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Analysing the state of digitisation in SME – A survey based on an SME-specific maturity model

Nicolas Wittine, Robin Sutherland, Sigrid Wenzel, Ana Luiza Amaral Bicalho
University of Kassel; Department of Organization of Production and Factory Planning, Germany

Abstract

The prevailing volatile changes in the market are forcing companies to perform increasingly complex planning tasks. Furthermore, shorter product life cycles and a more frequent adaption to customer requirements arise from a sellers' market shifting to a buyers' market. Regarding the digital factory planning, appropriate digital methods, tools, and models help master these new challenges. Depending on industry sectors and company size, the application and implementation of the methods and tools of the digital factory vary. Especially small and medium-sized enterprises (SMEs) show limited progress regarding digitisation due to a lack of expertise and qualified personnel. Thus, identifying suitable methods and tools for SMEs is essential for developing an implementation plan driving their digital transformation. Therefore, this article uses a survey analysing and classifying the situation of SME via an SME-specific maturity model. By investigating the correlations between the impacting variables, it is possible to identify the untapped potential, forming the basis for developing workshops and training to gain experience in dealing with methods and tools for digital factory planning.

Keywords

Digitisation; Digital Factory Planning; Organisation development; Industry 4.0; Maturity Index; SME

1. Introduction

The terms volatility, uncertainty, complexity, and ambiguity best describe the current industrial landscape [1]. In the wake of the ongoing corona pandemic, short response times and flexible change processes are vital abilities for businesses worldwide. Innovation, automation, and digitisation are more than ever of utmost importance in these times [2]. Over half of the European SMEs (see EU definition [3]) see reduced revenues and a fifth is even fearing to be unable to meet financial obligation [4]. Besides this out of ordinary pandemic, the digital change and a customer-driven switch to a buyers' market impact SMEs non the less [5, 6]. The digital factory offers a toolset dedicated to facilitating better planning capabilities and responsiveness [6]. To utilise these tools, companies need qualified and trained personnel. SMEs often lack those personnel and are overwhelmed by a holistic approach to digital change [6, 7]. The vast diversity of tools and methods suited for different business areas contributes to even more complexity within the workplace. Therefore, SMEs need to focus on the most critical aspects of the digital change and its primary drivers. This effort allows promoting change from within the company sustainably.

This paper aims to increase the understanding of SMEs' current situation regarding digitisation and examine its drivers. The core of this publication is an interview study based on an SME-specific maturity index. Using appropriate methods to analyse the data, the driving aspects behind successful digitisation – from a novice to a more advanced level – are identified and reflected regarding their related dimensions and indicators.

Therefore, the paper gives an overview of related works by detailing existing maturity models' content, shortcomings and why an SME-specific maturity model is necessary. The subsequent section explains the structure and procedure of the conducted interview-based survey. Consequently, an analysis of the obtained data allows for identifying SME-specific drivers for digitisation. A detailed description of the identified drivers offers valuable insight into connections and interrelationships of different fields inside the used maturity index. Finally, the paper offers a summary and points to future research.

2. Related work

The existing works regarding digital maturity assessment feature broad aspects regarding Industry 4.0 and offer companies a way for (self-)assessment. Since not all maturity models are also SME-specific or cover the same topics, reviewing existing literature is necessary. The maturity model used in this publication is part of a thesis at the Department of Production Organization and Factory Planning at the University of Kassel [8].

Based on more than 50 publications, the most cited and SME-oriented ones are used to build a comprehensive SME-specific maturity model. This model acts as a basis for the conducted survey and the following identification of drivers of digitisation. The models differentiate topics (dimensions) and sub-topics (indicators) with different levels to express the companies maturity. The overall structure, therefore, is an important metric to structure a comprehensive model.

