Key Dimensions That Measure the Digital Maturity Levels of Small and Medium-Sized Enterprises (SMEs)

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Abstract

Digital maturity models are not widely adopted or implemented in business practice, despite the interest in these models. It is unclear which dimensions and parameters are most crucial in measuring the level of digitalization within small and medium-sized enterprises. In this paper, we present a systematic literature review of studies on digital maturity models published from 2011 to 2021. The guiding research question of this study is: Which dimensions are included in digital maturity models to measure the level of digitalization in business models of SMEs? Existing research on the dimensions and parameters included in digital maturity models was reviewed. The review identified nine dimensions: (a) strategy, (b) leadership, (c) culture, (d) organization, (e) people/employees, (f) technology, (g) processes, (h) products, and (i) customers. Additionally, 16 parameters were identified that measure these dimensions. This paper concludes with a discussion of the implications of this review for future research and practice.

Keywords: digital maturity; digital transformation; SMEs; business modelling

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Introduction

Across industries, the digital age is changing all businesses' operating environments and threatening to transform existing business models and ways of doing business (Lorenzo et al., 2018). Change occurs at a much faster pace and is more volatile and complex than ever before. This includes but is not limited to changes in customer needs and behaviors, the structure of competitors, product designs, and service delivery (Fichman et al., 2014), which is why it has become crucial for businesses to respond and adapt to these changes. This phenomenon refers to digital transformation, which has become a lever for success in adapting to these changing conditions. Researchers and practitioners have given much attention to this phenomenon over the past few years (Teichert, 2019). One of the challenges experienced by businesses is to develop an appropriate response to digital change. Small and medium-sized enterprises (SMEs) are considered the backbone of most economies (North & Varvakis, 2016) and the catalysts for the future economy (Fedouaki et al., 2013). They tend to be more flexible and can execute decisions much faster than larger businesses. However, in contrast, SMEs often lack the resources, capital, strategy, customer base, and skilled workforce to advance their digital capabilities (Fedouaki et al., 2013). Businesses are experiencing pressure to align their business strategy and upskill their capabilities in line with the technological changes and identify and improve their digital maturity.

Digital maturity is a concept that has emerged with the Fourth Industrial Revolution. To date, there is no agreed definition and a lack of understanding of the concept (Aslanova & Kulichkina, 2020). Berghaus and Back (2016) defined digital maturity as a business's capabilities to succeed in digital transformation. The use of maturity models allows firms to assess their current position, develop a vision of where they want to be, and a roadmap planning how to get there (Valdez de Leon, 2016). Maturity models are often advocated to measure the impact and level of advancement of these initiatives or emerging practices on the business in the context of global events such as digitalization or the Fourth Industrial Revolution. Key performance indicators are often used to measure digital maturity (Kotarba, 2016). Literature has identified that SMEs have expressed interest in using digital maturity models, which can be more cost-effective since financial constraints hinder them from undergoing digital transformation programs (Bley & Schön, 2019; Mittal et al., 2018). Despite the interest, these models repeatedly do not suit the requirements of SMEs (McMahon, 2012). Consequently, maturity models are not widely adopted and implemented in business practice, despite the interest in these models (Felch et al., 2019). Maturity models that have been developed tend to be generalized, vague, or not precise, which allows SMEs to adapt it for their own needs (Bley et al., 2019). The literature identifies a lack of knowledge on digital transformation, which is reported to be a stumbling block for SMEs, resulting in an extensive task to determine the current and future digital transformation needs (Williams, et al., 2019). Additionally, Angreania et al. (2019) stated that digital maturity models and business models need to be aligned, based on the business's objectives.

We aimed to address this research gap by conducting a systematic literature review to identify, assess, and interpret research evidence from digital maturity models from 2011 to 2021. This will enable us to answer the following question: *Which dimensions are included in digital maturity models to measure the level of digitalization in business models of SMEs?* Answering this question is essential if researchers seek

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to contribute to the body of knowledge on the digital transformation of business models and develop a new maturity model that measures the level of digitalization within an SME's business model.

Theoretical Background

To assess the limitations of the current research on the dimensions included in existing digital maturity models, this study first reviewed the different digital maturity assessments. The review in this paper therefore starts with an overview of the concept of digital transformation, followed by a discussion on the use of maturity models and key performance indicators (KPIs) to measure the level of digital maturity.

Digital Transformation

There is no commonly agreed-upon definition of the concept of digital transformation (Schallmo & Williams, 2017). Fitzgerald et al. (2014) defined digital transformation as the ability of new technologies to improve business performance significantly. The concept refers to the fundamental change within a business, impacting strategy and structure (Matt et al., 2015). Kane (2017) agreed that more than just technology, but also strategy, talent management, organization, and leadership should be considered. Korachi and Bounabat (2019) claimed that for a business to lead digital transformation, it should develop a digital strategy, select a suitable maturity model, and use an effective measuring tool to manage, track and evaluate the progress of the digital strategy. It is therefore crucial to understand the areas in which digital transformation can happen to select the most suitable maturity model. Several authors (e.g., Gudergan & Mugg, 2017; Jafarzadeh et al., 2015) have acknowledged the importance of a digital business strategy. Bharadwaj et al. (2013) define it as an "organizational strategy formulated and executed by leveraging digital resources to create differential value" (p. 472). Implementing a digital strategy portrays a picture of the leadership team's digital abilities, the agility and scalability of operations, a digitally enabled customer experience, and the presence of digital innovations (Leischnig et al., 2017).

Digital transformation requires organizational changes, especially structural changes that allow greater flexibility (Eggers & Park, 2018). Fischer et al. (2020) agreed that an organization should rely on a flexible and adaptable structure that is responsive to the dynamic environment. Previous research studies (e.g., Lazarević & Lukić, 2018; Lee & Edmondson, 2017) have favored a more flattening structure, which allows for flexibility, agility, cross-collaboration, coordination, faster decision making, and knowledge transfer between employees. This strongly correlates with organizational culture, often perceived as a valuable strategic asset that has the potential to support and exploit digital technologies (Westerman et al., 2011). Mueller and Renken (2017) similarly stated that the organizational culture can impact the process and outcome of digital transformation. The entire organization should adopt a culture that supports digital transformation to ensure its viability. Hartl and Hess (2017) conducted a Delphi study to identify which cultural factors are most important for digital transformation, taking a value-centric approach. The findings suggested that openness towards change and focusing on customer-centricity were the two most prominent factors. The authors claimed that if an organization encourages openness to change, it ultimately accepts, implements, promotes, and establishes a change-oriented mindset, which is crucial in digital transformation.

Hartl (2019) conducted a study on cultural change in light of digital transformation and reported that employee participation is critical in the digital transformation process. Hartl found that top management initiated and drove digital culture change; however, the change process largely depended on the employees' intention and participation in various activities such as setting goals, co-creation, and acting as change ambassadors. Ajzen and Fishbein (1980) theorized that intention is a psychological antecedent for actual behavior. Such considerations can include the intention to participate or not participate, or stay or leave, which can be critical determinants of behavioral action. Bowen and Schoemaker (1998) defined employee behavior as the actions performed by employees within an organization that can have a positive or negative contribution and that can destroy a productive environment. Employees resist change such as digital transformation, as the outcome would involve facing the unknown and changes to their working routines, activities, and responsibilities, resulting in fear of poor performance or results (Gupta, 2018). Bowen and Schoemaker also identified several barriers to digital transformation: (a) lack of a clear vision and goal for digital transformation; (b) lack of agility; (c) lack of digital skills, experience, and knowledge among all levels of employees; (d) an inflexible culture; and (e) lack of employee involvement and engagement. It is thus clear that employees' intention to engage and participate in the digital transformation process depends on several factors.

