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## **Digitization in Outbound Logistics – Application of an Industry 4.0 Maturity Model for the Delivery Process**

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Institutionelles Repositorium der Universität Bamberg OPUS, 2018

Quelle: Felch, Vanessa; Asdecker, Björn; Sucky, Eric (2018): Digitization in Outbound Logistics – Application of an Industry 4.0 Maturity Model for the Delivery Process, in: Stentoft, Jan (Ed.) (2018): Proceedings of the 30th Annual NOFOMA Conference: Relevant Logistics and Supply Chain Management Research. Kolding: Syddansk Universitet, S. 113–128.

# **DIGITIZATION IN OUTBOUND LOGISTICS – APPLICATION OF AN INDUSTRY 4.0 MATURITY MODEL FOR THE DELIVERY PROCESS**

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## **ABSTRACT**

### **Purpose**

Available maturity models in the context of Industry 4.0 primarily focus on manufacturing processes. A research gap exists with regard to outbound logistics. This paper applies a maturity model that has been designed to support the digitization of the outbound logistics processes. The validation of the model in business practice completes the model's development.

### **Design/methodology/approach**

This work embraces a qualitative research design approach. In this context, it conducts a single case study. The case refers to a large multinational manufacturer of industrial electric equipment, which considers itself as one of the most digitized companies in the industry.

### **Findings**

The model appears to be applicable (1) to describe the status quo of the enterprise's digitization capabilities in outbound logistics, (2) to develop a corporate vision for delivery logistics excellence, (3) to provide guidance on the development path, and (4) to compare capabilities between different company sites.

### **Research limitations/implications**

The model has solely been applied to two sites of one company. However, it seems applicable to other organizations as well. Nonetheless, additional case studies are necessary to verify the model's generalizability.

### **Practical implications**

The case study provides an example of how to develop a roadmap towards delivery process excellence in the digital age ahead.

### **Original/value**

The applied maturity model complements approaches that focus on digitization of the manufacturing processes as well as logistics maturity models. The case study is of value for organizations that intend to build Industry 4.0 capabilities in outbound logistics, which has played a minor role so far.

*Keywords: Industry 4.0, digitization, maturity model, outbound logistics, delivery process*

# 1. INTRODUCTION

Digitization affects all parts of the business world and disruptively changes the process of value creation (Kagermann *et al.*, 2013). At the heart of this development is the interconnection of the real and the virtual world through innovations in the information and telecommunications technology. In business practice, digitization is particularly advanced in the production process. Most notably Cyber-Physical Systems (CPS) and the Internet of Things (IoT) are shaping a fourth industrial revolution to which various authors refer to as “Industry 4.0” (e.g., Almada-Lobo, 2015; Gökalp *et al.*, 2017; Hermann *et al.*, 2016). However, digitization is by no means limited to manufacturing but will inevitably expand to other processes. If the vision of Industry 4.0 is to be realized, the entire supply chain has to evolve towards a connected and smart ecosystem (Pan *et al.*, 2017). Herein, the logistics processes play an integral role as connecting elements (Pujo and Ounnar, 2018; Strandhagen *et al.*, 2017; Glistau and Coello Machado, 2018; Nicoletti, 2018).

On their way towards supply chain ecosystems companies require tools that help identifying transformation gaps. Herein, maturity models can be of great support. Over the past years, various CPS, IoT, and Industry 4.0 maturity models have been developed and presented in literature (e.g., Leyh *et al.*, 2016; Katsma *et al.*, 2011). However, there is a research gap with regards to maturity models in logistics (Gilchrist, 2016), particularly if they are to take the current digitization trends into account. This is of particular interest as McCormack *et al.* (2008) found that the delivery process’s maturity has a higher impact on business performance than other supply chain processes. This prevalent research gap motivated the development of the Delivery Process Maturity Model (DPMM) 4.0. As an integral part of the development process, which was guided by de Bruin *et al.* (2005), it is necessary to validate the model in business practice. This final development step is achieved with this work. Herein, we conduct a case study, which is by far the most common method to validate maturity models and is “[...] able to deliver useful results” (Wendler, 2012, p. 1332).

This study contributes to the available literature by incorporating digitization efforts into maturity models for logistics. Besides, it complements the existing CPS, IoT, and Industry 4.0 maturity models and thus represents a further step towards a fully digitized supply chain. It also contributes to case study research in general by providing insights into the current outbound logistics digitization efforts at one of the world’s leading electric equipment manufacturers.

The remainder of this paper is structured as follows: The second chapter provides the theoretical background with a focus on Industry 4.0 and logistics. The third chapter briefly introduces to the DPMM 4.0. Thereafter, the case study as the chosen method to validate the maturity model is introduced. Chapter 5 outlines the results of the DPMM 4.0 application. The paper summarizes the findings, points out theoretical and managerial implications, and proposes future research opportunities.