Combining such an overview with specific classification criteria allows building an SME-specific maturity index. Since SMEs still struggle with implementing methods and technologies regarded as Industry 3.0 [9], the inclusion of a maturity level of zero, which does not require a complete implementation, is necessary. Furthermore, the model has to be comprehensible and straightforward enough to be accessible to a broad audience, acting as guidance and eliminating uncertainties. Especially identifying areas of action and concrete measures increasing the companies digitisation level is an issue for many SMEs. [10] Therefore the developed model has to contain transformation steps acting as direct guidance to increase the digitisation level. Also, SMEs are often family-owned and lead. The often tech-savvy and authoritarian leadership tend to struggle with scalability in a growing company [11], thus hindering effective and efficient decision making. Especially non-technical aspects like modern leadership principles or enabling collaboration and ownership thinking are considered essential in digital change [12].

The following table presents an overview of the different maturity models consisting of the number of dimensions, indicators and levels. Models claiming to be SME-specific or addressing mid-tier companies are marked accordingly with an "x"(see Table 1). Regarding the classification criteria, an assessment ranging from not partly to wholly fulfilled is available.

The inclusion of level zero rates not fulfilled when not existent or the maturity model starts with an already advanced stage. On the contrary, the wholly fulfilled rating describes a clear definition for a technical maturity below Industry 4.0. If the concept of an incomplete Industry 3.0 stage is existent, but incomplete definitions or missing indicators hinder the understanding, awards a partly fulfilled rating.

A comprehensible and straightforward model that follows an accessible concept containing descriptions and visual aids is rated wholly fulfilled. If a user needs additional consulting by external experts or critical content is left unexplained, the criterion is rated not fulfilled. An explanation and guidance sufficient for a more advanced user justify the rating partly fulfilled.

Since transformation steps are valuable guidance models containing explicitly depicted transformation steps achieve the rating of wholly fulfilled. No description, missing or unpublicised content regarding the transformation result in the not fulfilled rating. Logically, partly fulfilled describes models that leave out descriptions of levels and means of their improvement.

When an essential element of the maturity model consists of non-technical aspects like leadership, management or company culture, the rating wholly fulfilled is awarded. Vice versa, a missing non-technical dimension results in not fulfilled. Models only partly considering social or cultural aspects also only partly fulfil this criterion.

Table 1: Overview of existing maturity models [8]

Author	*Dimensions*	*Indicators*	*Levels*	*SME-specific*	*Level zero*	*comprehensible and straightforward*	*Transformation steps*	*Non-technical aspects*
Akdil et al. 2018 [13]	3	13	4		◑	◑	◑	◑
Anderl 2015 [14]	2	12	5		◑	●	●	○
Bibby, Dehe 2018 [15]	3	13	4		◑	◑	◑	◑
De Carolis et al. 2017 [16]	4	-	5		◑	◑	◑	◑
Geissbauer et al. 2016 [17]	7	-	4		○	◑	◑	◑
Gökalp et al. 2017 [18]	5	-	6		◑	○	○	○
Häberer et al. 2017 [19]	5	17	5	x	○	◑	○	◑
Jodlbauer, Schagerl 2016 [20]	3	25	10		◑	○	○	◑
Landwehr-Zloch, Eichfelder 2019 [21]	6	19	4	x	◑	◑	◑	◑
Leineweber et al. 2018 [22]	3	44	8	x	◑	◑	◑	◑
Leyh et al. 2016 [23]	4	-	5		○	◑	◑	○
Lichtblau et al. 2015 [24]	6	18	6		◑	◑	◑	◑
Rauch et al. 2020 [25]	5	42	5	x	◑	◑	●	◑
Sames 2021 [26]	5	27	5	x	◑	●	●	◑
Schuh et al. 2017 [27]	4	31	6		●	◑	◑	●
Schumacher et al. 2016 [28]	9	62	5		◑	◑	◑	◑
Trotta, Garengo 2019 [29]	5	11	5	x	◑	◑	○	◑
State of fullfilement:				not ○		partly ◑		wholly ●