Digital capabilities are also a fundamental building block for digital transformation influencing customer experience, operational processes, and business models (Westerman et al., 2011). Westerman et al. (2012) defined digital capabilities as "the skills needed to go beyond pure IT to include specific technologies, such as social media or mobile, as well as analytic skills to drive value from big data" (p. 1). Digital capabilities enable employees to learn by doing and reacting to new technologies, which implies agility and responsiveness (Setia et al., 2013). Hartl (2019) argued that training employees to obtain digital skills is essential to conquering change and actively engaging in digital transformation.

Digital Maturity Models

Maturity is the possibility of achieving a state of excellence through a process of development and improvement (Mettler et al., 2010). Digital maturity has been defined by Kane et al. (2017) as the systematic approach businesses take to consistently adapt to the ongoing digital changes within the business environment. It is important to note that digital transformation and digital maturity are not the same. Aslanova and Kulichkina (2020) claimed that digital maturity is the foundation of digital transformation. Businesses aim to increase their level of digital maturity and engage with digital transformation in all aspects of the business. Digital maturity is the gradual integration of orga-

nizational processes and resources into digital processes. Achieving digital maturity requires businesses to develop technological capabilities that allow the use of technologies to gain a competitive advantage and improve overall performance (Aslanova & Kulichkina, 2020). Similarly, Bharadwaj et al. (2013) claimed that the primary purpose for using technologies should be to bring about and drive competitive advantage. In doing so, infrastructure plays a pivotal role in digital maturity levels and should allow for flexibility to up- or downscale information technology infrastructure (Bharadwaj et al., 2013). Flexibility also will enable businesses to engage with and adapt to their environments (Bucki & Pesqueux, 2000). Sensing the environment and responding to new information technology initiatives should play an essential role in achieving digital maturity (Teece, 2007).

Businesses can conduct an assessment using a maturity model to measure a specific discipline's current level of maturity, enabling one to identify strengths, weaknesses, and opportunities for improvements to advance the current level (Proença & Borbinha, 2016). Bley and Schön (2019) defined a maturity model as a structured, systematic refinement of best practices and processes within a discipline related to functioning and structure. This allows for the prioritization of certain activities and ultimately achieving a higher level of maturity. According to Poeppelbuss and Röglinger (2011), there are three specific reasons why businesses would use maturity models. Firstly, a maturity model can serve as a diagnostic tool to assess the current capabilities and skills of the business. Secondly, the model can identify a future desired state of maturity, providing guidelines for achieving it. Lastly, the model can be a comparison mechanism for internal and external benchmarking. Pursuing and implementing digital activities have become a challenge for businesses; thus, assessing digital maturity has become critical (Akdil et al., 2018). Digital maturity models are a tool to measure the level of digitalization activities within a business (Lichtblau et al., 2018). There is consequently a great need for maturity models (Akdil et al., 2018). Currently, a variety of digital maturity models are available to assist businesses with their digitalization activities (Lichtblau, Stich, Bertenrath, Blum, Bleider, Millack, Schmitt, Schmitz & Schröter, 2015; Rafael et al., 2020; Szedlak et al., 2019). These are also referred to as Industry 4.0 models (Nick et al., 2019; Ramos et al., 2020; Schumacher et al., 2016). The common goal of these models is to assess digital maturity and identify actions needed to increase the maturity level of a business. Suppose a business strives to achieve the highest level of digital maturity. In that case, a business must rely on a digital strategy with relevant KPIs to measure the implementation of digital initiatives (Aslanova & Kulichkina, 2020).

KPIs

KPIs are calculable values that depict how well a business achieves its key business goals and objectives (Saura et al., 2017). KPIs, also referred to as scorecards, are used across all industries today. The use of KPIs is widespread among most consulting companies, who use them as a toolkit to advise their clients on evaluating, monitoring, and measuring their performance in a specific discipline and providing suggestions for improvement (Özen et al., 2020). Businesses need to measure the implementation status of the transformation process to monitor and achieve the total value and potential of digital transformation, using KPIs, allowing these businesses to identify improvements and fine-tune the newly transformed business model (Verhoef et al., 2019). Digital KPIs are similar to KPIs that monitor and evaluate key business objectives; however, digital KPIs aim to assess and monitor digital initiatives (Saura et al., 2017). As a business adopts digitalization, metrics measure progress. The digital initiative should continuously be kept updated and remain relevant to the business.

Furthermore, the overall impact of these digital initiatives on the business performance needs to be measured using return on investment, profitability, and increase in the overall revenue (Verhoef et al., 2019). Libert et al. (2016) argued that these measurements should be conducted after the digital initiatives have been implemented. Businesses should conduct intermediate process-related metrics to determine to what extent the newly transformed business model is creating value. Verhoef et al. (2019) added that these intermediate digital metrics provide valuable information. Cognet et al. (2019) argued that digital maturity models can assist SMEs in identifying the current level of their digital maturity, focusing on specific KPIs and dimensions. These outcomes can better assist SMEs in designing and developing their digital transformation plans.

Methodology

In this study we conducted a systematic literature review to analyze contemporary research on digital transformation and how this has contributed to the theoretical developments of digital maturity models. Additionally, the systematic review allowed us to answer the main research question of which dimensions measure digitalization in an SME's business model. A systematic literature review serves as a means to identify, evaluate, and interpret all available research, whether quantitative or qualitative, relevant to a particular phenomenon of interest (Mallett et al., 2012). Furthermore, a systematic review allows researchers to summarize existing research, identify gaps in current research, and develop a framework on a particular topic, directing new research activities (Kitchenham & Charters, 2007). A systematic review is fundamentally different from traditional and narrative reviews, as a systematic review follows a replicable, predetermined scientific process in identifying relevant published and unpublished studies to ultimately minimize bias during the literature search (Cook et al., 1997). This technique exposes studies to rigorous methodological scrutiny, and the strict criteria used in a systematic review aim to base reviews on the best quality documentation (Tranfield et al., 2003). The study followed the review methodology described by Kitchenham and Charters (2007). The review process consisted of three steps: *search strategy, study selection,* and *data extraction.*

Search Strategy

A search strategy was conducted to identify the most relevant literature and included three steps: (a) identifying pertinent literature databases, (b) defining key search words and strings, and (c) retrieving an initial list of articles.

Literature Resources

Identifying relevant articles and accessing a wide range of literature is essential when conducting a systematic review; therefore, we selected the literature databases before starting the search. The databases included in the search were

SpringerLink, IEEE Xplore, Taylor & Francis, Science Direct, and Web of Science, based on their scientific relevance and being sources of academic articles from multidisciplinary databases from 2011 to 2021. The chosen timeframe is relevant, as some of the first works to measure digitalization were published in 2011 by Friedrich et al. (2011).

Search Strings

Considering the different terms used to describe the measurement of digitalization, the researchers used several terms to search for published work, and after several tests, the primary search strings used were as follows:

- "Digital maturity" or "digital maturity" and SMEs
- "Digital readiness" or "digital readiness" and SMEs
- "Digital assessment" or "digital assessment" and SMEs
- "Digital metrics" or "digital metrics" and SMEs
- "Digital KPI" or "technology KPI" or "digital KPI" or "technology KPI" and SMEs
- "E-business maturity" or "E-business maturity" and SMEs
- "Industry 4.0 maturity model" or "Industry 4.0 assessment model" or "Industry 4.0 readiness" and SME.

Study Selection

Inclusion and exclusion criteria were used to select the most relevant studies and to remove the subjectivity of the data collection process.