# 2. THEORETICAL BACKGROUND

## *The concept of Industry 4.0*

The term “Industry 4.0” has been created by the German Federal Ministry of Education and Research and indicates a new era of industrialization (Oesterreich and Teuteberg, 2016). Thereby, Industry 4.0 is enabled by CPS and IoT technologies, which are integrated in industrial processes (Gökalp *et al.*, 2017). Apart from these two, other essential Industry 4.0 technologies are cloud computing, big data, augmented reality, machine learning, cyber security, autonomous robots and simulation (Gökalp *et al.*, 2017; Gilchrist, 2016). Through the interplay of these technologies the automation and digitization of the manufacturing processes are

increased and “[...] a highly flexible production model of personalized and digital products and services, with real-time interactions between people, products and devices during the production process” (Zhou *et al.*, 2015, S. 2147) is facilitated. Overall, Industry 4.0 depicts a new concept to reach higher information transparency and flexibility with a “[...] significant impact on supply chains, business models and processes [...]” (Gökalp *et al.*, 2017, S. 129).

#### *Logistics in the context of Industry 4.0*

Logistics comprises the “[...] process of strategically managing the procurement, movement and storage of materials, parts and finished inventory (and the related information flows) through the organization and its marketing channels in such a way that current and future profitability are maximized through the cost-effective fulfilment of orders.” (Christopher, 2016, p. 2). Ernst and Kamrad (2000) distinguish between inbound and outbound logistics (Ernst and Kamrad, 2000). The former concentrates on the material flow that supplies the production processes, while the latter focuses on the delivery to the customer (Ernst and Kamrad, 2000). McCormack *et al.* (2008) emphasize that the delivery process’s maturity has a higher impact on business performance than other supply chain processes.

Digitization also affects logistics (Strandhagen *et al.*, 2017; Glistau and Coello Machado, 2018; Nicoletti, 2018). It has the potential to significantly improve efficiency when matching demand and supply through the seamless integration of several logistics actors. Some authors refer to this as cyber-physical logistic systems (e.g., Pujo and Ounnar, 2018), which pursue the goal of increasing process intelligence, connectedness and responsiveness. This pursued state of excellence requires embedded, linked, autonomously acting IT-systems to achieve end-to-end supply chain transparency and self-regulation (Hofmann and Rüsçh, 2017; Göçmen and Erol, 2018; Pujo and Ounnar, 2018).

### **3. THE DELIVERY PROCESS MATURITY MODEL (DPMM) 4.0**

To develop into the next generation of logistics systems, decision-makers require tools that support the realignment, reconfiguration, and renewal of existing capabilities. In general, maturity models contribute to these purposes. While several available models cover digitization on the strategic level (Klötzer and Pflaum, 2017), others refer to CPS and IoT in manufacturing (e.g., Ganzarain and Errasti, 2016; De Carolis *et al.*, 2017) and IT capabilities (e.g., Leyh *et al.*, 2016; Weber *et al.*, 2017). The existing logistics maturity models have not taken into account current digitization trends (e.g., Van Landeghem and Persoons, 2001; Battista *et al.*, 2012).

Motivated by this research gap the authors developed a model with a focus on outbound logistics: the Delivery Process Maturity Model (DPMM) 4.0. The development process was methodologically guided by de Bruin *et al.* (2005). While the first four stages (scope, design, populate, and test) are extensively documented in a separate essay (Asdecker and Felch, 2018), this paper is supposed to verify the model in business practice, which is the final development step (populate). Therefore, the model will only be briefly introduced before being applied in a case study.

The peculiarity of the DPMM 4.0 is its flexibility of the modelling architecture. Unlike other models, it can be adapted to the specific needs of a supply chain, which is derived from its reference to the Supply Chain Operations Reference (SCOR) framework (SCOR, 2017). The structure of SCOR follows a modular principle. It contains six top-level process types that can be further subdivided into more detailed process categories and process elements (SCOR, 2017). The DPMM 4.0 adopts the delivery process elements and distinguishes between three activity dimensions: order processing, warehousing, and shipping (Figure 3.1).

