DIGITAL TRANSFORMATION MATURITY: A SYSTEMATIC REVIEW OF LITERATURE

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Abstract

The goal of this paper is to present contemporary developments in the field of digital maturity models. By conducting a systematic literature review finally 24 relevant studies including 22 different models were identified and various characteristics of different digital maturity models were extracted. Focus was placed on the dimensions used to measure digital maturity in different model approaches. Special light was shed on organizational culture and to what extent it is represented in the models. Among other things, the findings indicate, that dimensions applied in various models can be very different and that just a few models incorporate transformational in addition to digital capabilities. In particular, organizational culture as a dedicated dimension of digital maturity is represented already in a few models, which indicates the growing importance of culture as an enabler of digital transformation efforts. Beside a comprehensive overview of the most widely used dimensions measuring digital maturity, a synthesis of the most frequently addressed cultural attributes is presented in this paper as well. This review finally reveals that most of the existing models give an incomplete picture of digital maturity, that cultural attributes reflecting a digital culture are not integrated systematically, and that digital maturity models specific to the domain of services are clearly under-represented. It also clearly demonstrates that research about digital transformation maturity as a holistic concept is scarce and needs more attention by research in the future.

Keywords: systematic literature review, digital transformation, digital maturity, digital maturity models, digital transformation maturity, digital culture

INTRODUCTION

In the digital age, the environment of organizations is changing faster and has become more volatile, uncertain and complex than in the past. Rapid changes in competition, demand, technology and regulations make it more important than ever for organizations to be able to respond and adapt to their environment. In this context, the pressure on firms for aligning their business strategy with the technological changes in the environment has significantly increased with the emergence and growing importance of new digital technologies, such as Social Media, Cloud Computing, Big Data and Analytics, Embedded Devices, 3D-Printing, the Internet of Things, and Artificial Intelligence. They are profoundly transforming the strategic context of organizations: changing the structure of competition, the behaviour and expectations of customers, the way business is conducted, the way products are manufactured and services are delivered, the way of working and, ultimately, the nature of entire industries (Fichman *et al.*, 2014). Consequently, the phenomenon of digital transformation, notably the levers crucial for success and the hurdles critical to transformation efforts, have gained a lot of attention and interest from practitioners and researchers in recent years. In this regard, also the role of organizational culture as a roadblock or a catalyst

for digital transformation is moving more and more to the foreground and to the top of CEOs' agendas. Several surveys reported that company culture is considered as the number one hurdle to digital transformation (Goran *et al.*, 2016; Buvat *et al.*, 2017; Solis, 2017). Hence, cultural change is a prerequisite and can become a bottleneck for digital transformation, if not adapted properly. Especially in a volatile environment and its pressure to innovate, organizational culture must change and evolve (Sörensen, 2002). This suggests a dynamic view of culture, which defines an adaptive organizational culture as an inherent attribute by which cultures change and respond to environmental changes (Kotter and Heskett, 1992). Therefore it can be argued that adaptive attributes of culture can positively influence progress of digital transformation efforts.

Digital transformation itself simultaneously affects multiple areas of an organization. Several stakeholders have to be involved in defining a transformation strategy. All these groups need a common and consistent understanding of the relevant areas to be addressed and the prioritization of digital transformation activities (Berghaus and Back, 2016). Therefore managers need to understand the current state with regard to digital transformation of their organization and "need to define action items for their transformation roadmap, prioritize between different activities and develop a strategic vision for the digital age" (Berghaus and Back, 2016). Consequently, the need to systematically assess an overall status of digital transformation and to map an effective path towards a desirable future digital maturity state is significantly growing in organizations. Digital maturity matters for companies because there is evidence that firms with a higher level of digital maturity outstrip industry competitors along different dimensions of financial performance (Westerman *et al.*, 2012).

A digital maturity model can assist management and employees in developing a clear roadmap for their transformation activities in order to improve the level of digital maturity. In recent years, an unclear number of various maturity models have been developed to conceptualize and assess digital maturity in organizations with the intention to effectively manage and guide digital transformation. Although previous reviews of digital maturity models have already been conducted (Chanias and Hess, 2016; Remane and Hanelt, 2017; Canetta *et al.*, 2018), there is still a lack of understanding what the most common maturity dimensions used across existing models are. Chanias and Hess (2016) also stated that there is a content-related (e.g. underlying dimensions) heterogeneity of the different digital maturity models. In addition, there is indication that a lot of models are too generic in nature to be applied to any particular industry and as such

are not designed to offer specific guidance (Valdez-de-Leon, 2016). Moreover, none of the previous reviews investigated the aspect of company culture as a dimension of digital maturity, even though there is evidence that culture is the number one hurdle to digital transformation (Goran *et al.*, 2016; Buvat *et al.*, 2017; Solis, 2017). In the light of this, a systematic literature review is carried out with the following questions guiding the review:

1. Who is driving the development of digital maturity models – practitioner or academic?
2. What are the different domains (industrial contexts) addressed by digital maturity models?
3. What are the most common maturity dimensions used in digital maturity models?
4. To what extent is organizational culture represented and which cultural attributes are addressed in digital maturity models?

