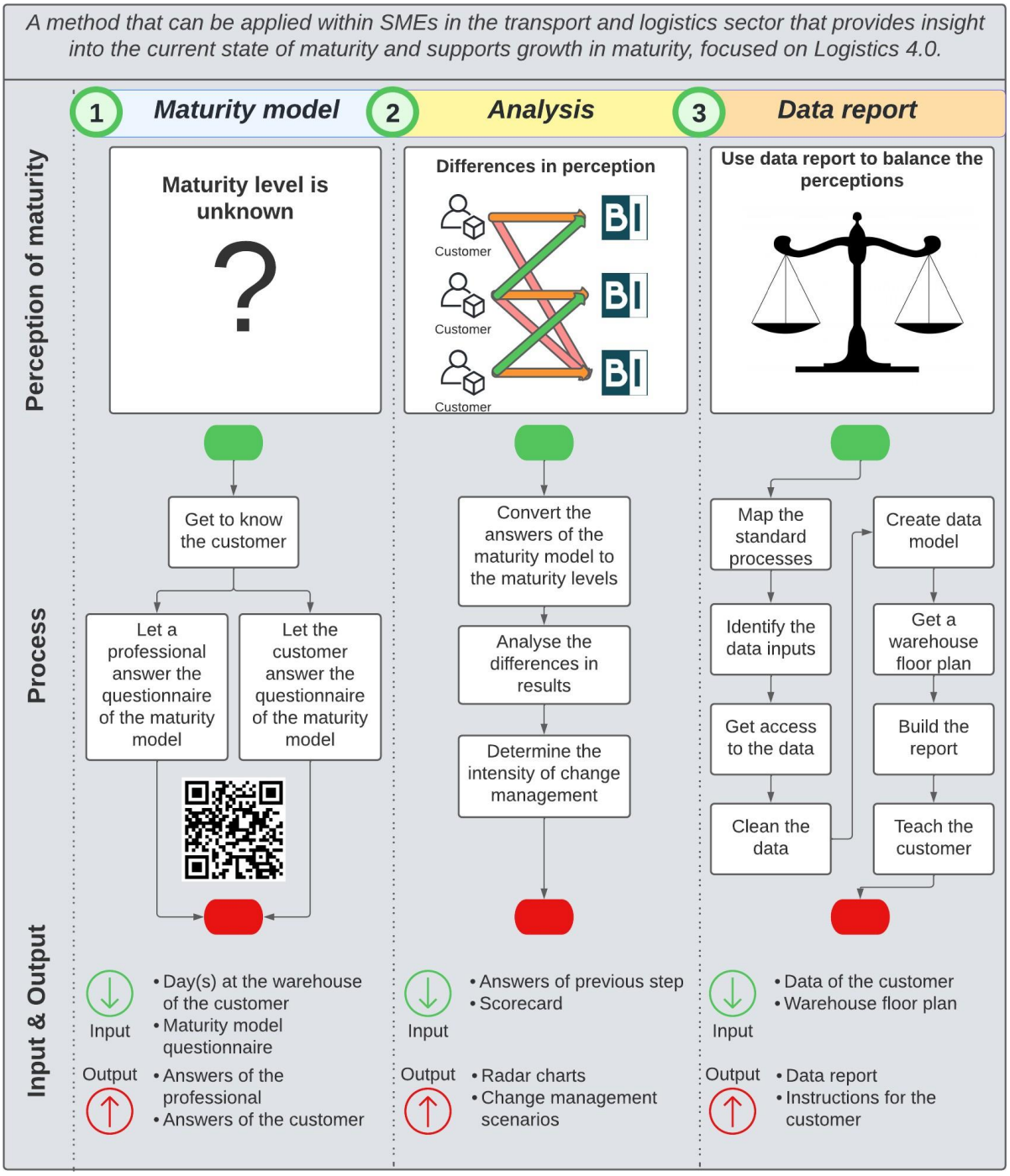

Figure 23, An overview of the developed method

4.4 Summary

The literature review has shown that the maturity model of Facchini et al. (2020) fits well with the topic of this research. The maturity level is determined based on the 66 questions for seven different sub-dimensions. The maturity model shows the difference in the perception of employees and consultants about the developments regarding Logistics 4.0 at a company. The data report provides objective information about the working method within a warehouse. The steps taken in this chapter are part of the second iteration of the DSRM. The combination of both tools answers research question three:

RQ 3. How should we design a method that can be applied within SMES transport that provides insight into the current state of maturity and supports growth in maturity, focused on Logistics 4.0?

The method combines the information from both tools and consists of three phases. For Bricklog, the combination of both tools is an important method that they can apply to all customer journeys related to digitization/automation of intralogistics. Bricklog is advised to let a consultant fill in the questionnaire of the maturity model for every new customer and to have this done by the customers' employees as well. This provides insights into the readiness for change and awareness of the current state of the company from the point of view of the employees and the consultants. The more differences are apparent from the analysis of both results, the more important change management becomes in the customer journey. After analysing the maturity model, it is advised to use the data report to substantiate the results of the consultant and to guide the customer in improving their processes.