Order Processing	Warehousing	Shipping
<ul style="list-style-type: none"> <li>• Process inquiry and quote (sD1.1/sD2.1)</li> <li>• Receive, enter (,configure) and validate order (sD1.2/sD2.2)</li> <li>• Reserve inventory and determine delivery date (sD1.3/sD2.3)</li> <li>• Consolidate orders (sD1.4/sD2.4)</li> <li>• Invoice (sD1.15/sD2.15)</li> </ul>	<ul style="list-style-type: none"> <li>• Receive product from source or make (sD1.8/sD2.8)</li> <li>• Pick product (sD1.9/sD2.9)</li> <li>• Pack product (sD1.10/sD2.10)</li> </ul>	<ul style="list-style-type: none"> <li>• Build loads (sD1.5/sD2.5)</li> <li>• Route shipments (sD1.6/sD2.6)</li> <li>• Select carriers and rate shipments (sD1.7/sD2.7)</li> <li>• Load product/vehicle &amp; generate shipping docs (sD1.11/sD2.11)</li> <li>• Ship product (sD1.12/sD2.12)</li> <li>• Receive and verify product by customer (sD1.13/sD2.13)</li> <li>• Install product (sD1.14/sD2.14)</li> </ul>

*Figure 3.1 Overview of the three dimensions and their respective elements*

For each of the three dimensions a vision for the highest maturity stage is derived, which is based on available literature and own empirical work. The content of the lower levels has been derived according to these three principles: the lower the maturity stage, (1) the more human interventions are necessary, (2) the lower is the inter- and intra-organizational integration, and (3) the less automatized are data and information flows. Thereafter, the populated model's comprehensibility, comprehensiveness, relevance, consistency, systematic structure, detailedness, conceptual reliability, and applicability were empirically tested with satisfactory results. Figure 3.2 summarizes the final DPMM 4.0.

During a maturity assessment, participants are presented specific statements for their relevant process elements that have to be rated on a four-tiered Likert scale (0="not implemented"; 1="partly implemented"; 2="for the most part implemented"; 3="fully implemented"). To provide a deeper insight into the assessment Table 3.1 provides exemplary assessment statements of one of the most fundamental activities in outbound logistics: the picking process (sD1.9/sD2.9 Pick product).

*Table 3.1 Exemplary assessment statements to measure the process element sD1.9/sD2.9*

Statement ID	Statements
sD1.9/sD2.9-01	Automated real-time retrieve of the required order and determination of inventory availability
sD1.9/sD2.9-02	Automated real-time planning of picking waves in cloud-based IoT operating system
sD1.9/sD2.9-03	Use of carrier information (e.g., carrier's expected arrival time) for automated scheduling of picking waves
sD1.9/sD2.9-04	Automated real-time rescheduling of picking waves in case of delay (e.g., delay of production or carrier)

	<b>Order processing (OP)</b>	<b>Warehousing (W)</b>	<b>Shipping (S)</b>
<b>Stage 1 – Basic digitization</b>	OP is not digitized; Manual data exchange between OP and other departments; Enterprise system supports only OP (department-specific)	W is not digitized; Manual data exchange between W and other departments; Enterprise system supports only W (department-specific)	S is not digitized; Manual data exchange between S and other departments; Enterprise system supports only S process (department-specific)
<b>Stage 2 – Cross-department digitization</b>	OP is digitally supported; Electronic data exchange between OP and other departments; Department-wide integration of OP into enterprise systems	W is digitally supported; Electronic data exchange between W and other departments; Department-wide integration of W into enterprise systems	S is digitally supported; Electronic data exchange between S and other departments; Department-wide integration of S into enterprise systems
<b>Stage 3 – Horizontal and vertical digitization</b>	OP is continuously digitally supported; Automated data flow of within the company (e.g., order confirmation); Shared, integrated inter-faces (e.g., receipt of orders); Recourse to company-specific data for OP (e.g., determination of delivery date); Company-wide integration of OP into cloud-based IoT operating system; Access to OP information through mobile device	W is continuously digitally supported; Automated data flow within the company (e.g., planning picking waves); Recourse to company-specific data for W (e.g., product storage); Company-wide integration of W into cloud-based IoT operating system; Access to W information through mobile device	S is continuously digitally supported; Automated data flow within the company (e.g., planning transportation mode); Recourse to company-specific data for S process (e.g., delivery date); Automated monitoring for full traceability; Company-wide integration of S into cloud-based IoT operating system; Access to S information through mobile device
<b>Stage 4 – Full digitization</b>	Automated real-time OP is continuously digitally supported; Automated real-time data flow; Recourse to customer-specific data as well as business partner data for comprehensive OP (e.g., carriers' capacity); Supply chain-wide integration of OP into cloud-based IoT operating system	Automated real-time W is continuously digitally supported; Automated real-time data flow; Recourse to customer-specific data for comprehensive W (e.g., customized packaging); Supply chain-wide integration of W into cloud-based IoT operating system	Automated real-time S is continuously digitally supported; Automated real-time data flow; Recourse to customer-specific data as well as business partner data for comprehensive S (e.g., customer's preferred routes); Supply chain-wide integration of S into cloud-based IoT operating system
<b>Stage 5 – Optimized full digitization</b>	Automated real-time OP is continuously digitally supported within the supply chain; Real-time simulation for decision making (e.g., order confirmation); Real-time optimization (e.g., determination of delivery date); Self-learning abilities from solved cases; Supply chain-wide integration of OP into self-optimizing cloud-based IoT operating system	Automated real-time W is continuously digitally supported within the supply chain; Real-time simulation for decision making (e.g., cost-effective packaging); Real-time optimization (e.g., routes of autonomously acting transportation system); Real-time self-adjustment to changing environment; Self-learning abilities from solved cases; Supply chain-wide integration of W into self-optimizing cloud-based IoT operating system	Automated real-time S is continuously digitally supported within the supply chain; Real-time simulation for decision making (e.g., efficient grouping of orders); Real-time optimization (e.g., routes of autonomously acting transportation system); Real-time self-adjustment to changing environment; Self-learning abilities from solved cases; Supply chain-wide integration of S into self-optimizing cloud-based IoT operating system