Many of the reviewed models have specific areas they excel in, but no single one is suited for a comprehensible, SME-specific maturity model. Yet, regarding the individual assessments, the entries in bold are considered as particularly appropriate to develop a comprehensive model. The derived SME-specific maturity model from the analysed literature, as depicted in Figure 1, features 6 different dimensions and 26 underlying indicators. Beginning with a level 0, the model details 5 levels, each with a description of its fulfilment requirements. The dimension “Production”, for example, contains information and communications technology (ICT) or monitoring, quality management (QM) & maintenance. Whereas “leadership, management and culture” deals with corporate and failure culture. The latter divides into levels beginning with a working environment shaped by blame (level 0) and finishing with a public analysis of failure (level 4).

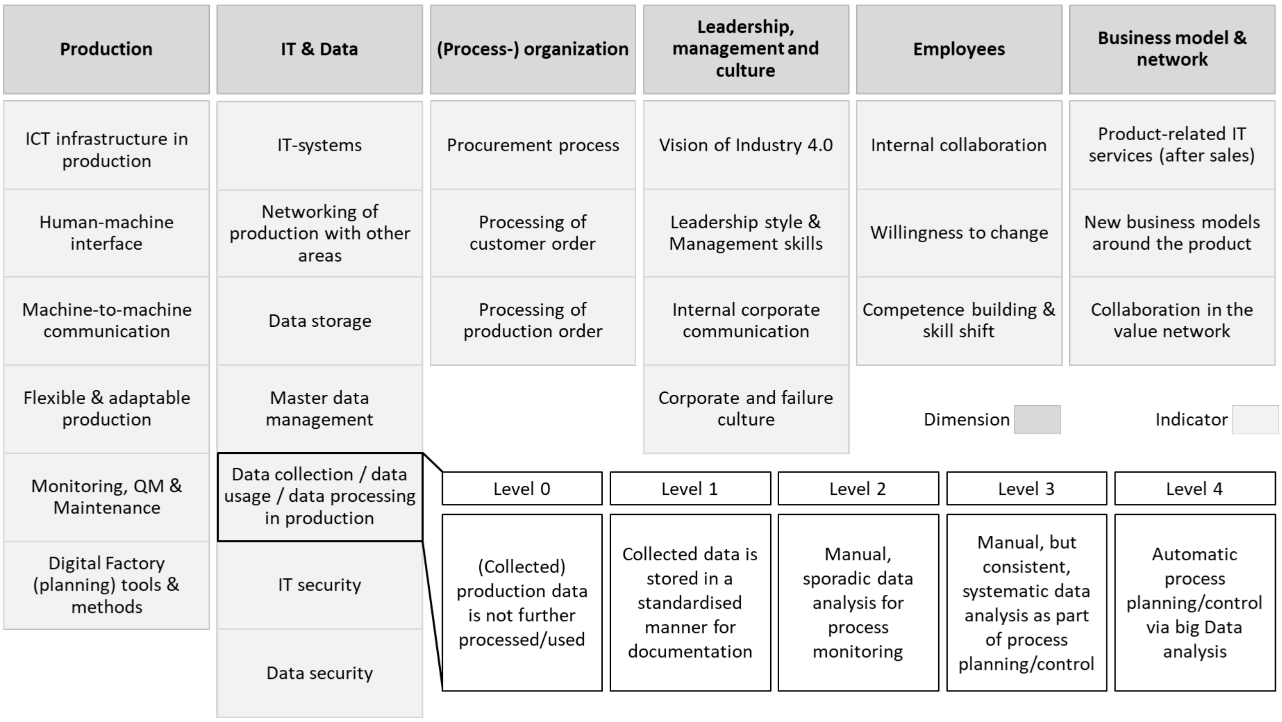

Figure 1: The SME-specific Industry 4.0 maturity model

3. Interview framework

An empirical study aims to grade SMEs' situation regarding their digital maturity based on the developed maturity model. The study uses verbal interviews of company representatives and their experts from different fields. The questions asked explicitly target the individual indicators in a sequence from the lowest to the highest maturity level; in addition to a mere classification, the subsequent analysis uncovers the potential for improvement by identifying maturity clusters, correlations and deriving needs for action in practice.