5 Validation

Section 5.1 addresses the validation process, Section 0 addresses the validation results, and Section 0 summarizes this chapter. The third step of the second iteration of the DSRM is performed in this chapter.

5.1 Validation Process

One of the options for validating an artefact is through expert opinions. “The design of an artefact is submitted to a panel of experts, who imagine how such an artefact will interact with problem contexts imagined by them and then predict what effects they think this would have” (Wieringa, 2014). The observations of the experts form the validation. “Validation by expert opinion only works if the experts understand the artefact, imagine realistic problem contexts, and make reliable predictions about the effects of the artefact in context” (Salah & Cairns, 2014).

Validation using an expert panel is common in the validation of maturity models. Salah and Cairns (2014) have developed a model, combining open and closed questions, to validate a maturity model by an expert panel. The questions cover the criteria: sufficiency, accuracy, relevance, comprehensiveness, mutual exclusion, understandability, ease of use, and usefulness. These criteria were used during the validation of the developed method.

The method consists of three phases, and each phase has three sections. These sections are related to each other. Table 11 shows the interview questions used for the validation. For the phases and the sections, three multiple-choice questions each have been drawn up with answer options based on the Likert scale. In addition, two questions were formulated about the method in general. After these eight multiple-choice questions, five open questions were formulated.

Table 11, Questionnaire for the expert panel

Questions	**Answers**				
General information					
Date?					
Name?					
How long have you been working in the logistics sector?					
Likert-scale	Strongly disagree	Disagree	Neutral	Agree	Strongly Agree
Are all phases clearly defined?					
Do the phases comply with the process that takes place within a customer journey?					
Are all phases independent of each other?					
The sections are clearly defined?					
Do the sections cover all the information needed within this phase of the customer journey?					
The interrelationship between the sections is clear?					
Is the model clear and easy to understand?					
The model is useful within a customer journey?					
Are there any changes you would apply to the different phases in the model?					
Are there any changes you would make to the different sections in the model?					
Are there any changes you would make to the model in general?					
What is the strongest point of the model?					
What is the weakest point of the model?					

The expert panel consists of six employees who are active within Bricklog. The experts have been working in the logistics sector for between 4 and 25 years. They have received the information from section 0, including the model in Figure 23. They were then asked to imagine a customer journey where the model is applied. To limit the bias, the researcher did not provide additional information during the interviews.

5.2 Validation Results

The results of all interviews are divided between open and multiple-choice questions. For a complete overview of all the interviewees' answers to the multiple-choice questions, see Appendix D.

The average scores of the multiple-choice questions are higher than four on a scale of 1 to 5. It can be concluded from this that a model has been designed that can be used generically and that meets the requirements of Bricklog, but there is room for improvement. The highest score was obtained on the questions about the clarity of the phases, the usefulness of the model in a customer journey, and ease of use of the model. The completeness of the model has achieved the least perfect scores in the interviews. This is further explained in the next paragraph. Furthermore, the multiple-choice questions show that the clarity of the sections could improve.

Several points for improvement emerged from the open questions. According to the literature, negative opinions are most important for the improvement of an artefact. The last question in the validation highlights these weaknesses. In the interviews, the lack of a step between the transition from phase two to three was mentioned three times as the weakest point in the model. Once the differences in perception have been identified in phase two, time must be invested in levelling the customer's perception and Bricklog's according to the interviewees. With the insights into the differences in the perceptions about the customer's company, the question for Bricklog is whether or not they want to continue the customer’s journey. In addition, it is important to include the customer in the process that Bricklog believes is necessary to help the customer move forward. To achieve this, a choice has to be made in which marketing strategy should be applied. The more often this process step is applied in the customer journeys, it will become clear whether a standard strategy emerges when a certain difference in perception is established. Figure 24 shows the model where this last step has been added.

From the answers to the open questions, it appears that a second improvement is possible in the first sections. The first section in the first and third phases is only information about the state of the maturity insights for the customer and Bricklog. However, the first section in the second phase contains a lot of information about the differences that can arise in the customer and Bricklog perceptions. This information can even be decisive for Bricklog whether or not to continue with a customer. The structure of this section is therefore an interesting subject for future improvement.

The final negative opinion from the expert panel is the lack of information about the duration of each phase. The first phase takes less time than the third phase in which the data report is developed. However, this information is not reflected in the model. An indication of duration is also an interesting objective for future research.

In addition to the negative opinions, the positive opinions in the answers of the experts were also examined. This shows that all experts agree unanimously that the model is clear, logical, and easy to understand.