MATERIALS AND METHODS

Defining Digital Transformation & Digital Maturity

Digital Transformation

Currently, there is no commonly accepted definition for the term "digital transformation" (Schallmo *et al.*, 2017). The term "transformation" expresses a fundamental change within the organization, which impacts strategy, structure (Matt *et al.*, 2015) and the distribution of power (Wischnevsky and Damanpour, 2006). Digital transformation itself can be seen as an ongoing process of adoption to a significantly changing digital landscape in order to meet the digital expectations of customers, employees and partners. This process of adoption has to be actively designed, initiated and executed (Berghaus and Back, 2016; Kane *et al.*, 2017). McKinsey developed a definition which states that digital is less about any one process and more about how companies run their business (Dörner and Edelman, 2015). Their definition of "digital" can be broken down into three areas: creating value at the new frontiers of the business world, optimizing the processes that directly affect the customer experience, and building foundational capabilities that support the entire overall business initiative. The implementation of technologies in business processes is only a small part of digitally transforming a business. Moreover, digital technologies need to create additional value for the customers, the business itself, and other essential stakeholders (Schallmo and Williams, 2017). For a successful digital transformation, companies have to focus on two complementary activities: reshaping customer value propositions and transforming their operations using digital technologies for greater customer interaction and collaboration (Berman, 2012). Henriette *et al.* (2016)

propose defining the digital transformation as a disruptive or incremental change process. It starts with the adoption and use of digital technologies, then evolving into an implicit holistic transformation of an organization. Morakanyane *et al.* (2017) compared several definitions of digital transformation (Liu *et al.*, 2011; Bharadwaj *et al.*, 2013; Fitzgerald *et al.*, 2013; Lucas *et al.*, 2013; Mithas *et al.*, 2013; Westerman *et al.*, 2014; Henriette *et al.*, 2015; Piccinini *et al.*, 2015; Schuchmann and Seufert, 2015; Chanias and Hess, 2016; Hess *et al.*, 2016) and proposed that digital transformation is "an evolutionary process that leverages digital capabilities and technologies to enable business models, operational processes and customer experiences to create value". Overall, the definitions of Henriette *et al.* (2016) and of Morakanyane *et al.* (2017) are proposing good definitions of digital transformation. Especially the definition of Henriette *et al.* (2016) underlines that in the context of using and adopting digital technology a holistic transformation of an organization is required in order to create value.

Digital Maturity

The term "maturity" refers to a state of being complete, perfect or ready (Lahrmann *et al.*, 2011) and is the result of progress in the development of a system. Maturing systems (e.g. organizations) improve their capabilities over time towards the achievement of some desirable future state. Sometimes digital transformation and digital maturity are used interchangeably without considering differences (Leipzig *et al.*, 2017), but digital maturity can be seen more as a systematic way for an organization to transform digitally (Kane *et al.*, 2017). Hence the term "digital maturity" specifically reflects the status of a company's digital transformation (Chanias and Hess, 2016). It describes what a company has already achieved in terms of performing transformation efforts and how a company systematically prepares to adapt to an increasingly digital environment in order to stay competitive. Digital maturity goes beyond a merely technological interpretation simply reflecting the extent to which a company performs tasks and handles information flows by IT, but also reflects a managerial interpretation describing what a company has already achieved in terms of performing digital transformation efforts including changes in products, services, processes, skills, culture and abilities regarding the mastery of change processes (Chanias and Hess, 2016). Thus, digital maturity comprises a technological and a managerial aspect and therefore can be seen as a holistic concept. Organizations reach the highest level of maturity when they have both a strong digital foundation and a good understanding of how to leverage this foundation for a strategic business advantage (Shahiduzzaman *et al.*, 2017). Moreover, digital maturity is not a static concept because the digital landscape is continuously changing. As such, an organization will need to assess maturity over time (Shahiduzzaman *et al.*, 2017). In this systematic literature review, the term "digital transformation maturity" is used to reflect the connection between the concept of "digital transformation" and "digital maturity" and to underline that digital maturity is a holistic concept reflecting a technological and managerial aspect.

Digital Maturity Model

A maturity model provides some guidance on how organizations approach their transformation and maps out typical paths of how organizations go about their transformation (Berghaus and Back, 2016). Maturity models can be seen as a tool that mainly enables an assessment of the status-quo (Becker *et al.*, 2009) and indicates a potential, anticipated or typical development path to the desired target state (Pöppelbuß and Röglinger, 2011; Paulk *et al.*, 1993). Digital maturity models help companies to assess their ability to encounter digital transformation according to pre-defined dimensions. Especially in the case of transformation journeys can they assist in understanding the current state and the capabilities of an organization in effectively managing and guiding digital transformation efforts in a systematic way. Digital maturity models consist of dimensions and criteria which describe areas of action and measures in various levels which indicate the evolution path towards maturity (Berghaus and Back, 2016). A dimension is a specific, measurable and independent component which reflects a major, fundamental and distinct aspect of digital maturity and describes an area of action (de Bruin *et al.*, 2005). The definition for the term "maturity level" can be linked to the Capability Maturity Model. In that context, a maturity level consists of related specific and generic practices for a predefined set of maturity dimensions that can improve the organization's overall maturity. The maturity level of an organization provides a way to characterize its performance and can be defined as an evolutionary plateau for organizational maturity improvement. The terms "maturity stage" and "maturity level" can be used interchangeably.