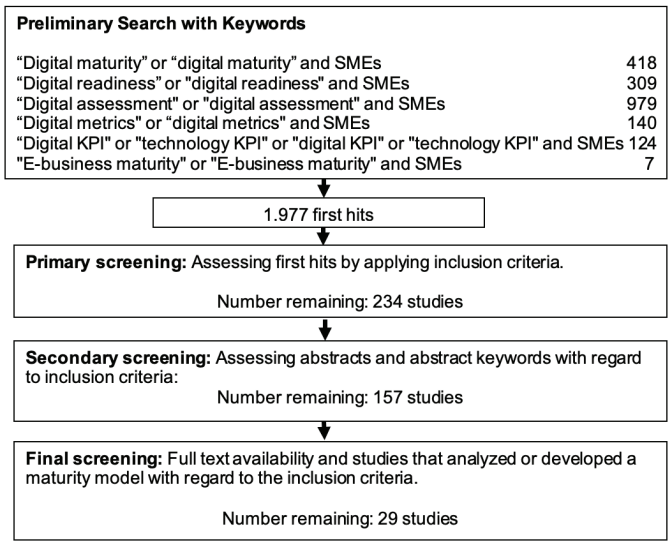
Table 1 shows the inclusion criteria that had to be met by previous studies in the databases for their inclusion in the present study.

Table 1: Screening Phases and Inclusion Criteria

Screening Phase	Inclusion Criteria
Primary screening	1. Written in English 2. Search keywords identified in the title or text of displayed search result 3. Publication year 2011–2021 4. Publication type that included review/research articles, chapters, books, and conference papers
Secondary screening (Title, abstracts, keywords)	Conceptualising digital maturity Addressing digital maturity in a company context
Final screening (Full-text assessment for eligibility)	Full-text article available Criteria used for secondary screening Studies that analyzed and developed a maturity model, readiness/assessment model, KPIs/metrics aimed at measuring digitalization/digital initiatives within SMEs

The exclusion criteria excluded studies that did not adhere to the inclusion criteria mentioned in Table 1. The primary screening of articles yielded 1,977 studies, followed by a secondary screening, which resulted in 157 studies. The studies were checked manually to assess the suitability and eligibility of each article against the final screening phase criteria of Table 1. The studies that did not meet the criteria were excluded. Among the excluded studies were those that did not measure digital maturity, resulting in 29 studies being retained. The entire screening process and results yielded from the search strategy are illustrated in Figure 1.

Figure 1: Overview of the search process (Authors compilation)



Data Extraction

We analyzed the final set of studies to extract the digital maturity models used, along with information regarding the characteristics of the study itself. The 29 included studies represented 23 different digital maturity models. We paid particular attention to the research focus, the measurement of the models, the dimensions included in each model, and the number of maturity stages/levels. Table 2 presents an overview of the studies and can be found in the appendix of this study.

Key Dimensions of Digital Maturity Models

The systematic review aimed at answering the research question: *Which dimensions are included in digital maturity models to measure the level of digitalization in business models of SMEs?* Dimensions from the reviewed digital maturity models were identified in Table 2 as seen in the appendix. A summary of the most common dimensions identified in the review is provided in Table 3.

Table 3: Existing Dimensions of Digital Maturity Models

Model/Author(s)	Total	Cult.	Cust.	Lead.	Org.	Ppl/Emp.	Proc.	Prod.	Strat.	Tech.
Blatz et al. (2018)	4	X		X	X				X	
Caiado et al. (2021)	1		X							
Colli et al. (2018)	1									X
Eirich (2020)	3					X	X		X	
Gamache et al. (2019)	5	X	X	X	X					X
Geissbauer et al. (2016)	3	X			X	X				
Goerzig et al. (2018)	4				X	X			X	X
González-Varona et al. (2020)	4	X			X	X				X
Härting et al. (2019)	1		X							
Horvat et al. (2018)	4				X	X			X	X
Klohs and Sandkuhl, 2020	1		X							
Lichtblau et al. (2015)	4				X	X		X	X	
Majstorović et al. (2020)	7		X	X	X	X		X	X	X
Nick et al. (2019)	4				X		X	X	X	
Rafael et al. (2020)	4				X	X		X	X	
Ramos et al. (2020)	4	X		X			X		X	
Schumacher and Sihn (2020)	4			X		X	X		X	
Schumacher et al. (2016)	6	X	X	X		X		X	X	
Schumacher et al. (2019)	6		X	X		X	X		X	X
Sheen and Yang (2018)	2	X							X	
Szedlak et al. (2019)	3					X	X		X	
Trotta and Garengo (2019)	4					X		X	X	X
Yıldırım et al. (2020)	4	X	X		X					X
Total		**8**	**8**	**7**	**11**	**13**	**6**	**6**	**15**	**9**

Note. Cult. = Culture; Cust. = Customers; Lead. = Leadership; Org. = Organization; Ppl/Emp. = People/Employees; Proc. = Processes; Prod. = Products; Strat. = Strategy; Tech. = Technology.

To further answer the main research question, it is vital to identify which parameters assess each of the dimensions that would assist in measuring the overall digital maturity level of an SME. Table 4 presents the most common parameters for each of the dimensions.

Table 4: Parameters of the Identified Dimensions in Digital Maturity Models

Dimension	Parameters	Author(s)
Strategy	Digital transformation roadmap	Nick et al., (2019); Majstorović et al., (2020); Schumacher et al., (2016); Schumacher et al., (2019)
	Strategy implementation for Industry 4.0	Blatz et al., (2018); Horvat et al., (2018); Majstorović et al., (2020); Nick et al., (2019); Trotta and Garengo (2019); Rafael et al., (2020); Szedlak et al., (2019)
	Designing new business models	Blatz et al., (2018); Majstorović et al., (2020) Schumacher et al., (2016); Szedlak et al., (2019)
Leadership	Attitude and commitment of the leadership team	Blatz et al., (2018); Gamache et al., (2019); Rafael et al., (2020); Ramos et al., (2020); Schumacher et al., (2016); Schumacher et al., (2019); Schumacher and Sihn (2020); Szedlak et al., (2019)
Culture	Continuous improvement and skill development	Gamache et al., (2019) González-Varona et al., (2020)
	Cross-collaboration and communication	Blatz et al., (2018); Geissbauer et al., (2016); Schumacher et al., (2016); Sheen and Yang (2018)
Organization	Openness towards change in adopting digital technologies	Blatz et al., (2018); Gamache et al., (2019); Goerzig et al., (2018); González-Varona et al., (2020)
	Implementation of strategy	Goerzig et al., (2018); Nick et al., (2019); Rafael et al., (2020)
People/ Employees	Digital skills, knowledge, and training	Goerzig et al., (2018); Horvat et al., (2018); Lichtblau et al., (2015); Majstorović et al., (2020); Schumacher et al., (2016); Schumacher et al., (2019); Schumacher and Sihn (2020); Szedlak et al., (2019)
	The openness of employees towards the adoption of new technologies	Eirich (2020); González-Varona et al., (2020); Majstorović et al., (2020)
	Degree of employee autonomy	Schumacher et al., (2019); Szedlak et al., (2019)
Technology	Application of digital technologies	Colli et al., (2019); Gamache et al., (2019); Goerzig et al., (2018); González-Varona et al., (2020); Majstorović et al., (2020); Schumacher et al., (2019); Trotta and Garengo (2019); Yıldırım et al., (2020)
Processes	The intelligence of processes *(i.e., automation, data exchange, real-time monitoring)*	Nick et al., (2019); Ramos et al., (2020); Schumacher et al., (2019); Schumacher and Sihn (2020); Szedlak et al., (2019)
Products	The digitalization of products *(i.e., smart products, innovation in products)*	Lichtblau et al., (2015); Majstorović et al., (2020); Nick et al., (2019); Rafael et al., (2020); Schumacher et al., (2016); Trotta and Garengo (2019);
Customers	Customer database	Caiado et al., (2021); Härting et al., (2019); Majstorović et al., (2020); Schumacher et al., (2016); Schumacher et al., (2019)
	Customer experience and interaction	Caiado et al., (2021); Gamache et al., (2019); Klohs and Sandkuhl (2020); Majstorović et al., (2020); Schumacher et al., (2019)

Strategy

The literature reviewed revealed that most studies (e.g., Goerzig et al., 2018; Horvat et al., 2018; Majstorović et al., 2020; Ramos et al., 2020; Schumacher et al., 2016; Szedlak et al., 2019) placed an essential emphasis on strategy as a key dimension in measuring the level of digital maturity. Schumacher et al. (2016) claimed that supporting digital transformation would require the strategy to include a roadmap of the implemented process, identify the resources available, and set out a clear plan for the business model adopted. This is in line with the findings of Majstorović et al. (2020), assessing strategy based on the implementation of a digital transformation roadmap. The authors also assessed strategy based on the process of designing new business models. Goerzig et al. (2018) supported the notion of strategy, describing it as a long-term orientation focusing on digitalization.