5.2.1 The sequence of the method

In the research, the data report was implemented at the customer by the exploratory research strategy before the knowledge of the maturity model was known. The current data report has been available to Customer XX since December 2021 At that time, the maturity model had not yet been discussed within Customer XX and no advice was given on which changes are most important. The possibilities for improvement have been discussed with a Customer XX employee and the report was accessible to all employees. In March 2022, all possible improvements from the case study are still visible in Customer XX's current processes. This concludes that no changes have been made, although it has been made clear where the company can improve.

The results of the maturity model show that the employees score a higher maturity level on average than the professionals for all sub-dimensions. The willingness to change is therefore low. This explains why no changes have been made to the current processes, even though there are processes to be improved. The results of the professionals show that Customer XX scores worst on the sub-dimensions Knowledge and Employees. In addition, these sub-dimensions also have the largest differences concerning the results of the employees. The knowledge and developments of the employees will have to be addressed first. Once this improves, the willingness to change will grow and process improvements can be implemented. This concludes that the insights of the maturity model are important for the effect that the data report will have on the company

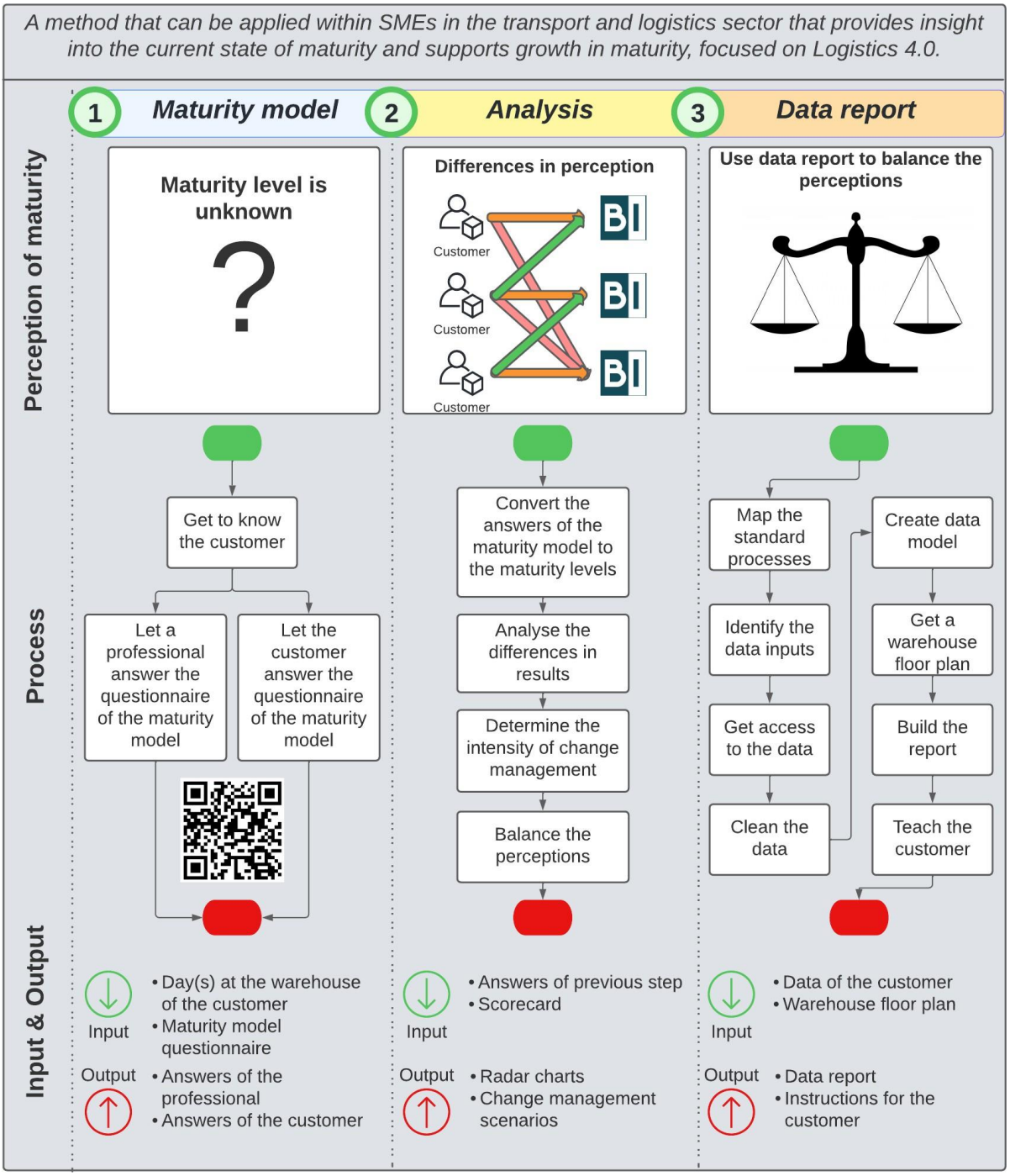

Figure 24, First improvement to the developed method

5.3 Summary

The developments of the data report have been validated within the warehouse. The maturity model from Facchini et al. (2020) has already been validated within several case studies. By combining both tools, the final model was developed. The validation of the model is part of the second iteration of the DSRM. The last research question has been answered by an expert panel to validate the model:

RQ 4. How can the developed method be used in practice?