Search Strategy

The primary tool used for preliminary search with keywords was Google Scholar, a freely accessible web search engine that indexes the full text or metadata of scientific documents across an array of publishing formats and disciplines. Other electronic databases were used to extract abstracts, and finally full texts in the following screening phases (Tab. I). The search process applied consists of four phases and was not restricted to a certain time period. All results of the first three search and

I: *Search process documentation*

Data source	Search process documentation
Google Scholar	• Date of search: 8 October 2018 – 29 October 2018 • Preliminary search by using defined keywords (Tab.II), not limited to a time period • First hit results sorted by relevance; most cited literature is ranked higher • All screening and search results are saved and retained in Google Scholar Library
ResearchGate, IEEE Xplore Digital Library, ScienceDirect, Emerald	• Retrieve and review abstracts in terms of inclusion criteria (secondary screening) • Retrieve and review full text in terms of inclusion criteria (final screening) • Final set of included studies documented ("characteristics of included studies & reports")
Reference lists	• Screening reference lists of already included papers • Retrieve identified papers (Google) • Review identified papers in terms of inclusion criteria • Final set of included studies documented ("characteristics of included studies & reports")

II: *Search terms used*

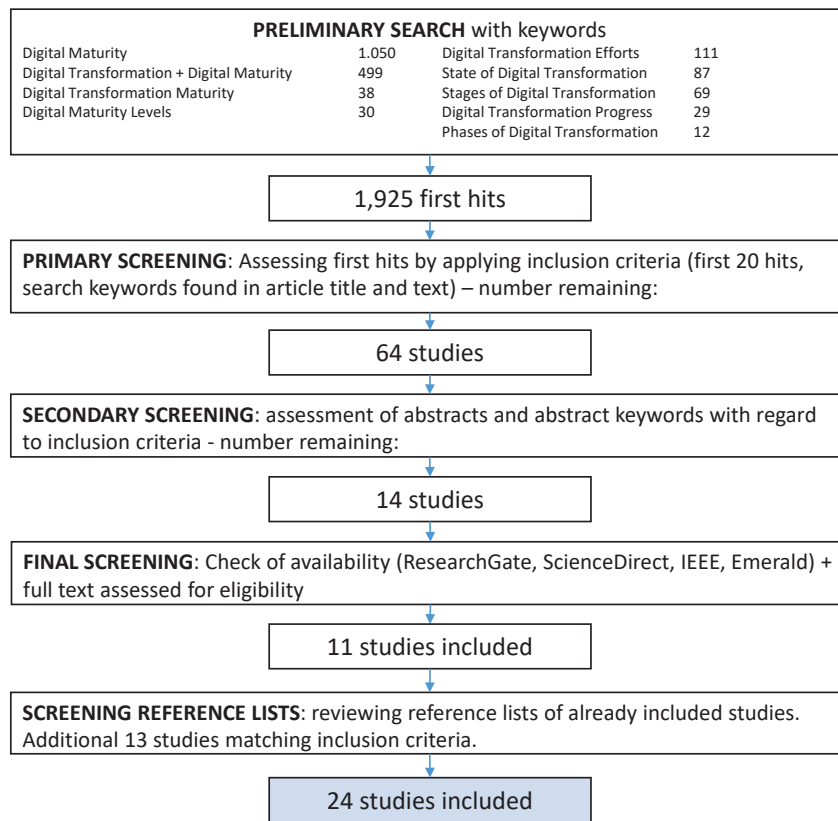| Search terms |
|---|
| "Digital Maturity" / "Digital Transformation" + "Digital Maturity" / "Digital Transformation Maturity" / "Digital Maturity Levels" / "Digital Transformation Efforts" / "State of Digital Transformation" / "State of Digital Transformation" / "Digital Transformation Progress" / "Phases of Digital Transformation" |

III: *Inclusion criteria used*

Screening phase	Inclusion criteria
Primary Screening	1. English language 2. Search keywords identified in the title or text of displayed search result 3. Not restricted to a time period 4. First 20 hits sorted by relevance 5. Industrial company context (B2B, B2C) 6. Scholarly literature (no text books) 7. No duplicates
Secondary Screening (abstracts, keywords)	1. A research article / study 2. Addressing digital transformation maturity in a company context 3. Conceptualizing digital transformation maturity
Final Screening (full text assessment for eligibility)	1. Full-text article available 2. Criteria used for Secondary Screening
Screening reference lists of the already included papers	1. Article is addressing the concept of digital maturity models 2. Papers describing digital maturity models

screening phases were saved and retained in the Google Scholar Library. Together with the results stemming from screening the reference lists of included studies, all finally included studies were documented in a separate overview reflecting characteristics of included studies and reports on digital transformation maturity.

Search terms that address the concept of digital transformation maturity (Tab. II) were used in order to identify applicable articles and papers. In the adopted search strategy, the buzz-word "digital transformation" was not used as a stand-alone search term, but in combination with words like efforts, progress, levels, stages, phases and maturity, with the intention of emphasizing the evolutionary aspect of maturing digitally. This search strategy generated 1,925 first hits sorted by relevance after running the preliminary search.