*Figure 3.2 Overview of the final model*

The assessments are transferred into maturity scores based on the following procedure. First, the relevant SCOR process elements in the dimensions  $i = \{1, 2, 3\}$  are assigned the consecutive index  $j(i) = \{1, \dots, J(i)\}$ . Second, the provided  $k(j(i)) = \{1, \dots, K(j(i))\}$  assessment statements are evaluated on the previously mentioned four-tiered Likert scale. Third, the assessments

$as_{i,j(i),k(j(i))}$  are converted into percentage scores for each model element, dimension, and the entire process. Table 3.2 provides the calculation formulas.

*Table 3.2 Maturity stage calculation*

Potential element score $PES_{i,j(i)}$	$PES_{i,j(i)} = K(j(i)) \cdot 3$	$\forall i, j(i)$
Achieved element score $AES_{i,j(i)}$	$AES_{i,j(i)} = \sum_{k(j(i))=1}^{K(j(i))} as_{i,j(i),k(j(i))}$	$\forall i, j(i)$
Relative element score $RES_{i,j(i)}$	$RES_{i,j(i)} = \frac{AES_{i,j(i)}}{PES_{i,j(i)}} \cdot 100 \%$	$\forall i, j(i)$
Relative dimension score $RDS_i$	$RDS_i = \frac{\sum_{j(i)=1}^{J(i)} AES_{i,j(i)}}{\sum_{j(i)=1}^{J(i)} PES_{i,j(i)}} \cdot 100 \%$	$\forall i$
Total relative process score $TRPS$	$TRPS = \frac{\sum_{i=1}^3 \sum_{j(i)=1}^{J(i)} AES_{i,j(i)}}{\sum_{i=1}^3 \sum_{j(i)=1}^{J(i)} PES_{i,j(i)}} \cdot 100 \%$	

Fourth, the scores are converted into a maturity stage. With the five stages describing a path towards excellence, the scale is evenly distributed. The first stage corresponds to a score between 0 and 20 %, the second stage to a score between 20 and 40 %, the third stage to a score between 40 and 60 %, the fourth stage to a score between 60 and 80 %, and the fifth stage to a score between 80 and 100 %. The following case study will further illustrate the model's applicability.

#### 4. MODEL EVALUATION METHODOLOGY

Helgesson *et al.* (2012) suggest three maturity model evaluation types. Type 1 (evaluation by the authors) and type 2 (evaluation by practitioners) were already conducted during the development of the DPMM 4.0. So far, the application in business practice, which represents type 3 in the evaluation process, is still missing (Helgesson *et al.*, 2012). The main purpose is both to improve and to demonstrate the applicability of the model. For this step, Helgesson *et al.* (2012, p. 437) recommend “[...] analyzing the effect on one organization in a case study”. While other method approaches are possible, case studies are most frequently used (Wendler, 2012).

Yin (2009, p. 18) defines a case study as an “[...] empirical inquiry that investigates a contemporary phenomenon in depth and within its real-life context, especially when the boundaries between phenomenon and context are not clearly evident”. Case studies differ from other research methods in their (1) particularity, (2) complexity and (3) real-time circumstances (Yin, 2009; Stake, 2005).

Before conducting a case study, a research question must be formulated, which reads in this paper: How can the DPMM 4.0 be used in business practice and identify potentials for improving the degree of digitization in outbound logistics? This question determines the design of the case study with regards to the following four factors: (1) subject, (2) purpose, (3) approach, and (4) process (Thomas, 2011). Table 4.1 shows the classification of our case study according to these factors. For our purpose, we use it as a supportive tool for testing the applicability of the DPMM 4.0.