According to the experts, the developed method meets the demand from Bricklog, which initiated the research. The method is generically applicable, clear, logical, and easy to understand. The main improvement in the model is an extra process step at the end of phase two. This step can be crucial for Bricklog to determine whether they want to continue the customer journey or if the differences in perceptions are too great to continue. In addition, in this process step, it can be determined which marketing strategy should be applied to convince the customer of the perception of the consultants. Figure 24 shows the final model in which the process step has been added at the end of phase two. In addition, the model can be further improved by an indication of the duration per phase and possible changes to section one. By applying the model to customer journeys, it will become apparent how the changes should be shaped.

6 Conclusion

Section 6.1 answers the research questions, Section 6.2 addresses the contribution to theory, Section 6.3 describes the contribution to practice, Section 0 states limitations, and future work, and Section 6.5 states the recommendations.

6.1 Answering the Research Questions

All research questions have been answered, below is a summary of each question.

RQ 1. What is the current state of SME Transport towards the developments of Industry 4.0 regarding intralogistics?

SMEs are familiar with the developments of Industry 4.0 but have no in-house knowledge to take advantage of these developments. Compared to corporations, SMEs lag since innovations are first implemented within corporations. The latest technologies, emerging from Industry 4.0, have made various innovations available to SMEs. So, SMEs are aware of the added value of digitization and automation possibilities but do not have the knowledge and/or methods to realize this themselves.

RQ 2. What are available maturity models that focus on intralogistics of SMEs transport?

In the SLR it was concluded that maturity models that focus on Logistics 4.0 are in line with the subject of this research. Six different models have been found for Logistics 4.0, one of which also focuses on SMEs. Due to the limited availability, year of publication, substantiation for developing the model, and the similarities between the model and the problem of this research, it was decided to apply the model of Facchini et al. (2020).

RQ 3. How should we design a method that can be applied within SMES transport that provides insight into the current state of maturity and supports growth in maturity, focused on Logistics 4.0?

The method combines the information of the maturity model with the data report and consists of three phases. For Bricklog, the combination of both tools is an important method that they can apply to all customer journeys related to digitization/automation of intralogistics. Bricklog is advised to let a consultant fill in the questionnaire of the maturity model for every new customer and to have this done by the customers' employees as well. This provides insights into the readiness for change and awareness of the current state of the company from the point of view of the employees and the consultants. The more differences are apparent from the analysis of both results, the more important change management becomes in the customer journey. After analysing the maturity model, it is advised to use the data report to substantiate the results of the consultant and to guide the customer in improving their processes. Figure 23 is an overview of the developed method.

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6.2 Contribution to Theory

The theoretical value of this research is divided into the developed method and establishing a new area of research.

The literature shows that the maturity models only serve the purpose of gaining insights into the status quo of companies. Guidance to improve maturity is lacking. In this research, the maturity model is applied in the first step of the developed method. The results of the maturity model are used to determine the intensity of change management within the customer journey and identify which sub-dimensional to focus on. Then, through a data report, the findings of the maturity model are applied and the processes within a company are improved. The developed method not only provides insight into the current state of the company but helps the company to work data-driven and to improve maturity concerning Logistics 4.0.

Through an SLR it has been established that there are no maturity models that focus on SMEs and Logistics 4.0. This gap could be an interesting topic for future research.

6.3 Contribution to Practice

The practical value of this research is divided into the contribution of the method in general and the development of the data report in specific.

The developed method can be applied to customers with issues related to intralogistics. Bricklog believes that advancements in technology within the company or other business processes are only successful with the human being as a central spot. Using the maturity model, the intensity of change management can be quickly determined for the customer journey. This information is of great importance as Bricklog focuses on SMEs. Subsequently, a data report can be developed that can be used to support the results of the consultants and let the customer work data-driven. An aspect of change management has also been incorporated in this data report, which makes the data more understandable and recognizable. The result of the method is an improvement in the willingness to change, to make a company work data-driven, and to increase the possibilities for applying technologies from Industry 4.0.

The integration of a floor plan in the data report is not innovative. However, the functions that the floor plan has in the developed data report are. The floor plan shows internal movements, current stock, and other insights. Until now, a floor plan was only used to indicate the intensity of use of a stock location in a warehouse. Due to this innovative design of the data report, Bricklog has a unique product with which they can enter the market. The data report can therefore also be used in a sales pitch to bring in new customers.

6.4 Limitations and Future Work

The limitations and future work are stated per subject.