The participants in the survey are from nine different branches, all originating in the manufacturing sector SMEs from the region of Hesse in the middle of Germany. Interview partners are employees in crucial positions, including managing directors, production, process, IT or digitisation managers. The sample comprises 11 companies from different branches representing one small, eight medium-sized and two large enterprises (acc. to EU definition [3]). However, the latter fall under the more broad mid-tier concept [30], making their evaluation results still relevant. The validated interview guideline used is the outcome of a master thesis created at the research institute. The interview takes about 4 hours and is conducted either at the companies' sites or within a web meeting. The high complexity of the interview and its long duration tend to cause respondent fatigue. Therefore, the interview guides through the different topics in descending order of complexity, counteracting the loss of attention throughout the interview. In total, the guideline contains 32 guiding questions derived from the indicators and over 100 sub-questions detailing the explicit level. E.g. regarding the data collection / data usage / data processing in production (see Figure 1), the leading question of how production data is handled starts the dialogue. Follow up questions concerning whether, how and for what purpose the collection and analysis of production-related data deepen the topic. Also, general information, such as annual sales or the number of employees, are requested. For visual and thematic guidance, an accompanying presentation contains the current dimension of the questions asked. A transcript writer prepares a protocol for documentation purposes and later acts as a data basis for the classification in the SME-specific maturity model. Additionally, recording the audio is highly advised but needs the interviewees' consent beforehand.

4. Analysis of the interview

Each consecutive interview extends the database containing each companies maturity profile and overall maturity rating. The profile offers valuable insights into every companies area for improvement and targets specific topics in particular. While this information is valuable for each participant, it also enables analysis potential for a broader view regarding the state of maturity regarding SME. Since the database consists of only a small sample size regarding the number of questions asked, not every data analysis method is suited. A worthwhile goal is to classify the companies and to check for overarching similarities and differences. Another meaningful insight is the identification of drivers for digitisation.

The cluster analysis offers means to identify unknown groups (clusters) inside a given set of data and is viable to explore the conducted interviews. The calculated silhouette coefficient (S_c) classifies the clusters and represents how well elements can be assigned to a specific cluster, dividing into weak ($0.25 < S_c \leq 0.50$), medium ($0.50 < S_c \leq 0.75$) and strong structures ($0.75 < S_c \leq 1.00$). [31] In the present case, the analysis finds two distinct clusters ($S_c = 0.56$) across all dimensions (see Figure 2). The primary differentiation seen in the spider chart breaks down to Cluster 1, containing beginner companies and cluster 2 advanced companies. The more advanced dimensions are “Leadership, management and culture”, “employees”, “IT & Data”, and “Business model & network”. Therefore, those dimensions seem to be essential to advance a companies maturity level. Organization and production are dimensions that lag behind the overall in the more advanced companies and also highlight a need to catch up.

Additionally, the found clusters further prove the validity of the underlying maturity model. The found groups are distinct and have no overlap coinciding with the overall maturity level. Each company in cluster 1 also scores an overall maturity level of 1. Whereas the companies belonging to cluster 2 achieve level 2. The levels 0, 3, and 4 are missing in the surveys data set, and as a result, a corresponding cluster is also nonexistent, illustrate the current state of digitisation in the sampled SME.