*Table 4.1: Case study design*

(1) Subject	Key case
(2) Purpose	Instrumental
(3) Approach	Testing a theory / maturity model (DPMM 4.0)
(4) Process	Single case study with two embedded units

In the following, the company, the objects of investigation, and the respondents were identified. The company was selected for two reasons: (1) the company's corporate strategy and (2) already implemented Industry 4.0 projects as an indicator of digitization experience. The participating company is a leading multinational manufacturer of electric equipment with more than 300.000 employees. Multiple Industry 4.0 initiatives have been successfully implemented and documented on the "Plattform Industrie 4.0" website (<https://www.plattform-i40.de/>). The company considers itself as one of the most digitized organizations in the industry. Therefore, we are confident that there is sufficient Industry 4.0 knowledge to contribute to this case study. As part of the corporate strategy the company is continuously looking for opportunities to take advantage of the possibilities of digitization. Therefore, it sought to apply the DPMM 4.0.

The authors decided to evaluate two heterogeneous delivery processes of the multinational manufacturer, which can be interpreted as two subcases. Both factories produce the majority of their products on the basis of a make-to-order production strategy. Factory A is located in Germany with approximately 2,000 employees. The factory generates annual sales between 500 million and one billion euros. Factory B is situated in the United States, employs about 500 people, and generates annual sales between 100 and 250 million euros.

Respondents, as the main source of information, were expected to have sufficient knowledge of both Industry 4.0 and the delivery process. It proved difficult to meet this requirement, but in the end an employee was found who was well enough qualified to carry out the assessment. The participating manager has been dealing with the Industry 4.0 concept for around two years and was able provide in-depth information on the delivery processes in both plants.

In February 2018, the corresponding author visited the manager in the German plant. To reduce subjectivity and in an attempt to triangulate the data, the outbound logistical processes were jointly inspected before the actual assessment. During the plant tour, the modular structure of DPMM 4.0 was introduced, which proved to be straightforward, as the manager was already aware of and familiar with the SCOR framework. The participating manager named twelve relevant process elements that were consistent with the insights gained during the factory tour: sD2.1, sD2.2, sD2.3, sD2.5, sD2.6, sD2.7, sD2.8, sD2.9, sD2.10, sD2.11, sD2.12, and sD2.15. Factory B was not visited, but due to the plausible and verifiable assessment of plant A, we are confident that the information provided also reflects reality. According to the manager, customers require an Ex Works (EXW) Incoterm. Therefore, plant B does not build efficient

loads (sD2.5), route shipments (sD2.6), select carriers (sD2.7), and ship the product (sD2.12). Moreover, packing (sD2.10) has been outsourced to a third party service provider. Overall, sD2.1, sD2.2, sD2.3, sD2.8, sD2.9, sD2.11, and sD2.15 were considered relevant.

The manager then carried out the assessment for both factories. He went through the statements of each relevant element and evaluated them using the predefined Likert scale. During the assessment, he explained why he chose an answer option. Finally, we asked the respondent about the suitability of the model and possible implementation barriers. The results of the maturity model's assessment are presented in the next paragraph.

## 5. RESULTS OF THE DPMM 4.0 APPLICATION WITH A MULTINATIONAL MANUFACTURER

Upon completion of the questionnaire, the maturity scores and stages were determined according to the formulas described in chapter 3. The results were then evaluated and interpreted by the authors. Table 5.1 summarizes the individual maturity scores for both factories neglecting the one that do not take place in the factories.

*Table 5.1 Assessment results for both factories regarding their delivery processes*

	<b>Results factory A</b>	<b>Results factory B</b>
<b>TRPS</b>	<b>Stage 2 (29.1 %)</b>	<b>Stage 1 (19.8 %)</b>
<b>RDS “Order processing”</b>	<b>Stage 2 (31.7 %)</b>	<b>Stage 2 (23.3 %)</b>
sD2.1	Stage 1 (12.5 %)	Stage 1 (12.5 %)
sD2.2	Stage 2 (30.9 %)	Stage 1 (19.0 %)
sD2.3	Stage 2 (26.7 %)	Stage 2 (23.3 %)
sD2.15	Stage 3 (58.3 %)	Stage 3 (41.7 %)
<b>RDS “Warehousing”</b>	<b>Stage 1 (19.8 %)</b>	<b>Stage 1 (14.5 %)</b>
sD2.8	Stage 2 (20.5 %)	Stage 1 (12.8 %)
sD2.9	Stage 1 (20.0 %)	Stage 1 (16.7 %)
sD2.10	Stage 1 (19.0 %)	-
<b>RDS “Shipping”</b>	<b>Stage 2 (33.3 %)</b>	<b>Stage 1 (18.2 %)</b>
sD2.5	Stage 2 (35.7 %)	-
sD2.6	Stage 1 (16.7 %)	-
sD2.7	Stage 2 (36.7 %)	-
sD2.11	Stage 3 (42.4 %)	Stage 1 (18.2 %)
sD2.12	Stage 2 (33.3 %)	-

In general, the delivery process in factory A is more mature than in factory B. No process element scores higher in factory B than in factory A and thus confirms the heterogeneity of the processes. However, the assessment revealed great potential for improvement in factory A. The most digitized process element is “invoice” (sD2.15) for both sites. The least digitized element

is the “inquiry and quote” (sD2.1). The tabular results can be visualized, which is particularly useful in practice. Radar charts are used for this purpose (see Figure 5.1).