6.4.1 The data report

A floor plan of the warehouse has been incorporated in the data report of the case study. Customer XX's warehouse has only one floor. If a new customer has a warehouse with several floors, another way must be found for processing a floor plan in the report. In addition, Customer XX only has bulk storage for pallets. When a customer uses racks, an alternative must also be devised for processing the floor plan in the report.

The artefact consists of two tools, one of which can be used generically, the maturity model. However, this is not the case for the data report. Bricklog is advised to analyse which aspects of the data model are generic. When the data model can be built up and consists only of generic elements, a report can be developed for each customer as soon as the data is accessible to Bricklog. A generic report requires fewer working hours, which is advantageous for Bricklog.

Within Bricklog they are working on making various reports generic, for which research is being done into 'data quality sheets' that are used to clean up and validate the data. It is advised to continue the research on data quality sheets for the data report of this research.

The information in the data report can be expanded by creating insights into how much time an employee spends moving a pallet. This can be done, for example, by drawing different zones in the floor plan and measuring the time it takes to move between the different zones. This information can then be used to calculate how much time can be gained when certain adjustments are made in the working method.

The data report is updated every 24 hours. This makes the data in the data report less accurate as the day progresses. When a company wants to direct its employees to the information in the data report, it is advised to update the report more frequently.

6.4.2 The SLR

In the SLR, articles are filtered by the criteria: the paper is published in Dutch or English. Since Industry 4.0 originated in Germany and they have the largest contribution to papers on maturity models, maturity models exist which are written in German and are more suitable for this research.

Based on research question two, keywords and associated synonyms have been drawn up that are used in the search string of the SLR. The terms 'intralogistics', 'internal logistics', and Logistics 4.0 were not used in the final search string. The SLR concluded that models that focus on Logistics 4.0 fit in well with the subject of this research. The lack of these terms may have resulted that relevant articles and models were not selected.

6.4.3 The maturity model

The SLR shows that maturity models are still under development. Additionally, the choice of suitable maturity models for this research is hampered by the availability of the entire model. As new maturity models are developed based on the existing maturity models, a new model may be developed that is more suitable for Logistics 4.0 within SMEs. It is therefore interesting for Bricklog to analyse the latest models in the future and possibly implement them.

The answers to the maturity model are currently manually processed and visualized in a radar chart. This process can be automated, for example in a Power BI report.

The chosen maturity model does not contain an additional beginner level, which according to the literature is important when the focus groups are SMEs. Researching a suitable beginner level can improve the maturity model.

The 66 questions in the questionnaire are not evenly distributed over all sub-dimensions. The maturity level of the Employee's sub-dimension is determined based on one question. It is important to take this into account when analysing the results.

6.4.4 The method

The method has been applied to a transit warehouse and has not been validated for warehouses with a different function. The literature shows that enough data is available in the logistics environment that only needs to be used. Regardless of the type of warehouse, it is, therefore, possible to gain insights into the processes in a warehouse based on the available data. In the future, it will be interesting to test this with customers with a different type of warehouse.

During the validation, several important points emerged where the model could be improved. Information about the duration of a phase, review moments, and the comprehensibility of the sections offer opportunities for improvement. These are interesting points for Bricklog that can be included in a follow-up study.

6.5 Recommendations

The recommendations for Bricklog are stated below.

6.5.1 Bricklog

Bricklog is advised to use the developed method to realize improvements in intralogistics for all new customers with related issues. Use the maturity model to see what the employees' perception of the company is and compare it with the analysis of a consultant. The bigger the gap between the two perceptions, the more important change management becomes in the customer journey. Then use the data report to substantiate the results of the consultants. Based on the results on the sub-dimensions, determine where the improvement can be achieved and tackle this sub-dimension first.

For the follow-up process at Customer XX, it is important to first make employees aware of the possibilities within Logistics 4.0. The results of the maturity model, completed by the consultants, show that the greatest gains can be made in the sub-dimensions Employees and Knowledge. Try to make the employees aware of the current state of the company and change their perception of the company towards Logistics 4.0. To make progress within Customer XX, willingness to change is a must. Only start managing improvement processes from the data report once the willingness to change has increased.

The final recommendation to Bricklog is, to keep improving the model. Let every customer journey be a learning moment and adjust the model where necessary. The experiences gained in each customer journey will contribute to the improvement of the method.

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Appendices

A. Detailed drawing of the halls of Customer XX

The warehouse in Location XX has been rearranged by a project executed by Bricklog. During this project, a detailed drawing of the warehouse layout was made for all halls except hall 2. Hall 2 is not considered due to the variable processes. Figure 25 shows the layout of hall 10, Figure 26 of hall 9, and Figure 27 of hall 5. Hall 10 is almost identical to the layout of halls 4 and 8. Hall 9 is representative of halls 1, 3 and 7. Finally, hall 5 is the same as hall 6, except that there are no docking stations for the trucks in front of hall 6.