Leadership

The second dimension included by most of the studies is leadership (e.g., Blatz et al., 2018; Gamache et al., 2019; Ramos et al., 2020; Schumacher et al., 2016; Schumacher et al., 2019; Schumacher & Sihn, 2020). For example, Schumacher et al. (2016) assessed this dimension based on leaders' skills, competencies, and willingness, and whether central coordination of Industry 4.0 is present. Gamache et

al. (2019) agreed and added the direction and vision of the business, the development of new business models, and the presence of technological activities as additional parameters. Some authors (e.g., Blatz et al., 2018; Ramos et al., 2020; Schumacher & Sihn, 2020) argued that strategy and leadership should be unidimensional. Gamache et al. (2019) agreed with Blatz et al. (2018) that new business models are needed and that both strategy and leadership assess attitude towards digital transformation. Ramos et al. (2020) concurred that strategy and leadership indicate the tendency towards digital transformation; however, the authors added that this dimension should be directly associated with the culture dimension to measure if the digital transformation has become part of employees' daily working routine.

Culture

The literature review shows agreement among the authors (e.g., Gamache et al., 2019; Ramos et al., 2020; Schumacher et al., 2016; Sheen & Yang, 2018) that culture is another important dimension in measuring digital maturity. Gamache et al. (2019) argued that culture represents fostering innovation, continuous improvement and skills development, and the extent to which employees are open to change. This is in line with the definition of digital transformation as an ongoing process that changes how the business is conducted (Oestreicher-Singer & Zalmanson, 2011). González-Varona et al. (2020) claimed that a business at the forefront of digital transformation has a culture that is open towards change, a greater appetite for risk, and invests in the development of skills. Additionally, Schumacher et al. (2016) and Majstorović et al. (2020) assessed the degree of cross-collaboration, communication, level of innovation, and external collaboration within the organizational culture. Schumacher et al. (2016) reported the results using a radar chart, scoring the culture dimension among their sample relatively highly.

Organization

Some authors have combined the organization dimension either with culture (e.g., Blatz et al., 2018; Gamache et al., 2019; Majstorović et al., 2020) or strategy (e.g., Nick et al., 2019; Rafael et al., 2020). Goerzig et al. (2018), Horvat et al. (2018), and González-Varona et al. (2020) included organization as a separate dimension in their models. Goerzig et al, assessed the dimension based on the implementation of the strategy, opposed to Horvat et al. who merely evaluated the organization of production and logistics. González-Varona et al. assessed the openness and usage of digital technologies, changes within the value chain and structure, agility, and dynamic capabilities.

People/Employees

The reviewed studies used different terminologies for this dimension. For example, some studies referred to people (e.g., Majstorović et al., 2020; Schumacher et al., 2016; Trotta & Garengo, 2019), while others referred to employees (e.g., González-Varona et al., 2020; Rafael et al., 2020; Schumacher & Sihn, 2020). Nevertheless, the dimension is assessed similarly across the identified studies. The criteria included the level of digital skills, knowledge, training, the openness of employees towards the adoption of new technologies, the degree of employee autonomy, and employee development through knowledge transfer (Eirich, 2020; Goerzig et al., 2018; Majstorović et al., 2020; Nick et al., 2019; Schumacher et al., 2016; Szedlak et al., 2019). Horvat et al. (2018) measured interfirm cooperation and employee communication as separate dimensions, while Schumacher et al. (2020) focused on these two employee processes as a single dimension including value creation and administrational processes.

Technology

The technology dimension was included in most studies (e.g., Colli et al., 2018; González-Varona et al., 2020; Trotta and Garengo, 2019; Yıldırım et al., 2020). Within this dimension, we also noticed the use of different terminologies alongside various equivalent measuring criteria. Trotta and Garengo (2019), Gamache et al. (2019) and Colli et al. (2019) similarly measured the technology dimension by focusing on creating digital data using digital technologies such as big data, cloud computing, and intelligent tools. Horvat et al. (2018) measured the level of technology across different departments, such as research and development, production, purchasing, and in- and outbound logistics. Data management, which is also related to the concept of technology, was included in two studies (Brunner et al., 2020; Gamache et al., 2020), measuring the capturing, storing, processing, and quality of data used in the business. Brunner et al. (2020) also refer to this as big data, highlighting those different terminologies are used. Colli et al. (2018) and Szedlak et al. (2019) included connectivity as a single dimension that focuses on the data transfer within and outside the business, the level of communication between machines, real-time systems, and cloud computing. The literature review revealed that more recent studies measured specific technologies within the technology dimension, as opposed to grouping them together, as in some of the previously mentioned studies. Some authors (e.g., Brunner et al., 2020; Lichtblau et al., 2015; Nick et al., 2019; Rafael et al., 2020; Ramos et al., 2020) referred to smart products, smart operations, and smart factories, which assess the enablers of intelligent processes, products, and machines. For example, Nick et al. (2019) evaluated the smart factory for its ability to identify existing equipment and the future development plans of the production system. Lichtblau et al. (2015) assessed the smart factory based on data usage, IT systems, equipment infrastructure, and digital modelling. Authors evaluated smart operations based on information sharing, cloud usage, IT security, and the number of autonomous processes.

Processes

The processes dimension is measured across broad criteria by a few authors (e.g., Eirich, 2020; Nick et al., 2019; Ramos et al., 2020; Schumacher et al., 2019; Schumacher & Sihn 2020). For example, Nick et al. (2019) assessed processes intelligence from production, logistics, and IT perspectives. Blatz et al. (2018) evaluated processes in terms of the activities, tasks, and interdependencies within the business, focusing on the flexibility of the processes and fluctuations such as seasonal increases. Szedlak et al. (2019) included digital production, digital processes, and connectivity in their model, assessing, for example, information processing, cloud computing, machine-to-machine communication, and the decentralization of processes. Schumacher and Sihn (2020) considered various processes, such as employee value creation, administrational practices, and production and logistics.

Products

The review showed that several studies included products in the digital maturity measurement. The identified studies used several assessment methods; some referred to smart products (e.g., Lichtblau et al., 2015; Nick et al., 2019; Rafael et al., 2020; Schmitt et al., 2019), while others referred just to products (e.g., Schumacher et al., 2016; Trotta et al., 2019). Despite the different uses in terminology, the assessment of the dimension of the product is similar. It focuses on the level of innovation within the products, the customization of products, and the level of integration with all other systems, among other factors (Majstorović et al., 2020; Nick et al., 2019; Schumacher et al., 2016). Most authors assessed the IT add-on functionalities to products that enable adaptative and learning capabilities, track products during their life cycle, and present virtual product models (Lichtblau et al., 2015; Rafael et al., 2020; Trotta et al., 2019). Blatz et al. (2018) similarly argued that if a product needs to collect data, it should be equipped with the relevant digital technologies such as sensors, computing, and communication features.