The first three screening phases for the final inclusion of articles and studies were guided by defined inclusion criteria (Tab. III). In the primary screening phase, only the first 20 search results were considered. Search results beyond those first 20 hits did not bring any additional valuable search results. Results were evaluated on their applicability by assessing, whether all used keywords were identified in the displayed title or text of the search result. After this initial screening phase, 64 studies were left. In the secondary screening stage, the abstracts and associated keywords of the remaining studies were evaluated on their eligibility with regards to the concept of digital transformation maturity. Of the remaining 14 papers, full texts were

PRELIMINARY SEARCH with keywords

Digital Maturity	1.050	Digital Transformation Efforts	111
Digital Transformation + Digital Maturity	499	State of Digital Transformation	87
Digital Transformation Maturity	38	Stages of Digital Transformation	69
Digital Maturity Levels	30	Digital Transformation Progress	29
		Phases of Digital Transformation	12

1,925 first hits

PRIMARY SCREENING: Assessing first hits by applying inclusion criteria (first 20 hits, search keywords found in article title and text) – number remaining:

64 studies

SECONDARY SCREENING: assessment of abstracts and abstract keywords with regard to inclusion criteria - number remaining:

14 studies

FINAL SCREENING: Check of availability (ResearchGate, ScienceDirect, IEEE, Emerald) + full text assessed for eligibility

11 studies included

SCREENING REFERENCE LISTS: reviewing reference lists of already included studies. Additional 13 studies matching inclusion criteria.

24 studies included

1: *Overview of search process*

retrieved, completely read and again checked for matching inclusion criteria. In the end, 11 eligible studies remained. To increase the reliability of the systematic literature review and to avoid missing important literature describing digital transformation maturity models and concepts, a complementary search was conducted. For this, the reference lists of the 11 included studies were screened, which resulted in 13 additional studies describing various digital maturity models. Finally, 24 studies were suitable for data extraction and were retrieved successfully from the used data sources (Tab. I).

The entire screening process and yielded results of the search strategy are illustrated in Fig. 1.

Data Extraction

From the final set of included studies, information regarding the characteristics of the study itself and the included digital maturity models was extracted. The 24 included studies represented 22 different digital maturity models. Special attention was placed on the model approach and the design parameters of the included models in order to better categorize and compare different approaches (Tab. IV). To gain insight, as to who was driving research about digital maturity over time, all studies were clustered into studies published by practitioners or academics.

With the purpose of taking the context and challenges of different industries into account, the included digital maturity models further were categorised into two model approaches: (i) models addressing a specific industrial domain, e.g. manufacturing, and (ii) models not developed for a specific industrial context which therefore can be considered as general models. This categorization enables a better understanding of which different domains are addressed by contemporary models and furthermore if various model approaches differ with regard to maturity dimensions used. All 22 included digital maturity models comprise

IV: *Used characteristics for data extraction*

Study	Model design	Model approach	Culture
Author Year of publication Journal Publisher	Dimensions and specific attributes (content) Number of maturity levels/stages Number of assessment items	Focus of model (domain, general) Application purpose (descriptive, prescriptive) Maturing approach (linear, non-linear) Application method (self-/ 3rd party assessment) Developed by practitioner or academic	Culture reflected in the model (yes/no)

125 maturity dimensions, out of which 41 are similar across all models and 84 have quite different and unique denominations, which makes comparability impossible. To gain a better insight into the meaning of maturity dimensions, all identified attributes which describe the dimension in more detail were extracted. This allowed for developing a nomenclature representing the most common maturity areas and facilitated mapping each of the 125 original dimensions. How often a common maturity area could be mapped with original dimensions of included models was counted and consequently resulted in a frequency per common maturity area. In a similar way, 25 different attributes related to culture across all models were identified and counted based on their occurrence across all models. All 25 identified attributes were clustered into main categories of cultural attributes (Tab. IX) in order to better analyse and compare them with other cultural models. In a next step, all identified attributes were mapped to the main categories. In this way, the frequency of occurrence of cultural categories could be evaluated.

RESULTS

Descriptive Results of Studies (n = 24)

The first hit results (Tab. V) for applied search keywords addressing the concept of digital maturity are significantly lower (1,925 first hits) than first hit results for "digital transformation" (25,400 first hits). This indicates in general that there is little scholarly literature available in the field of digital maturity compared to the field of digital transformation. With the specific keyword "digital transformation maturity", just 38 first hits were found, and during the screening process the number of eligible studies remaining for synthesis was reduced down to 3 studies. This evidences that there was less attention to this field in the past, and therefore academic research seems quite immature

in that area. Additional sources were identified by screening the reference lists of the 11 included studies (Canetta *et al.*, 2018; Remane *et al.*, 2017; Colli *et al.*, 2018; Chanias and Hess, 2016). Thus, 13 additional studies describing digital maturity models and concepts were identified and included in the final set of studies. All digital maturity models (n = 22) included in the final set of studies were clustered into the categories "practitioner" and "academic" and classified by specific characteristics (Tabs. VI–VII).

Most of the studies were published in the last 3 years, whereas nearly 40% of the included studies were published in 2016 (Fig. 2).