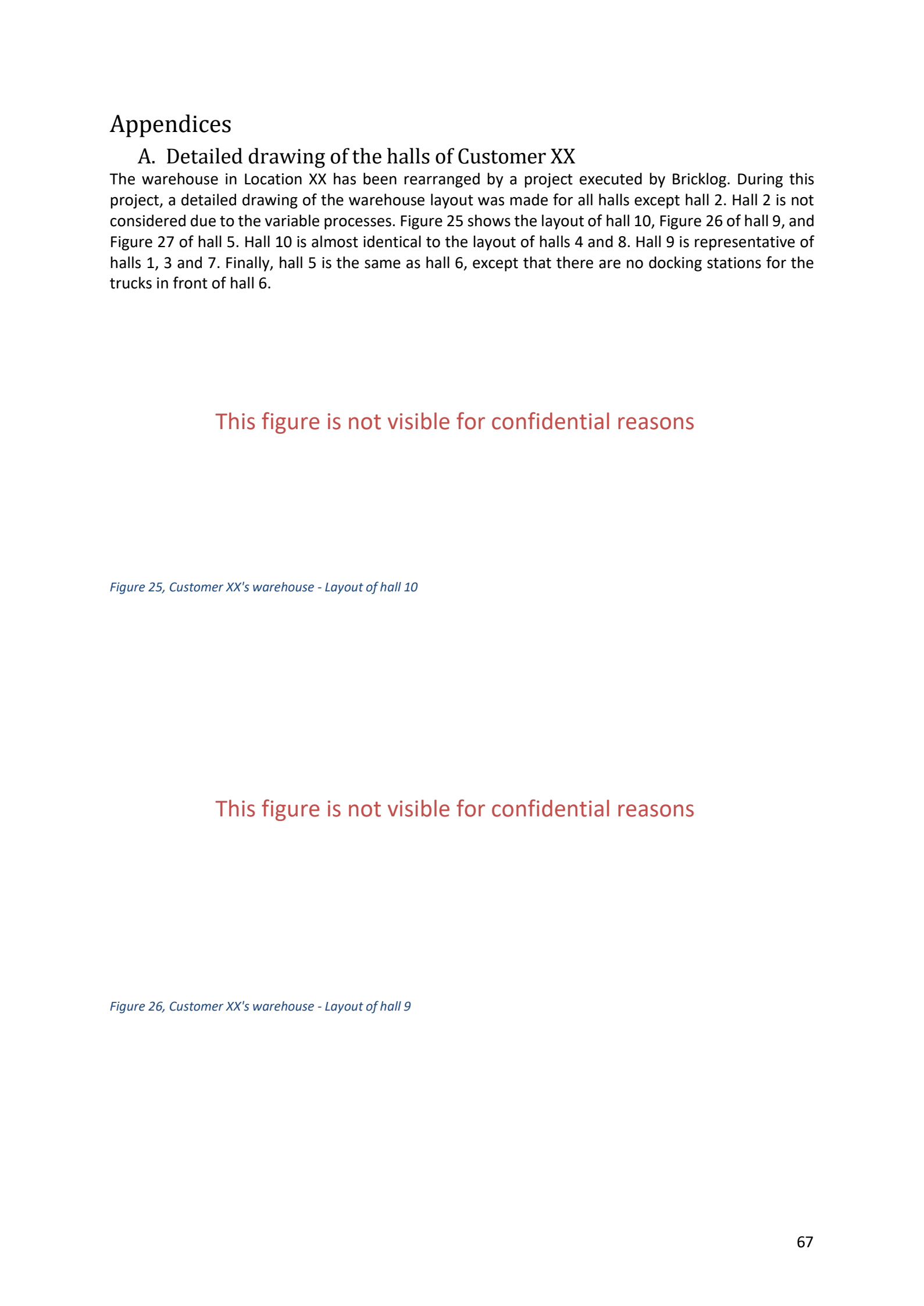

Figure 25, Customer XX's warehouse - Layout of hall 10

Figure 26, Customer XX's warehouse - Layout of hall 9

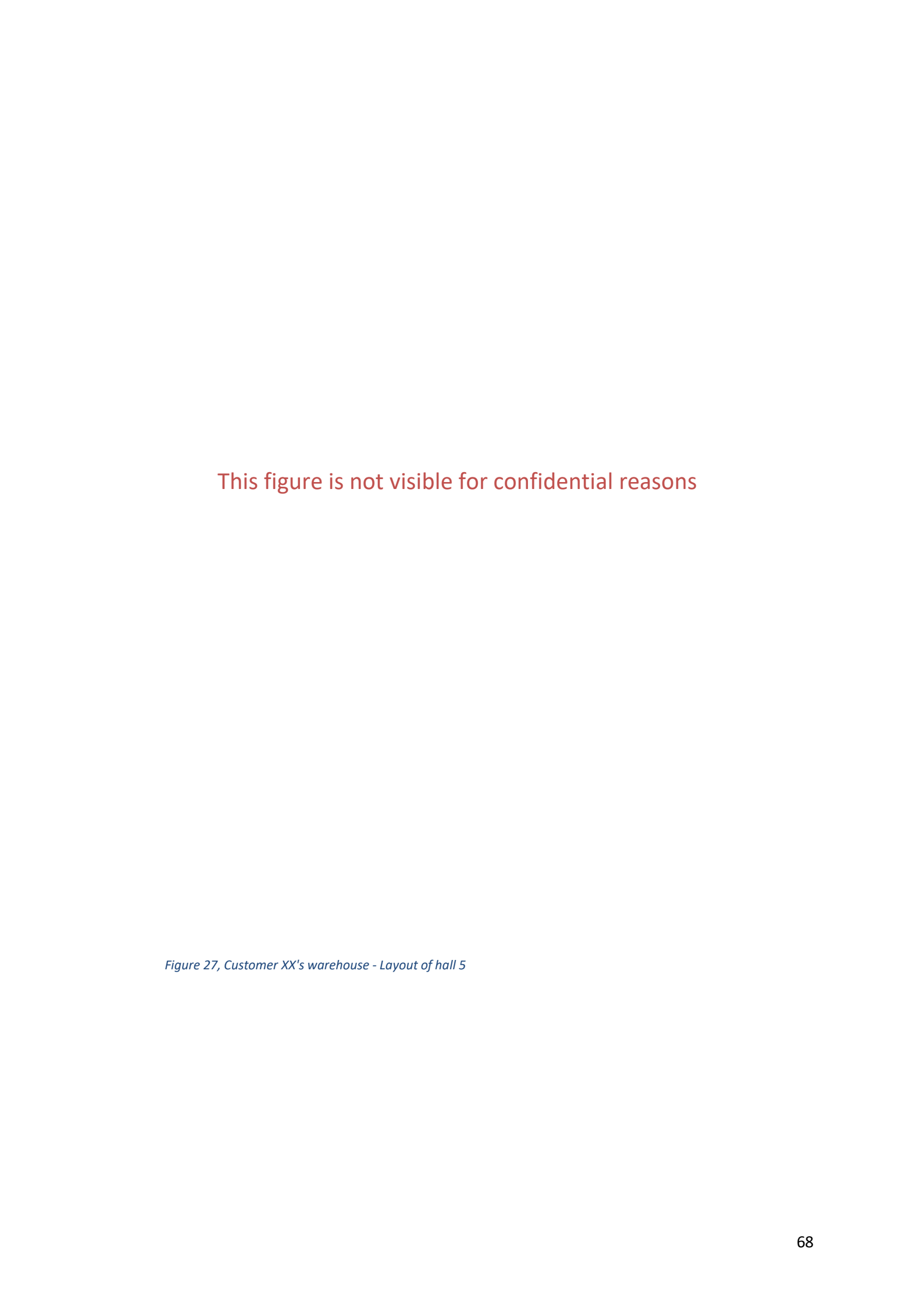

Figure 27, Customer XX's warehouse - Layout of hall 5

B. Customer XX's Report

Page one 'Voorraad Info'

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Figure 28, Power BI report – Page 1, Voorraad Info

Page two 'Mutatie Geschiedenis'

This figure is not visible for confidential reasons

Figure 29, Power BI report – Page 2, Mutatie Geschiedenis

Page three ‘Flow Per Pallet’

This figure is not visible for confidential reasons

Figure 30, Power BI report – Page 3, Flow Per Pallet

Page four ‘Verplaatsingen en Classificatie’

This figure is not visible for confidential reasons

Figure 31, Power BI report – Page 4, Verplaatsingen en Classificatie

Page five ‘Overige Info’

This figure is not visible for confidential reasons

Figure 32, Power BI report – Page 5, Overige Info

C. Maturity models in SLR

Model references	Title	Reviewed	Dimensions	Levels
(Lichtblau et al., 2015)	IMPULS Industrie 4.0 Readiness	7	6	6
(Schrauf, 2016)	Industrie 4.0/Digital operations self assessment	4	7	4
(Jodlbauer & Schagerl, 2016)	Reifegradmodell Industrie 4.0		3	10
(Ganzarain Epelde & Errasti Lozares, 2016)	3 Stage Maturity Model for SME's towards I4.0	3	4	5