Customers

The customer dimension was included in only a few studies (e.g., Caiado et al., 2021; Gamache et al., 2019; Härting et al., 2019; Klohs and Sandkuhl, 2020; Majstorović et al., 2020; Schumacher et al., 2016, 2019; Yıldırım et al., 2020). For example, Schumacher et al. (2016) and Majstorović et al. (2020) assessed businesses by whether a customer database existed and how this data was utilized, as well as the business's digitalization of sales and services. Geissbauer et al. (2016) and Klohs and Sandkuhl (2020) focused on the customer experience, interaction, and the degree to which a business understands the customer needs and can react to changes. Härting et al. (2019) focused on customer reviews and whether the business offers personalized propositions.

Discussion

In this systematic review, a total of 1,977 articles were screened according to a number of inclusion criteria. After final screening, 29 studies were found to be suitable for analysis and retained for inclusion in the present study. The review aimed to bring together research published in the past 10 years that could answer the following question: *Which dimensions are included in digital maturity models to measure the level of digitalization in business models of SMEs?* To answer this question, the authors first reviewed digital transformation and the related process, and how this process is measured, which can help to explain which dimensions are included in a digital maturity model. This was followed by a review of existing empirical research on the topic, synthesizing the findings of 29 studies. It is evident from the review, summarized in Table 2, that the dimensions included in the models are noticeably different across the 29 studies; however, there is agreement among several authors on the essential dimensions included in digital maturity models, as presented in Table 3. In addition, the parameters within each dimension differ significantly, as indicated in Table 4.

While existing findings provide crucial empirical evidence, we observed that several of the digital maturity models developed were for the manufacturing industry. This highlights a lack of empirical research that validates digital maturity models across industries. Blatz et al. (2018) argued that industries demand different parameters per dimension, and the weightings of these dimensions also differ. Thus, developing and validating digital maturity models across industries could also possibly highlight new additional dimensions and industry-specific parameters, which have practical implications for the industry in question. As demonstrated in the theoretical background to this study, to improve digital maturity, a business should engage with digital transformation across all business activities, and the process should be measured accordingly. Several authors suggest using KPIs as metrics, yet most studies included in the review did not mention key metrical elements. This offers future research opportunities to identify the key metrical elements that can measure the success of the dimensions and their parameters. The thematic synthesis of the review is presented in Figure 2 below, with a subsequent discussion that highlights several important insights about the dimensions and parameters of digital maturity models, allowing for several recommendations for further research.

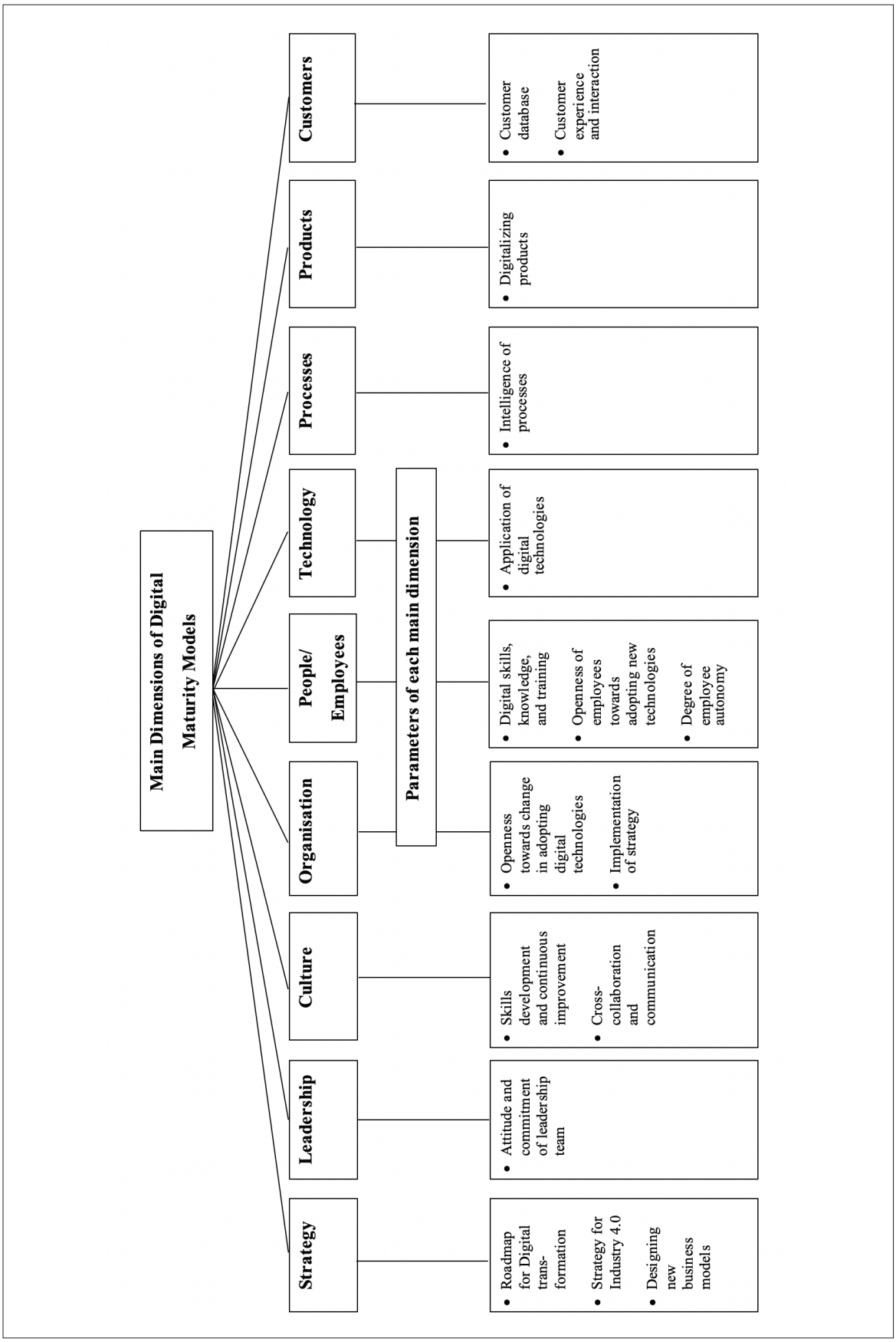


Figure 2: Overview of the research findings (Authors compilation)

Strategy

Firstly, several authors (e.g., Goerzig et al., 2018; Majstorović et al., 2020; Schumacher et al., 2016) identified strategy as one of the most common dimensions in digital maturity models. Designing and implementing a strategy is needed to plan out how a business can achieve its goals, such as digital transformation. Some authors highlighted the need for a digital transformation roadmap and designing entirely new business models. In addition, some authors claimed that the strategy should allow for the implementation of Industry 4.0 elements. Yet Blatz et al. (2018) and Szedlak et al. (2019) claimed that businesses should design a separate digital strategy and determine how it connects to the overall business strategy. Therefore, from the review, we cannot conclude whether a digital strategy is also required. This offers a future research opportunity to determine the need for an existing business strategy and a separate digital strategy.

Leadership

The second important dimension from the review is *leadership,* with several authors including this dimension (Blatz et al., 2018; Gamache et al., 2019; Ramos et al., 2020; Schumacher et al., 2016). Most of the authors who included this dimension argued that it is measured based on the attitude and commitment of the leadership team towards digital transformation and the opportunity to redesign the business model to accommodate digitalization. Yet, the lack of attention paid to business models in the review is noted as a significant gap in the literature. Teichert (2019) reported similar findings in his systematic review. Some authors claimed that strategy and leadership should be unidimensional, as the two are strongly related since the leadership team also drives the strategy. Ramos et al. (2020) further claimed that it should be directly associated with the culture dimension to determine if digital transformation has become part of the culture.