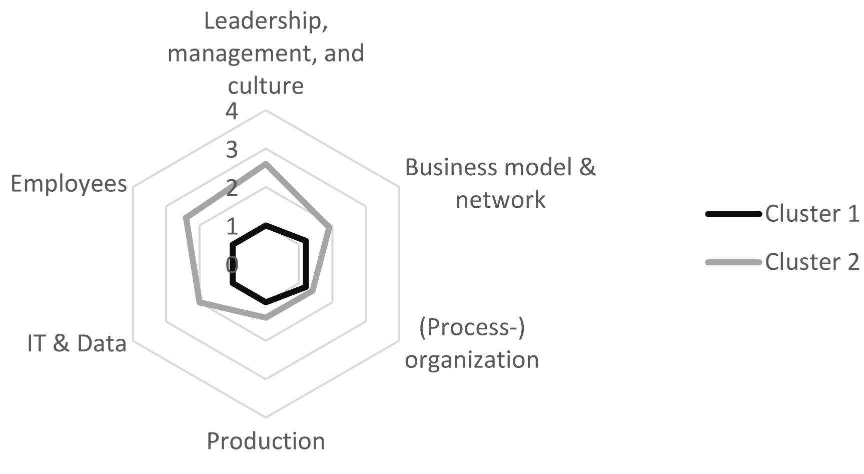

Figure 2 Result of the cluster analysis

The clustering already enables differentiated recommendations for various levels of digitisation and allows for a further investigation of specific drivers. The correlation analysis offers insight into relationships between the different dimensions and the overall maturity level and quantifies the direction and strength of a found correlation [32]. A correlation coefficient of +1 means that the two variables are positively related, whereas a value of -1 indicates the opposite. The small and not normally distributed dataset used in the paper requires a particular correlation analysis method, the Kendall tau (τ) correlation, and prevents false associations due to low significance [33].

Table 2 shows the correlation analysis results emphasising the correlations between the individual dimensions and the overall maturity level. Also, the table contains the significance of the found values. The relevance of a dimension derives from the respective τ-value and its effect strength from the *r*-value (weak $0.1 < r \leq 0.3$, medium $0.3 < r \leq 0.5$ and strong $0.5 < r$) [34]. The table contains the effect strength only for relevant values ($p < 0.05$), highlighting three dimensions, "IT & data", "Management, leadership and culture", and "employees". Those dimensions show a strong correlation with the overall maturity level and are also strongly related to other dimensions.

Table 2: Results of the correlation analysis

τ *r*	*Production*	*Organisation*	*IT & Data*	*Management, leadership and culture*	*Employees*	*Business model and network*	*Overall maturity*
Production							
Organisation	.195 -						
IT & Data	.242 -	.086 -					
Management, leadership and culture	.109 -	.101 -	.617 .845				
Employees	.160 -	.147 -	.617 .845	.487 .801			
Business model and network	.175 -	.078 -	.380 .639	.359 .651	.336 .622		
Overall maturity	.242 -	.086 -	.798 .953	.617 .845	.617 .845	.380 .639	

Regarding the identified drivers for digitisation, the cause, causation, and interconnectivity need consideration. The following statements can be formulated by further examining the identified dimensions and summarises the found relationships forming a concise overview of the identified drivers.

Specific IT infrastructures must be available to implement the digital transformation to Industry 4.0, enabling components or systems inside the factory and interconnecting the value-adding network. In addition to the information technology infrastructure, aspects of the collection, storage, and processing of data, including its use and maintenance. These aspects are necessary for primarily data-based decision making thus supporting the management. A digitally transformed enterprise requires consistent data in real-time to implement the digital factory's methods and tools, especially IT and data security. For example, ICT must be in place so employees, products, and machines can interact. ICT is essential for implementing digital factory methods and cross-divisional and cross-company collaboration and enabling new business models. The correlation analysis highlights IT infrastructure's influence regarding the overall maturity level, appointing this dimension a driver of digitisation. A low correlation with production is identifiable, but the effect strength is negligible. Even though the overall maturity benefits significantly from a strong IT & Data dimension, it acts as a supporting role, enabling, supporting and connecting the other dimensions.