(Schuh, Anderl, Gausemeier, Hompel, & Wahlster, 2017)	Industry 4.0 Maturity Index	4	4	6
(Schumacher et al., 2016)	Maturity model for assessing I4.0	6	9	5
(Anderl et al., 2015)	Guideline Industry 4.0	2	2	5
(Rockwell Automation, 2014)	The connected enterprise maturity model	4	4	5
"An industry 4.0 readiness assessment tool" (Amaral et al., 2019)	An Industry 4.0 Readiness Assessment tool		6	4
(Jung, Kulvatunyou, Choi, & Brundage, 2016)	An Overview of a Smart Manufacturing System Readiness Assessment.		4	6
(Leyh, Bley, Schäffer, & Forstenhäusler, 2016)	A Maturity Model for Classifying the Enterprise-wide IT and Software Landscape Focusing on Industry 4.0.	2	4	5
(Gökalp, Şener, & Eren, 2017)	Development of an Assessment Model for Industry 4.0: Industry 4.0-MM	3	5	6
(Lee, Jun, Chang, & Park, 2017)	Smartness Assessment Framework for Smart Factories Using Analytic Network Process.	2	4	3
(Akdil, Ustundag, & Cevikcan, 2018)	Maturity and Readiness Model for Industry 4.0 Strategy	2	3	4
(Anna De Carolis et al., 2017)	Guiding manufacturing companies towards digitalization a methodology for supporting manufacturing companies in defining their digitalization roadmap	6	5	5
(Fantini, Pinzone, Taisch, & Engineering, 2020)	Placing the operator at the centre of Industry 4.0 design: Modelling and assessing human activities within cyber-physical systems		6	3-7