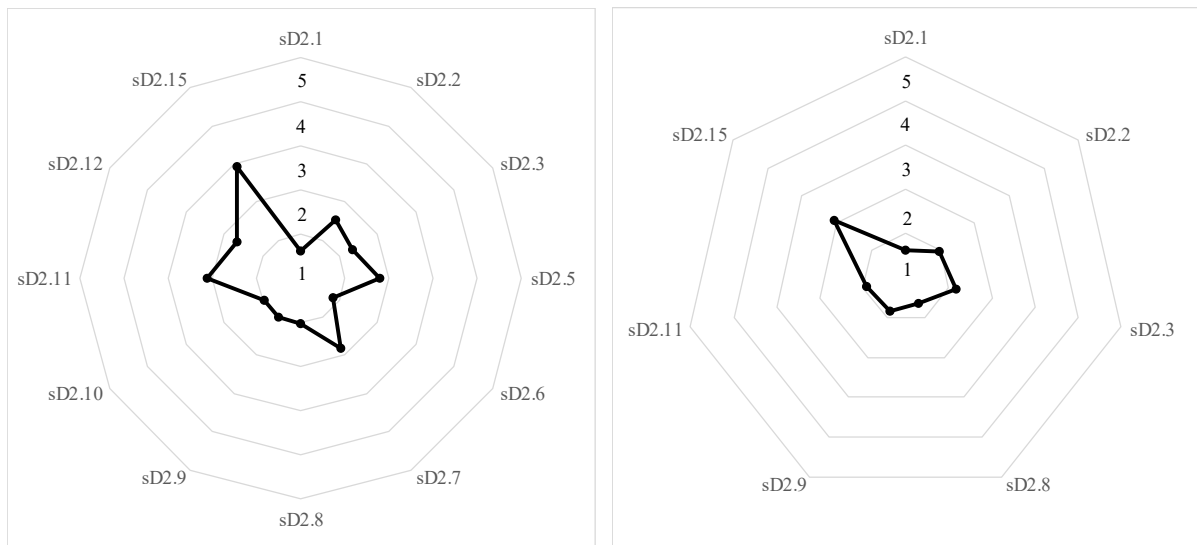


Figure 5.1 Radar chart for factories A (left) and B (right)

Figure 5.2 helps decision-makers to see at first glance how their factories compare with respect to the process elements present at both sites. The reasons for the differences were discussed in the accompanying interview. The manager provided two possible explanations: Whereas performance measurement in plant B focuses on order lead and production lead times, factory A regards customer satisfaction as the most important key performance indicator. This may have served as an incentive to perform well in the customer-bound delivery process. Moreover, as already mentioned, the two factories work on different Incoterms. This leads to different perceptions of relevance within the factories and is reflected by the assessment results.

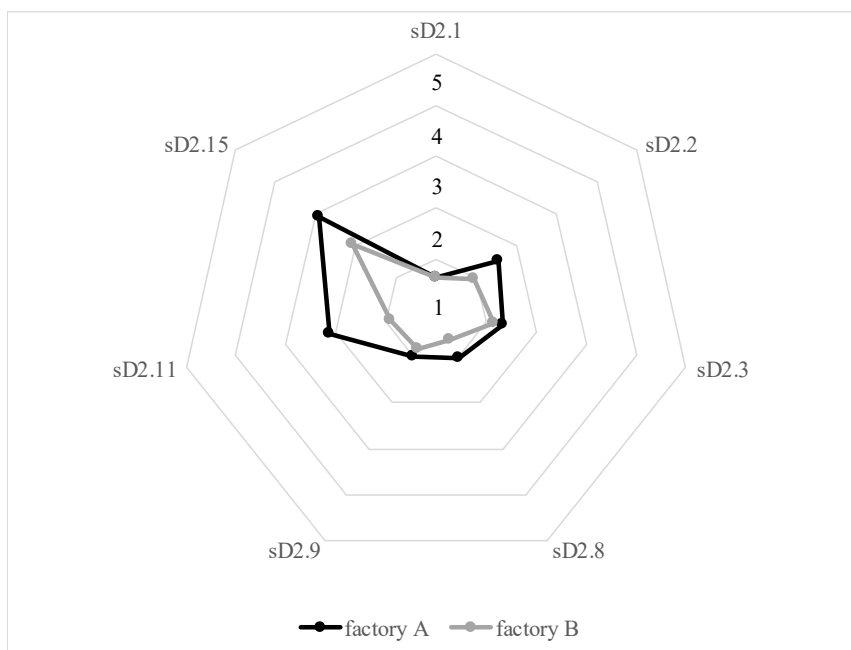


Figure 5.2 Radar chart for internal benchmarking of both factories

When deriving a development path, it is recommended to concentrate on the process elements with the lowest scores, which in turn have the greatest digitization deficits. To derive appropriate measures for closing existing gaps within the process elements, the next level of maturity used. Thus, factory A should improve the two process elements with the lowest relative scores, sD2.1 and sD2.6 followed by sD2.8, sD2.9 and sD2.10. Table 5.2 outlines suitable measures for the process elements mentioned.