Culture

Following this, *culture* is the next dimension included by several authors (e.g., Gamache et al., 2019; Ramos et al., 2020; Sheen & Yang 2018). A business that seeks to transform its business model through implementing digital technologies will require a culture that is open to change and more risk orientated, and it will need to invest in skills development (González-Varona et al., 2020). The review indicated that this dimension is measured based on the importance that businesses place on employees' continuous improvement and skills development. Digital transformation requires employees to possess the relevant digital and analytical skills that will enable them to use digital technologies, analyze digital data such as product information, customer reviews, and feedback. Therefore, the review has identified skills development as a crucial parameter within the culture dimension. This is an ongoing process as technology advances and new skills are required. In addition, cross-collaboration and communication is another important parameter that enables employees to work across departments and share and access information across platforms; however, the business should implement the relevant digital technologies to allow for this.

Organization

The *organization* is the fourth dimension included in some of the studies reviewed (e.g., Blatz et al., 2018; Gamache et al., 2019; Rafael et al., 2020); however, these studies either combined it with culture or strategy, with few studies including it as a separate dimension. The review found that the parameters used to measure this dimension varied across the studies. Some studies used this dimension to determine if the strategy had been successfully implemented, while other studies measured the degree of openness towards adopting digital technologies. Due to variations in parameters within this dimension, we suggest that more research be performed. This will provide a comprehensive view of the parameters and the possibility of combining them with another dimension, as some authors have previously done.

People/Employees

Another important finding is the *people/employees* dimension (e.g., Majstorović et al., 2020; Schumacher et al., 2016; Trotta and Garengo, 2019). This dimension strongly relates to every other dimension – as Westerman (2016) put it, digital transformation needs a heart, and employees are the ones that make businesses work. Szedlak et al. (2019) claimed that employees' openness towards and willingness to enforce change forms a crucial basis for digital transformation. Goerzig et al. (2018) emphasized that employees' qualifications, training, and level of motivation play an important role. These parameters are measured in both the culture and organization dimensions. Yet many other authors have included a variety of parameters in measuring the people/employee dimension. This indicates a lack of consensus among the authors in the review, calling for more research on this dimension.

Technology

Digital transformation is about the implementation and adoption of digital technologies, in line with the findings of this review, which identified *technology* as an essential dimension (e.g., Colli et al., 2018; Trotta and Garengo, 2019; Yıldırım et al., 2020). Interestingly, most studies that included this dimension developed a digital maturity model for the manufacturing industry. Angreania et al. (2020), who also conducted a systematic literature review, reported similar findings. Due to the lack of available digital maturity models for other industries, the technology dimension mainly reflects the manufacturing sector driven by Industry 4.0. This calls for more research to confirm if this dimension plays an equally important role in other industries.

Processes

Some studies included processes as a separate dimension (e.g., Eirich, 2020; Nick et al., 2019; Ramos et al., 2020; Schumacher & Sihn, 2020). These authors assessed the intelligence of the processes, which strongly relates to the technology dimension. These findings therefore suggest that the technology and processes dimension can be combined, since the studies included in the review measured the technology functionality of processes.

Products

The review further identified that several studies included the products dimension (Lichtblau et al., 2015; Rafael et al., 2020; Schumacher et al., 2016; Trotta & Garengo, 2019). In light of digital transformation, the products dimension is measured based on product customization and the level of innovation applied to the design of products. Also measured are the IT add-on functionalities that, for example, will allow the product to collect data. Customers can also view virtual models to track their products. Therefore, this dimension is closely related to the technology dimension, but a clear distinction must be made between the parameters.

Customers

The products dimension is closely associated with the final dimension, *customers.* An interesting finding is that only a few studies included this dimension (e.g., Caiado et al., 2021; Gamache et al., 2019; Härting et al., 2019; Klohs & Sandkuhl, 2020; Majstorović et al., 2020; Schumacher et al., 2016; Schumacher et al., 2019; Yıldırım et al., 2020). The authors of those studies measured whether a customer database existed, the customer interaction, experience, and whether the business understood the needs of customers and could adapt based on changing customer needs. It became clear that this relates to the products dimension that measures, for example, the ability for customers to track their product, contributing to the overall customer interaction and experience. These findings agree with various other authors (e.g., Carcary et al., 2016; Latifi et al., 2017; Spieth & Schneider 2016), who argued that products and customers are drivers of digital transformation and business model redesign. In conclusion, the customer dimension is crucial in digital maturity models, as one of the main goals of a business is to satisfy the customer's needs. All the other dimensions contribute to customer satisfaction and therefore cannot be excluded in measuring the overall digital maturity of a business. However, due to the limited number of studies that included the customers dimension, further research is needed to determine which parameters would best measure this dimension.

Managerial Implications

Globally, SMEs are considered significant contributors to economic growth and job creation. Therefore, SMEs must stay abreast of market changes, particularly rapid technological changes, to ensure a sustainable and competitive position. However, SMEs are lagging in the adoption of digital technologies. Digital maturity enables SMEs to measure and assess their current position regarding digitalization. Yet, this study aimed to address a lack of knowledge on how this can be measured. The findings of this study have several important implications. Firstly, the study identified that (1) strategy, (2) leadership, (3) culture, (4) organisation, (5) people/employees, (6) technology, (7) processes, (8) products, and (9) customers are the main dimensions that play a crucial role in the digital transformation process. However, as standalone dimensions, SMEs cannot accurately measure their level of digitalization. Secondly, this study identified the parameters that can be used to measure each dimension. SMEs can thus focus on these dimensions and parameters when potential gaps are identified in their level of digitalization and implement appropriate strategies to close these gaps. Thirdly, future studies can use these dimensions and parameters to construct and develop digital maturity models suitable for SMEs, as there is a significant gap in the literature. These digital maturity modules can be constructed for individual contexts such as South Africa, Latin America, Europe, Asia etc. Fourthly, digital skills and continuous employee training are critical; however, several developing countries, such as African and Latin American countries, need more digital skills. Policymakers can thus drive a national digitalization strategy aimed at improving the levels of digital technology adoption within SMEs and employees' digital skills. The digitalization strategy can also create awareness of the types of digital technologies and their advantages. Lastly, a culture change is essential to enable cross-collaboration between the public and private sectors that can open up several opportunities for SMEs. Research and development (R&D) institutions should work closely with SMEs during the R&D stage to support the transition from R&D to commercializing technologies within SMEs.

Limitations

Besides the various theoretical and practical implications provided in the previous sections, some limitations that are important for future research were also noted. The first limitation of the study is the databases chosen from which to source studies for review; only five databases were searched, possibly resulting in some studies' being overlooked. Secondly, the chosen keyword searches influenced the included studies, with many contributions using excluded synonyms. Lastly, we mainly focused on the dimensions and parameters, overlooking other areas within the models, and thus the scope of the research could be broadened. We encourage future research studies to extend these findings by drawing on various other databases in light of these limitations. In addition, the results can be enriched by including related keywords and topics such as digital disruption, digital business models, and digital convergence. Future research studies could examine the extent to which existing digital maturity models have been validated and seek to develop digital maturity models for several industries, other than the manufacturing industry, as this was highlighted as a gap in the findings. The literature review also presented other perspectives that have received little attention in the studies included in the review, such as the beneficial use of KPIs to measure digital maturity (Aslanova & Kulichkina, 2020; Verhoef et al., 2019). In addition, future research could determine if both a business strategy and digital strategy are required or whether these can be combined. The findings also suggest that future research could measure the culture and leadership dimensions to determine if the digital transformation has become part of the culture. In addition, future research should determine if the relevant digital technologies exist that enable the respective parameters. The findings suggest that the organization, people/employees, and products dimensions lack agreement on the included parameters, calling for more research. Lastly, due to the limited number of studies that included the customer dimension, future research should identify which parameters best measure this dimension.