(Scremin, Armellini, Brun, Solar-Pelletier, & Beaudry, 2018)	Towards a framework for assessing the maturity of manufacturing companies in Industry 4.0 adoption.		3	5
(Colli et al., 2019)	A maturity assessment approach for conceiving context-specific roadmaps in the Industry 4.0 era	2	5	6
(Frank, Dalenogare, & Ayala, 2019)	Industry 4.0 technologies: Implementation patterns in manufacturing companies		5	3-4
(Lanza, Nyhuis, Ansari, Kuprat, & Liebrecht, 2016)	Befähigungs- und Einführungsstrategien für Industrie 4.0		-	-
(Canetta, Barni, & Montini, 2018)	Development of a Digitalization Maturity Model for the manufacturing sector		3	4
(Sjödin, Parida, Leksell, & Petrovic, 2018)	Smart Factory Implementation and Process Innovation: A Preliminary Maturity Model for Leveraging Digitalization in Manufacturing Moving to smart factories presents specific challenges that can be addressed through a structured approach focused on people, processes, and technologies	2	3	4
(Kampker, Frank, Emonts-Holley, & Jussen, 2018)	Development of Maturity Levels for Agile Industrial Service Companies		-	-
(Sameer Mittal, Romero, & Wuest, 2018)	Towards a Smart Manufacturing Maturity Model for SMEs	3	5	5
(Fraser, Moultrie, & Gregory, 2002)	The use of maturity models/grids as a tool in assessing product development capability		-	-
(Banyani, 2013)	Development of the industry maturity framework facilities management.		-	-
(Joanna Oleśków-Szłapka & Stachowiak, 2018)	The Framework of Logistics 4.0 Maturity Model	3	3	5
"Plan digitalization precisely with the Industry 4.0 CheckUp" (Joanna Oleśków-Szłapka & Stachowiak, 2018)	Plan digitalization precisely with the Industry 4.0 CheckUp		-	-

(Karolina Werner-Lewandowska & Monika Kosacka-Olejnik, 2019)	Logistics 4.0 Maturity in Service Industry: Empirical Research Results	2	0	6
(Gajšek et al., 2018)	Maturity levels for logistics 4.0 based on NRW's Industry 4.0 maturity model	2	4	5
(M. Krajcovic, P. Grznar, M. Fusko, & R. Skokan, 2018)	Intelligent Logistics for Intelligent Production Systems	2	7	5
(Facchini et al., 2020)	A framework for a logistics 4.0 maturity model with a specification for internal logistics	2	7	5
(Onur Agca, 2018)	An Industry 4 readiness assessment tool		6	6
(Singapore, 2018)	The singapore smartt industry readiness index		3	6
(Zeller, Hocken, & Stich, 2018)	acatech industrie 4.0 maturity index		4	6
(Berghaus & Back, 2016)	Stages in digital business transformation: results of an empirical maturity study		9	5
(Mike Dennis, 2017)	Asset Performance Management Maturity Model		6	5
(Pacchini, Lucato, Facchini, & Mummolo, 2019)	The degree of readiness for the implementation of industry 4.0		8	6
(Bibby & Dehe, 2018)	Defining and assessing industry 4.0 maturity levels		3	4

D. Answers of the expert panel

Questions	**Interviewee**					
	A	B	C	D	E	F
Are all phases clearly defined?	5	5	5	5	4	5
Do the phases comply with the process that takes place within a customer journey?	5	5	4	3	4	4
Are all phases independent of each other?	4	5	5	3	4	4
The sections are clearly defined?	2	5	5	5	4	5
Do the sections cover all the information needed within this phase of the customer journey?	4	4	4	5	4	4
The interrelationship between the sections is clear?	3	5	5	5	4	5
Is the model clear and easy to understand?	4	5	5	4	4	5
The model is useful within a customer journey?	4	5	5	4	5	4