The first studies on digital maturity were published in 2011 and 2012. Both studies were developed by a practitioner (Friedrich *et al.*, 2011; Westermann *et al.,* 2012). The first study was measuring industry digitization across 15 different industry sectors and different business process dimensions. The study of MIT/Capgemini described a digital transformation maturity model which distinguishes between "digital intensity" and "digital transformation intensity" and defined 4 archetypes reflecting different levels of digital maturity. This study pointed out that beside IT capabilities also transformational capabilities are necessary for a successful digital transformation. Up to 2015, practitioners were driving the development of digital maturity models. Just one of the included studies was published by academics (Lichtblau *et al.*, 2015). Since 2016, academics have started to bring attention to this field of research, and since then, nearly 70% of the included studies have originated from academics. Overall, the included set of studies shows that slightly more digital maturity models have been developed by academics (12 models) than by practitioners (10 models) since 2011 (Fig. 3).

A domain-specific approach is reflected in 41% of all included models, whereas 78% (7 models) of all domain-specific digital maturity models are developed by academics, which underlines

V: *First hits of search process (n = 1,925) and final number of studies included (n = 11)*

| Search keywords	First hits	Studies included after 3 screening phases
"Digital Maturity"	1,050	5
"Digital Transformation" + "Digital Maturity"	499	0
"Digital Transformation Maturity"	38	3
"Digital Maturity Levels"	30	3
"Digital Transformation Efforts"	111	0
"State of Digital Transformation"	87	0
"Stages of Digital Transformation"	69	0
"Digital Transformation Progress"	29	0
"Phases of Digital Transformation"	12	0
	1,925	11

the increasing attention academics have started to place on research about digital maturity since 2015, driven by Industry 4.0 and the need for more specific and sophisticated models.

This also explains why the most-represented domain is "manufacturing" (89% of all domain-specific digital maturity models). There is only one included study on digital transformation maturity representing "telecommunication services". Clearly this shows that there is not sufficient focus on the service industry – neither by practitioners nor academics.

Nearly all included digital maturity models are descriptive in their nature and therefore limiting their scope to just assessing the level of digital maturity, but not giving guidance nor a clear road-map as to how to achieve a higher level of maturity (prescriptive). 13 models (59%) pursue a linear maturity approach, which means that they assume a linear evolutionary path for organizations pursuing digital transformation efforts. The rest reflect a non-linear maturity approach. The majority (78%, 7 models) of the non-linear digital maturity models represent a general model approach.

Assessing the level of digital maturity is carried out by means of self-assessment in 59% of the models. Models developed by practitioners – mostly consultants – tend to apply a third-party assisted assessment, because their intention is to identify

Included studies (n=24)
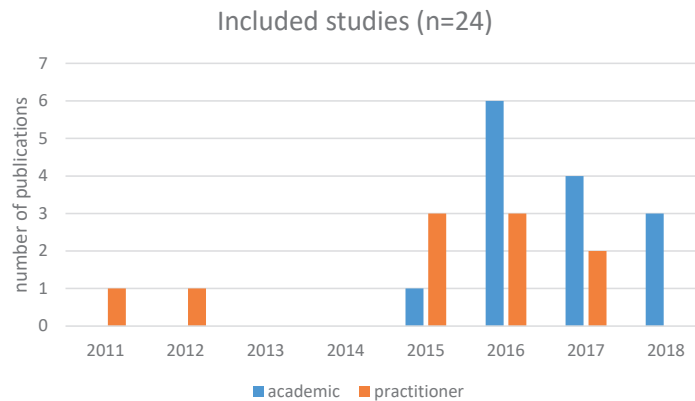
2: *Distribution of publications over time (n = 24)*

	General approach	Domain-specific approach
Academics	5 models (23%)	7 models (32%)
Practitioners	8 models (36%)	2 models (9%)

3: *Models clustered by originator and model approach (n = 22)*

VI: *Digital maturity models developed by practitioners*

PRACTITIONER				
Study	Model Character. (# dimensions/ # maturity levels)	Model approach (focus of model, maturing approach, application method)	Domain	Culture
Valdez-de-Leon (2016) [ ]	7 / 6 stages	Domain-specific, linear, self-assessment	Telecom Serv.	Yes
MIT / Deloitte (2017) [ ]	4 / 3 archetypes	General, n/a, n/a		Yes
MIT / Capgemini (2012) [ ]	6 / 4 archetypes	General, non-linear, self-assessment		No
PWC (2016) – Industry 4.0	7 / 4 stages	Domain-specific, linear, 3rd party assisted	Manufacturing	Yes
Forrester (2016)	4 / 4 archetypes	General, linear, self-assessment		Yes
McKinsey (2015)	4 / "Dig. Quotient"	General, non-linear, 3rd party assisted		Yes
Roland Berger (2015)	4 / "Digital Gap"	General, linear, 3rd party assisted	Industry sectors	No
Strategy&/Booz (2012)	4 / "Digitiz. Index"	General, linear, 3rd party assisted	Industry sectors	No
Neuland (2015)	8 / 5 stages	General, linear, 3rd party assisted		Yes
PWC (2017)	9 / 4 archetypes	General, non-linear, self-assessment		Yes

maturity gaps and offer consultancy services to close the gaps.