*Table 5.2 Recommended measures for factory A*

<b>Process element to be improved</b>	<b>Recommended measures</b>
sD2.1 Process inquiry and quote	<ul style="list-style-type: none"> <li>• Automated receipt of customer inquiries / request for quotes and manual data correction in case of failure</li> <li>• Recourse to carrier data and experience for inquiries / request for quote</li> <li>• Automated response to customer about inquiries / request for quote</li> </ul>
sD2.6 Route shipments	<ul style="list-style-type: none"> <li>• Automated planning of routes</li> <li>• Recourse to carrier information for route planning</li> <li>• Automated comparison of data, decision-making concerning route planning and response to customer about most favorable route</li> <li>• Manual analysis in case of any failure and learning process from solved cases of failure</li> </ul>
sD2.8 Receive product from source or make	<ul style="list-style-type: none"> <li>• Automated planning of picking waves</li> <li>• Automated rescheduling of picking waves in case of short-term changes (e.g., carrier delay)</li> <li>• Automated product reception by autonomously acting transportation system</li> <li>• Automated intelligent product arrangement in warehouse and optimization of warehouse space for an optimized material flow</li> <li>• Product surveillance in the warehouse through sensors and notification when product reaches critical level</li> <li>• Automated recording of product location</li> <li>• Access to sD2.8 information through mobile devices</li> </ul>

sD2.9 Pick product	<ul style="list-style-type: none"> <li>• Automated retrieval of the required order and determination of inventory availability</li> <li>• Automated planning of picking waves</li> <li>• Automated rescheduling of picking waves in case of short-term changes (e.g., carrier delay)</li> <li>• Product collection by picker supported through wearables (especially glasses)</li> <li>• Manual analysis in case of any failure and learning process from solved cases of failure</li> </ul>
sD2.10 Pack product	<ul style="list-style-type: none"> <li>• Automated sorting and combing of products to efficient bundles</li> <li>• Automated configuration of an efficient and resource-saving packaging / package units</li> <li>• Recourse to carrier information for product packaging and efficient bundles</li> <li>• Manual recombining of bundles or rescheduling of picking waves in case of short-term changes (e.g., carrier delay)</li> <li>• Manual analysis in case of any failure and learning process from solved cases of failure</li> </ul>

Accordingly, factory B is recommended to focus on the process elements sD2.1, sD2.8, and sD2.9. However, priority should be given to elements sD2.2 and sD2.11, which have slightly higher scores. Because factory A has reached higher stages at the process elements sD2.2, sD2.8, and sD2.11, it can serve as a role model and guide the transformation process. In particular, process element sD2.11, which records the highest absolute difference of all values, would benefit from such an exchange between the factories. Besides, since both factories perform poorly in the elements sD2.1 and sD2.9, it might be useful to improve the process together. Table 5.3 summarizes the measures for improving the respective process elements.

Overall, the measures derived indicate that the degree of automation must be increased in both plants. In addition, data and information flows, especially between factory and business partners, need to be automated to get closer to Industry 4.0 process excellence. Automated data and error analysis is required to enable machine learning as the next step. The measures listed in Table 5.2 and Table 5.3 can be interpreted as a short list for process development. It must be ensured that they are in line with both the corporate and the supply chain strategy. The participating manager ensured that this would be the case for all proposed measures. Before a suggested measure is selected and implemented, company-specific cost-benefit analyses must be carried out. To achieve this, quotes must be sought and compared with potential benefits such as a faster, more reliable, cheaper delivery.