Besides the companies ICT, the leadership has a strong influence on the overall maturity. Especially a well-defined Industry 4.0 vision and strategy is as essential as familiarity with modern management concepts. It plays a decisive role in motivating the employees to work together and achieve a common goal. Further, the management needs the will to drive and implement changes and provide suitable communication channels for internal networking. Strong support of the employees enables another major influencer of the overall maturity. However, in addition to structural changes, management must prepare employees for the digital factory's new requirements. The increasingly higher IT competencies lead to shifts in qualifications, which management must counteract with suitable training programs. To be prepared for the general changes in addition to the technical requirements, an open and innovative corporate culture must be in place and practised by management. An open failure culture that treats failures as means to improve and evolve existing technologies and processes. Such cultural aspects can promote new forms of internal collaboration making all those aspects essential for a successful digital transformation.

Even though employees strongly correlate with the overall maturity, they need enabling from management as leverage. This dimension strongly correlates with management, leadership and culture since employees form the connection between essential elements in business, highlighting the need for a non-technical dimension. Also, communication and collaboration between employees benefit highly from an IT and data-driven surrounding, making this interconnection logical. Nevertheless, the employees inside a company cannot drive the digital change without the digital framework and the support from the management, therefore even though essential employees are not considered direct drivers.

In conclusion, the state of digitisation in SME derives by combining the found drivers with the identified clusters. Especially the lack of higher scoring SME indicates their necessity for support and further research. Whether improving the drivers also acts as guidance for digitisation needs evaluation and validation.

5. Summary and outlook

In this paper, an interview study is evaluated based on an SME-specific maturity model. The model and the analysis results are explained and increase the understanding of the current situation of SMEs regarding digitisation. A performed cluster analysis classifies the different companies in the sample depending on their digitisation progress and validates the used maturity model. Additionally, further analysis has made it possible to identify and describe two digitisation drivers in the context of the used maturity model. Thus, SMEs should focus on the dimensions “IT & Data” and “Management, Leadership and Culture” in the early phases. Management that promotes employees and leads with a vision forms the foundation for digital change. Also, the availability of data and the resulting transparency enable informed and efficient decision making. This insight enables SMEs to focus on only a few key areas facing the constantly changing market’s challenges. Since the surveyed companies only ranked level 1 or 2, a larger data set containing more advanced companies (level 3 or 4) should confirm these findings and whether the interconnections and drivers change due to digitisation progress. Also, the reason for the lacking involvement of the production and organisation needs further investigation. Ultimately, based on the identified drivers, specific recommendations for SMEs can now be formulated. Besides practical guidance, future research should contain the necessary competencies and suitable ways to acquire them.

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Biography

Sigrid Wenzel is a professor and head of the Department of Organization of Production and Factory Planning, University of Kassel. In addition to this, she is a board director of the Arbeitsgemeinschaft Simulation (ASIM), spokesperson for the ASIM Section Simulation in Production and Logistics, member of the advisory board of the Association of German Engineers Society of Production and Logistics (VDI-GPL), and head of the Committee Modelling and Simulation of the VDI-GPL.

Nicolas Wittine has been a research assistant at the Department of Organization of Production and Factory Planning at the University of Kassel since 2019. After obtaining his Master of Science in 2016, he worked as a development engineer in the automotive industry. He gained first-hand experience in developing safety-critical components, project management and industrialisation. Currently, his work focuses on traceability and digitisation.

Robin Sutherland has been a research assistant at the Department of Organization of Production and Factory Planning at the University of Kassel since 2020. He completed his master's degree in 2020 at the Karlsruhe Institute of Technology. Currently, his work focuses on Industry 4.0 and factory planning.

Ana Luiza Amaral Bicalho has been an industrial engineering master student at the University of Kassel since 2018. She has a bachelor's degree in production engineering focusing on simulation from the University of Brasília. Currently, she works as a student assistant at the Department of Organization of Production and Factory Planning at the University of Kassel.