All included studies were proposing digital maturity models with different maturity-dimensions, stages and assessment items. Some models distinguish between two main areas, encompassing digital assets (e.g. digital capabilities, investments, digital infrastructure) and transformation enablers (e.g. vision, culture, leadership, governance, innovation or agility), clustering dimensions into these two domains (Westerman and MacAfee, 2012; Shahiduzzamann *et al.*, 2017). This underlines the importance of the managerial and "soft" aspect of digital transformation efforts. The number of dimensions describing digital maturity is different between the models and lies between 4 and 9, the number of stages of digital maturity lies between 4 and 6. The majority of the examined models (55%) use defined stages for describing maturity. Some models (23%) propose archetypes describing digital maturity, which in combination with two main dimensions depict the digital maturity of a company in a 2 × 2 matrix. A minor part of the models – mainly originated by consultants – uses a kind of digital index to describe digital maturity (Catlin and Scanlan, 2015; Oltmanns *et al.*, 2015, Friedrich *et al.*, 2011). Regarding organizational culture, the research identified that 55% of the examined models include "culture" as one of the maturity dimensions. The majority of the models developed by practitioners represent "culture" as a dimension (in 70% of the cases), but only 40% of models developed by academics reflect "culture" in their models.

Qualitative Analysis of Studies (n = 24)

Most Common Maturity Areas Identified

To understand and compare to which extent digital maturity areas get addressed, all original dimensions from the existing maturity models that have been analysed were clustered to the proposed "most common maturity areas" (Tab. VIII). In a next step all original dimensions were mapped to the most common maturity areas. Multiple mappings per dimension were possible, because dimensions and included attributes sometimes address several maturity areas. The frequency of original dimensions mapped to common maturity areas in domain-specific and general digital maturity models was evaluated and is depicted in Figs. 4, 5. The analysis shows that in domain-specific digital maturity models, "technology" is the most addressed maturity area, followed by "digital skills" and "operations & processes". Due to the lack of available digital maturity models of other industries, this ranking mainly reflects the manufacturing sector driven by Industry 4.0 and its strong emphasis on technology. Directly linked to this is the importance of digital skills and expertise required to be able to handle the technological complexity. The importance of process-automation and -flexibility is evidenced by the strong representation of the maturity area "operations & processes". This maturity area is – similar to domain-specific models – also strongly addressed in general maturity model approaches. A strong difference can be identified regarding the maturity-area "products & services", which is much more strongly addressed in domain-specific models than in models with a general approach. This reflects

VII: *Digital maturity models developed by academics*

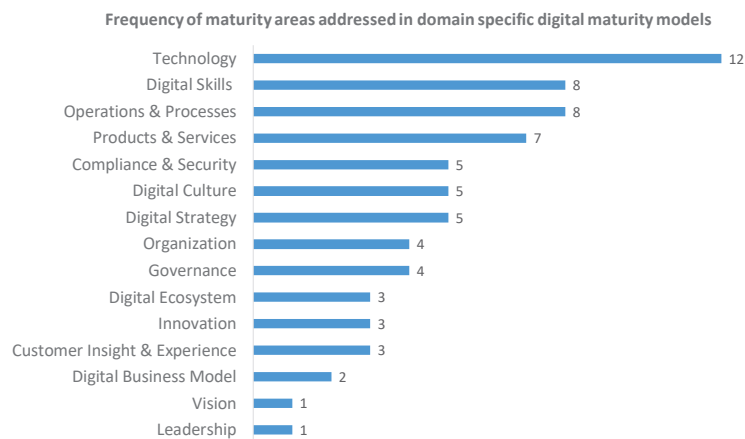|		ACADEMIC		
Study	Model Character. (# dimensions / # maturity levels)	Model approach (focus of model, maturing approach, application method)	Domain	Culture
Lichtblau *et al.* (2015)	6 /6 stages	Domain-specific, linear, 3rd party assisted	Manufacturing	No
Schuhmacher *et al.* (2016)	9 / 5 stages	Domain-specific, non-linear, self-assessment	Manufacturing	Yes
Colli *et al.* (2018)	5 / 6 stages	Domain-specific, non-linear, self-assessment	Manufacturing	No
Remane *et al.* (2017)	2 / 5 clusters	General, non-linear, self-assessment		No
Berghaus, Back (2016)	9 / 5 stages	General, linear, self-assessment		Yes
Canetta *et al.* (2018)	5 / n/a.	Domain-specific, non-linear, self-assessment	Manufacturing	No
Uhl, Gollenia (2016)	6 / 4 stages	General, linear, self-assessment		No
KPMG (2016)	7 / 4 archetypes	General, non-linear, self-assessment		Yes
Leyh *et al.* (2016)	4 / 5 stages	Domain specific, linear, 3rd party assisted	Manufacturing	No
A de Carolis *et al.* (2017)	4 / 5 stages	Domain-specific, linear, self-assessment	Manufacturing	No
Leino *et al.* (2017), VTT	6 / 4 stages	General, non-linear, self-assessment		Yes
Acatech (2017) [ ]	4 / 6 stages	Domain-specific, linear, 3rd party assisted	Manufacturing	Yes

the fact that in the domain of Industry 4.0, smart products and data-driven services play a critical role. It also highlights, that the aspect of "products & services" is clearly not of same relevance in general models because they apply to any industry.