*Table 5.3 Recommended measures for factory B*

<b>Process element to be improved</b>	<b>Recommended measures</b>
sD2.1 Process inquiry and quote	See Table 5.2
sD2.2 Receive, enter, configure and validate order	<ul style="list-style-type: none"> <li>• Recourse to business partner information for order confirmation</li> <li>• Verification of orderable configuration and calculation of accurate price</li> <li>• Automated check of customer's credit</li> <li>• Automated message to inform the customer and responsible parties about decision on approval or rejection by product modifications</li> <li>• Access for business partner to order data and product traceability</li> </ul>
sD2.8 Receive product from source or make	<ul style="list-style-type: none"> <li>• Planning of picking waves in company's enterprise system by storekeeper</li> <li>• Product verification by storekeeper supported through wearables, especially glasses</li> <li>• Transmission of relevant product data via RFID transponder</li> <li>• Intelligent product arrangement in warehouse and optimization of warehouse space with an optimized material flow by storekeeper supported through wearables, especially glasses</li> <li>• Product surveillance in the warehouse through 360° camera</li> <li>• Recording of product location in company's enterprise system by storekeeper</li> </ul>
sD2.9 Pick product	See Table 5.2
sD2.11 Load product & generate shipping docs	<ul style="list-style-type: none"> <li>• Automated planning of outbound logistics and rescheduling in case of short-term changes (e.g., carrier delay)</li> <li>• Manual transmission of product data and accompanying documents via Barcode</li> <li>• Manual planning of product loading onto transportation mode and of necessary loading equipment</li> <li>• Integration of carrier into the safety concept</li> <li>• Manual analysis in case of any failure and learning process from solved cases of failure</li> </ul>

Furthermore, the participating manager was asked for suggestions to improve the DPMM 4.0, especially for practicability. He particularly praised comprehensiveness and the customizability of the assessment. Within a short time, detailed and complete results were achieved for both factories. Evaluation results corresponded to the company's perception about its current Industry 4.0 capabilities with regards to the delivery process. The manager stressed that it would

be desirable to have additional external benchmarks of companies in the same industry and with a similar number of employees to get feedback on the company's relative position in the market.

Despite the positive feedback, the participating manager stressed the importance of shedding light on some potential blind spots of the assessment due to the adaptability. He referred to factory B which is currently working on an EXW policy. For this reason, several shipping process elements were omitted during the assessment (see Table 5.1). However, the corresponding process steps continue to take place – not at the evaluated sites but with the respective external service providers. It is therefore necessary to evaluate these steps in collaboration with the supply chain partners. When a company works with multiple service providers, it is unrealistic to collect data from everyone. In these cases, exemplary service providers should be selected to conduct the assessment.

## 6. IMPLICATIONS AND OUTLOOK

This paper presents a case study at two sites of one of the world's leading electric equipment manufacturers to complete the development process of the DPMM 4.0 as proposed by de Bruin *et al.* (2005). While such validation step is required with regards to a methodologically rigorous development process it also provides theoretical and managerial implications.

First, this research contributes to a more detailed understanding of the current digitization efforts in business practice. With a focus on outbound logistics it adds a complementary perspective to the often investigated manufacturing process (e.g., Leyh *et al.*, 2016; Katsma *et al.*, 2011). This is important as manufacturing processes are by no means the only supply chain processes to be digitized. Second, this work also contributes to the available logistics maturity models (e.g., Battista *et al.*, 2012). The existing models do not account for the current digitization trends and are therefore of little use for decision-makers, who want to prepare for the digital age ahead. Third, this work adds to the emerging literature of cyber-physical logistics systems (CPLS). The final DPMM 4.0 maturity stage describes a process that is fully transparent to all actors involved with embedded, linked IT-systems that autonomously act and interact with the environment, which reflect the concept of CPLS. So far, CPLS have only been described (e.g., Pujo and Ounnar, 2018), whereas our paper provides an example as of how to improve towards a state of excellence.

With regards to business practice, this work provides managers with valuable insights into how to approach the digitization of outbound logistics, which is particularly relevant as it involves direct customer contact. Such effort would most certainly not be too late as the case study reveals low digitization levels with regards to outbound logistics, although the company sees itself as one of the most digitized companies in the industry. Our results indicate that logistics processes could become a critical bottleneck on the path towards a connected and smart supply chain. Decision-makers who want to evolve their supply chains should therefore take a more balanced approach and not just focus on manufacturing.

A major limitation of this paper is that the model has only been applied to two factories of one company. Nevertheless, it appears applicable to other enterprises because of the high flexibility of the model's architecture and the positive feedback received during the case study. Moreover, the data within the case came from a single source within the company and the corresponding author's visit at the assessed production sites. In terms of data triangulation (Denzin, 2006), it would have been desirable to further increase the number of sources (time, space, and person). However, the number of persons with sufficient expertise concerning the digitization of the logistics processes is limited. This applies in particular to large companies with highly specialized job profiles. For these reasons, we call for future investigations to replicate our findings with other companies (e.g., different company size, different industry) and multiple

data sources. Against this background, studies using a mixed-method approach also appear promising.

While this case study concludes the model development, it is by no means the end of the project. We are currently working on an online DPMM 4.0 assessment tool to collect data about the actual status quo of digitization in outbound logistics. These data may serve as reference points for external benchmarks and give companies a quick first impression of how they compare. The successful model application can also motivate the development of other process-based maturity models, for example for the sourcing process, which is necessary to fully realize the vision of a seamless, transparent, and efficient value creation network that remains competitive in the digital age.

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