Conclusion

The purpose of this study was to present a systematic literature review of studies on digital maturity models for SMEs published in the period 2011–2021. The researchers sought to answer the question: *Which dimensions are included in digital maturity models to measure the level of digitalization in a business model of SMEs?* The review identified the nine most common dimensions in existing digital maturity models: *strategy, leadership, culture, organization, people/employees, technology, processes, products,* and *customers.* In addition, the findings reported 16 parameters across the nine dimensions. These dimensions provide valuable insight into the most important aspects that contribute to the level of digitalization, allowing SMEs to focus on these dimensions when improving their level of digitalization. Simultaneously, the identified parameters complement this process by indicating how each of the nine dimensions can be measured, which is crucial for successfully measuring the level of digitalization. The review revealed that a limited number of studies had developed a digital maturity model with the business model in mind. In addition, the theoretical section of this paper highlighted the importance of KPIs, yet only a few studies included key metrical elements to measure digital maturity. The review also revealed that most studies developed digital maturity models for the manufacturing industry, excluding other industries. An interesting finding is that only a few studies included the customer dimension, despite its being one of the main goals of a business (i.e., satisfying the needs of customers). Future research on digital maturity models will benefit from conducting cross-industry research through validating digital maturity models in other industries besides the manufacturing industry. In addition, researching the use of KPIs to measure digital maturity is another avenue for future research due to its importance, as highlighted by several authors. The review calls for more research to determine whether a business strategy and digital strategy are required or whether they can be combined. Furthermore, future studies could assess the culture dimension alongside the leadership dimension to determine if digital transformation has become part of a business's culture. Simultaneously, future studies should assess whether the relevant digital technologies exist that enable the respective parameters. The research can also be extended by identifying additional parameters that best measure the organization, people/employees, and products dimensions. Lastly, future studies could identify the parameters that measure the customer dimension, since all nine dimensions contribute to the customer dimension, and it can therefore not be excluded. In conclusion, the review provides a holistic overview of existing digital maturity models, along with the most important dimensions and parameters that measure each dimension, which contribute to the measuring of the level of digitalization.

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Appendix

Table 2: Overview of the Reviewed Studies and Their Findings

Author(s)	Research focus	Maturity Model Name	Maturity Measurement	Dimensions Included	Maturity Stages
Angreani, Vijaya, and Wicaksono (2020)	Synthesis maturity models related to Industry 4.0	Science mapping	A review was conducted on existing maturity models.	Nine dimensions: • strategy • leadership • customers • products • operations • culture • people • governance • technology	N/A – A review was conducted
Blatz, Bulander, and Dietel (2018)	Investigated the digital maturity levels of SMEs and seeks to identify correlations of relevant factors	Structure of the model	A questionnaire was used to rate items on a 5-point Likert scale. The result of each dimension was weighted according to the relevance of the respective dimension regarding digital transformation.	Six dimensions: • strategy and leadership • company culture and organization • IT infrastructure • data maturity • process and operations • product use	Three levels: 1 – > 0 points 2 – > 2 points 3 – > 3 points
Brunner and Jodlbauer (2020)	The study developed a standardized maturity model.	Maturity model	Interviews were conducted and each dimension rated on a scale of 1 to 10, using sub-criteria for each.	Three dimensions: • data management • smart factory • digital transformation	Readiness level ranges from 1 to 10
Caiado, Scavarda, Gavião, Ivson, de Mattos Nascimento, and Garza-Reyes (2021)	The study developed an Industry 4.0 maturity model for smart operations and supplies chain management (OSCM).	OSCM4.0 Maturity dimensions and indicators	A questionnaire with 15 indicators was used and divided into seven dimensions. A fuzzy expert system was used to process the results and was segmented into four stages. Each indicator was assigned a value between 0 and 100.	Seven dimensions: • customer • logistic • supplier • integration • production, three planning, and control • quality • maintenance	Four levels: 0 – Non-existent 1 – Conceptual 2 – Managed 3 – Advanced 4 – Self-optimized
Colli, Madsen, Berger, Møller, Wæhrens, and Bockholt (2018)	The study illustrated a new digital maturity assessment approach, based on the problem-based learning model.	360-degree Digital Maturity Assessment	A questionnaire with 50 indicators was used. The answers were mapped according to the definitions of the different maturity stages.	Five dimensions: • technology • connectivity • competences • value creation • governance	Six stages 1 – None 2 – Basic 3 – Transparent 4 – Aware 5 – Autonomous 6 – Integrated
Eirich (2020)	The study developed and adapted existing theories and frameworks regarding digital innovation. The adjusted model was then validated.	Adjusted STAR Model	Interviews were conducted on case studies; the case studies were coded by topics and sub-themes based on the extended STAR Model. The results were analyzed using MAXQDA, a qualitative software program.	Five dimensions: • strategy • structure • processes • people: staffing and knowledge • legacy	Three stages 1 – Low 2 – Medium 3 – High
Ekuobase and Olutayo (2016)	The study measured the information communication technology (ICT) maturity, and value of Nigerian service businesses.	ICT maturity index (ICTMI)	A questionnaire was used to collect data on the ICTMI of Nigerian businesses, after which a formula was used to calculate the maturity level. The results were then mapped to the ICT maturity levels.	Four dimensions: • infrastructure • application • human resource • policy	Five levels 1 – Inactive 2 – Basic 3 – Substantial 4 – Web-based 5 – Knowledge oriented

Author(s)	Research focus	Maturity Model Name	Maturity Measurement	Dimensions Included	Maturity Stages
Gamache, Abdul-Nour, and Baril (2019)	The study developed a model that evaluates digital performance and assesses the impact of specific parameters, based on a literature review and case studies.	Digital performance evaluation model	109 pre-set questions concerning the 24-digital performance sub-dimensions were rated on a 4-point Likert scale. A quantitative value for the maturity level was calculated.	Six dimensions: • leadership • culture and organization • technology • data management • measurement system • customer experience	A single quantitative value is assigned
Geissbauer, Vedso, and Schrauf (2016)	The study developed a blueprint for implementing Industry 4.0 based on the findings of first-mover companies.	PwC maturity model	Interviews were conducted with companies to identify Industry 4.0 capabilities placed across seven dimensions and four stages within which organizations can position themselves.	Seven dimensions: • digital business models and customer access • digitization of product and service offerings • digitization and integration of vertical and horizontal value chains • data & analytics as core capability • agile IT architecture • compliance, security, legal and tax • organization, employees and digital culture	Four stages 1 – Digital novice 2 – Vertical integrator 3 – Horizontal collaborator 4 – Digital champion
Goerzig, Luckert, Aichele, and Bauernhansl (2018)	The study developed a model based on product development analysis of innovative SMEs.	Working fields	A questionnaire was used to identify the approaches used in the digital product development of German engineering businesses.	Four dimensions: • strategy • organization • technology • people	Four levels 1 – Digitized customer 2 – Digital accelerator 3 – Digital natives 4 – Digital leadership
González-Varona, Acebes, Poza, and López-Paredes (2020)	The study developed a proposed model for SMEs based on a literature review on digital transformation, organizational competence, and the most relevant digital capabilities.	Organizational Competence for Digital Transformation (OCDT)	An in-depth analysis of the literature review was conducted to describe the enablers for advancing the digitalization of companies. The results were used to develop the OCDT model.	Five dimensions: • culture • organization alignment • technology • employees • governance	None
Härting, Reichstein, Haarhoff, Härtle, and Stiefl (2019)	The study investigated the digitalization capability of the tourism industry in South Africa and identified the main driving forces of digitalization.	Structural equation modelling (SEM) to examine the capability of digitalization	The hypothesis was tested through a questionnaire based on a 5-point Likert scale.	Six dimensions: • sales increase • sharing economy • process costs • personalized offers • social media • customer reviews	None
Horvat, Stahlecker, Zenker, Lerch, and Mladineo (2018)	The study presented a comprehensive conceptual approach that systematically analyzed and monitored the readiness of manufacturing companies in emerging economies.	The path towards readiness for Industry 4.0	Interviews and questionnaires were used to collect data. Based on the results, each company was assigned to one of the four maturity stages	Five dimensions: • technology • organization • management and strategy • employees and intra-organizational communication • inter-organizational cooperation	Four stages: Stages 1–4 measured for each dimension