At the same time, "innovation" gets much more attention in general digital maturity model, what underlines that the capability of an organization to develop new products and services i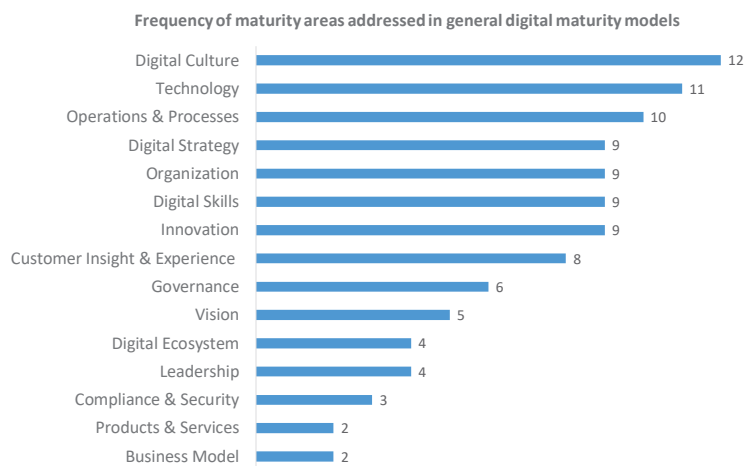s indicated there much more strongly. "Customer insight & experience" is also represented more strongly in general than in domain-specific digital maturity models, which could be an indication that the capability of understanding customers and designing an excellent customer experience is not seen as important in domain-specific models. Significantly more weight is placed on "Compliance & Security" in domain-specific than in general models. This is driven by the strong focus on "technology", which brings along IT compliance

VIII: *Most common digital maturity areas identified in included studies (n = 22)*

Maturity area	Attributes & characteristics
Digital Culture	Attributes enhancing digital transformation efforts: risk-taking, test & learn, no-blame culture, customer centric, open to change, agile, autonomy of employees, ...
Technology	ICT, IT architecture/systems and new digitalization-based IT systems, agility of supporting systems, digital data processing, ...
Operations & Processes	Process digitization and automation, flexibility/agility of processes, bringing processes to an industrialized standard, operations excellence, ...
Digital Strategy	Development/execution of a strategy using digital technology to do business in fundamentally new ways, bold long-term orientation, linked to business strategy, I4.0 roadmap, ...
Organization	Management structure/practices supporting digital business, cross-functional collaboration, digital skills embedded throughout the organization, roles/tasks related to digitalization defined, adequate resource allocation, cross-functional teams to implement digital business priorities, flexible communities, agile management, ...
Digital Skills	Digital skills, expertise, experience and interest; personnel dedicated to I4.0, ICT competencies of employees, data empowered decision making, openness to new technologies, employees have access to digital skills/expertise as needed, ...
Innovation	Capabilities enabling a more flexible/agile way of working, development of disruptive business models, using agile methods, involving customer into innovation process, funding innovation, innovation conducted regularly, ...
Customer Insight & Experience	Customer benefit from digitization; personalization of products/services; utilizing digital services to engage customers; focus on customer value; digitization of customer touchpoints; creating value out of data, customer participation and empowerment, ...
Governance	Ensuring comprehensive/reliable execution of digital strategy; everyone has a mandate to think creatively and innovate, systematic approaches are taken to innovation/change management, engagement on different hierarchical levels, standards and regulations, adequate resource allocation, ...
Vision	Organization has defined an initial digital vision; digital technology realizes the vision of the organization; all staff work in sync with the digital vision, ...
Digital Ecosystem	The organization works as a part of a digital ecosystem; digitization/integration of vertical/horizontal value chains, digital connection with the business network (e.g. through API), interoperable technology platforms enable new/highly customizable solutions configured by end-users, ...
Leadership	Leadership team learning new technologies, leaders have a compelling long-term vision, leaders actively identify and realize new opportunities, foster collaboration, existence of central coordination for I4.0 or digital transformation, ...
Compliance & Security	IT security, digital security, IT compliance within organization and towards stakeholders, assessing risk factors, risk management, IP, optimizing value-chain network for compliance; avoid unauthorized access, ...
Products & Services	Smart products/services, digitization of product/service offerings, data analytics deployed for individualization, data-based services, digital features, ...
Business Model	Development of new and disruptive business models, integrated customer solutions across supply chain, digital product/service portfolio with SW, network (M2M) and data as key differentiator, digital initiatives are generating value, business models are expanding, ...

Frequency of maturity areas addressed in domain specific digital maturity models

Technology	12
Digital Skills	8
Operations & Processes	8
Products & Services	7
Compliance & Security	5
Digital Culture	5
Digital Strategy	5
Organization	4
Governance	4
Digital Ecosystem	3
Innovation	3
Customer Insight & Experience	3
Digital Business Model	2
Vision	1
Leadership	1

4: *Frequency of maturity areas addressed in domain-specific models, n = 9*
Source: Included models, n = 22

Frequency of maturity areas addressed in general digital maturity models

Digital Culture	12
Technology	11
Operations & Processes	10
Digital Strategy	9
Organization	9
Digital Skills	9
Innovation	9
Customer Insight & Experience	8
Governance	6
Vision	5
Digital Ecosystem	4
Leadership	4
Compliance & Security	3
Products & Services	2
Business Model	2

5: *Frequency of maturity areas addressed general models, n = 13*
Source: Included models, n = 22

and IT/digital security topics. All maturity-areas of relevance for transformational capabilities of an organization (e.g. vision, leadership, digital culture, innovation, governance, ...), which leverage digital technology, are playing a more important role in general digital maturity models than in domain-specific ones. Both capabilities – digital and transformational capabilities – are needed in every organization to succeed in digital transformation efforts. This analysis gives some evidence that transformational capabilities are under-represented in domain-specific digital maturity models.