Author(s)	Research focus	Maturity Model Name	Maturity Measurement	Dimensions Included	Maturity Stages
Klohs and Sandkuhl (2020)	This study provided an overview of digitalization within SMEs.	Systematic mapping	A systematic mapping study was conducted to categorize the identified literature and identify possible research gaps.	12 dimensions: • customer experience • product innovation • strategy • organization • process digitalization • collaboration • information technology • culture and expertise • transformation management • leadership • governance • network partners (suppliers)	N/A – A literature search was conducted
Lichtblau, Stich, Bertenrath, Blum, Bleider, Millack, Schmitt, Schmitz, and Schröter (2015)	The study examined companies in the fields of mechanical and plant engineering, identifying their motivating factors and comparing SMEs with large organizations.	Readiness model	A questionnaire was used to measure Industry 4.0 readiness using a six-level model.	Six dimensions: • strategy and organization • smart factory • smart operations • smart products • data-driven services • employees	Six levels: 0 – Outsider 1 – Beginner 2 – Intermediate 3 – Experienced 4 – Expert 5 – Top performer
Majstorović, Mitrović, and Mišković (2020)	The study developed a model for assessing the maturity and readiness of manufacturing organizations to implement Industry 4.0 initiatives.	Model of assessment	A questionnaire was used for each dimension using a 5-point Likert scale. The data were used to calculate the coefficient for each dimension using a formula.	10 dimensions: • strategy • culture of the organization • leadership • customers • suppliers • products • technology • people • Industry 4.0 framework • governance	Four levels: 1 – Beginners 2 – An established project 3 – Roadmap 4 – All elements have been implemented
Nick, Szaller, Bergmann, and Várgedő (2019)	The study examined the Industry 4.0 readiness of Hungarian companies.	Industry 4.0 ecosystem map	A questionnaire with 99 questions was used to collect the data, after which each answer was converted to a simple scalar number (point).	Six dimensions: • strategy and organization • smart factory • intelligent processes • smart products • services based on product data • employees	Two levels
Rafael, Jaione, Cristina, and Ibon (2020)	This study developed a model based on previously validated models.	General Maturity Model	Semi-structured interviews were conducted, and a score of 0–5 assigned to each sub-dimension.	Six dimensions: • employees • smart products • smart operations • data-driven • smart factory • strategy and organization	Six levels: Level 0–5 is measured for each dimension

Author(s)	Research focus	Maturity Model Name	Maturity Measurement	Dimensions Included	Maturity Stages
Ramos, Loures, and Deschamps (2020)	The study developed a model based on nine companies from southern Brazil.	Industry 4.0 Maturity and Readiness Model	Interviews were conducted with nine companies using questionnaires from which the maturity index was calculated.	Eight dimensions: • innovation culture • strategy and leadership • smart factory • agile and modular management • governance and processes • digital infrastructure • smart logistics • smart product and services	Three levels: Very low – Absence Low – Existence Average – Survival
Sandkuhl, Shilov, and Smirnov (2019)	The study identifies the factors of digital transformation projects and the interrelationships of these factors, using an illustrative example.	A multi-aspect digital transformation ontology	A literature search was conducted to identify the factors of digital transformation.	Eight dimensions: • strategy • leadership • customers • culture • products • people • operations • governance • technology	N/A – A literature search was conducted
Schmitt, Schmitt, and Engelmann (2019)	The study conducted a literature review to gain an overview of Industry 4.0 projects in recent scientific publications.	Grouping of core elements	A comparison was made between the selected studies in the literature review, based on the Capability Maturity Model Integration for Development (CMMI-DEV) and the applicability to SMEs.	Six dimensions: • governance • products and services • strategy • processes • organization • information technology	N/A – A literature search was conducted
Schumacher and Sihn (2020)	The study provided a digitalization and automation (DA) implementation monitoring system using 143 developed KPIs.	DA-implementation monitoring system (DAIMS)	A questionnaire with 65 questions was developed using a 13-point Likert scale to measure the 143 KPIs of each of the nine dimensions.	Nine dimensions: • strategy and leadership • product and customer contact • employees value creation processes • employee administrational processes • production planning and control • production processes shop floor • logistics process shop floor • procurement and supplier contact • cyber security	A single quantitative value was assigned for each dimension
Schumacher, Erol, and Sihn (2016)	The study identified and extended dominating technology focus models by adding organizational aspects.	Industry 4.0 Maturity Model	Each dimension was measured on a 4-point Likert scale. The maturity level was then calculated using a formula of the weighted average of each dimension.	Nine dimensions: • products • customers • operations • technology • strategy • leadership • governance • culture • people	Five levels: Levels 1–5 measured for each dimension, where Level 1 describes a complete lack of attributes supporting Industry 4.0, and Level 5 represents the state of the art of the required attributes.

Author(s)	Research focus	Maturity Model Name	Maturity Measurement	Dimensions Included	Maturity Stages
Schumacher, Nemeth, and Sihn (2019)	The study provided a procedure model that can guide manufacturing companies through their Industry 4.0 journey.	Industry 4.0 realization model	A questionnaire with 65 items was divided into eight dimensions. The results ere statistically analyzed using the software package Tableau, in which a formula is used to assess the overall maturity and for every dimension.	Eight dimensions: • technology • products • customers and partners • value creation processes • data and information • corporate standards • employees • strategy and leadership	Four levels: Level 1–4 measured for each dimension
Sheen and Yang (2018)	The study provided an assessment method to measure manufacturing innovation related to Industry 4.0 and smart factory.	Assessment model for smart manufacturing and innovation	A 5-point Likert scale was used to measure eight criteria factors	Two dimensions: • smart factory facilities • strategy and culture	Five levels: 1 – Not prepared at all 2 – Environment/ system is set up in a limited range 3 – Environment/ system is set up in several areas and is being executed in a limited range 4 – Environment/ system is set up in most areas and is being executed in several areas 5 – Environment/ system is set up in all areas and is being executed actively
Szedlak, Leyendecker, Reinemann, and Pötters (2019)	This study proposed a digital maturity assessment for SMEs.	QuickCheck Digitalization (QCD)	Expert interviews were conducted with 38 SMEs regarding the key problems in implementing digitalization. This resulted in the development of the QCD. The model was then validated on the same SMEs using interviews.	Six dimensions: • business model and strategy • human capital and people • digital production • digital processes • connectivity • knowledge management	Six levels: 1 – represents a state of missing all the attributes to constitute the concepts of digitalization 6 – on the other hand, it represents a reasonable state of the art
Trotta and Garengo (2019)	The study developed a maturity scale based on a review of existing Industry 4.0 maturity models.	Dimensions' Goal	A questionnaire was used to measure each dimension using a 5-point Likert scale.	Five dimensions: • strategy • technology • production • products • people	A single quantitative value was assigned for each dimension
Xia, Jiang, Yang, Zheng, Pan, Shuai, and Yuan (2019)	This study proposed a model to measure the smart manufacturing capabilities and performance of a company.	Smart manufacturing capabilities measurement model	Questionnaires and interviews were used, along with a fuzzy comprehensive evaluation method (FCEM) to evaluate the smart manufacturing capabilities. This was then mapped to one of the six levels.	Seven dimensions: • design • production • supply chain • marketing and sale, service • financial management • quality management	Six levels: 1 – Entry level 2 – Low level 3 – Medium level 4 – High level 5 – Expert level 6 – Master level
Yıldırım and Demirbağ (2019)	The study explored the current Industry 4.0 practices of two Turkish white goods manufacturing companies.	The Digital Maturity Model	Structured expert interviews were conducted. The results were then analyzed as a comparative case study. The questions used a 5-point Likert scale, of which the maturity levels were calculated as a percentage.	Four dimensions: • culture • organization • technology • customer insights	A single quantitative value was assigned

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