Cultural Attributes Addressed in Included Digital Maturity Models

To understand to which extent organizational culture is reflected in digital maturity models, main categories of cultural attributes were established (Tab. IX) by semantically clustering all 25 various attributes identified across all models. All original cultural attributes were counted with regard to their occurrence across all included models and finally mapped to the main categories of cultural

attributes. The addressed cultural categories ranked by their count are depicted in Fig. 6. Cultural attributes like "collaboration", "agility & flexibility" and "organizational learning" are most frequently addressed in the included digital maturity models. The ability of an organization to change and continuously reinvent itself is another critical attribute of a digital culture, along with failure and risk tolerance. "Ideating new digitalized working methods", "open communication" and "customer centricity" are also addressed frequently in the cultural dimension of the models. To some extent this is in line with a recent research study which was conducted in order to establish a definition of "Digital Culture" in a digital mature organization (Buvat *et al.*, 2017).

Building on an extensive research programme and the definition of a digital organization, "digital culture" was defined as a set of several key attributes (Tab. X).

The cultural attributes identified in the included digital maturity models (Fig. 6) show some conformity with the digital culture definition established in the

IX: *Main categories of cultural attributes identified*

Main culture categories	Original cultural attributes identified
Knowledge sharing	Sharing knowledge
Empowerment	Empowerment, decentralized decision making
Customer centricity	Centred around customer needs, customer focus and alignment
Open communication	Openness of communication, transparency
Ideating new digitalized working methods and services	Employees are encouraged to ideate new digitalized working methods/services, value of ICT in company, trust in processes and systems
Risk tolerance	Taking risks, risk appetite, risk tolerance
Failure tolerance	No-blame culture, failure tolerance
Change-ability	Open/willing to change ways of work, change ability, ability of organ. to constantly reinvent itself
Organizational learning	Learning from failures, test & learn, experimenting, organizational mutual/continuous learning
Agility & flexibility	Flexible working, speed, agility, quickly sensing/responding to changes in the environment, external orientation, flexibility
Collaboration	Collaboration across company boundaries, cross-company/functional collaboration

Ranking of main categories of cultural attributes

6: *Main categories of cultural attributes ranked by their count*

X: *Attributes of a digital culture*

Attributes of a "digital culture"	Description
Customer Centricity	The use of digital solutions to expand the customer base, transform the customer experience and co-create new products
Innovation	The prevalence of behaviours that support risk-taking, disruptive thinking, and the exploration of new ideas
Data-driven decision making	The use of data and analytics to make better business decisions
Open Culture	The extent of partnerships with external networks such as third-party vendors, start-ups or customers
Digital-first mindset	A mindset where digital solutions are the default way forward
Agility and Flexibility	The speed and dynamism of decision-making and the ability of the organization to adapt to changing demands and technologies
Collaboration	The creation of cross-functional, inter-departmental teams to optimize the enterprise's skills

Source: Buvat *et al.*, 2017

study of Buvat *et al.* 2017. Particularly cultural attributes reflected in the examined digital maturity models, like "collaboration", "agility & flexibility" and "customer centricity", also can be found as an attribute of a digital culture definition established by Buvat *et al.* 2017. Attributes like "failure tolerance", "risk tolerance" and "ideating new digitalized working methods and services" show some correlation to the behavioural attribute "innovation", which is also part of the digital culture model developed by Buvat *et al.* 2017. Innovation itself is well represented as a separate dimension of examined digital maturity models, but rather addresses the process and methods of innovation. Attributes like "open culture", "data-driven decision making" and "digital-first mind-set" are not found to be part in the "culture" dimension of the examined digital maturity models. To some extent they are included in other dimensions like "digital ecosystem" and "technology". When furthermore comparing the extracted cultural attributes (Fig. 6) with the attributes of the cultural model of Denison (Denison and Mishra, 1995) – one of the most popular organizational culture models – it can be argued that the extracted cultural attributes are to a large extent described by a culture of adaptability (organizational learning, customer focus, creating change) and a culture of involvement (empowerment, team orientation). These cultural traits indicate higher levels of product & service innovation and creativity, as well as a fast response to customers' and employees' changing needs.

DISCUSSION

This systematic literature review takes stock of research and contemporary development in the field of digital maturity. The findings identify that there has been an increase in the quantity of academic research in the field of digital maturity since 2016 – mainly driven by Industry 4.0. The number of identified digital maturity models is in line with previously published papers (Chanias and Hess, 2016; Remane and Hanelt, 2017; Canetta *et al.*, 2018). In this systematic literature review, 22 eligible digital maturity models were identified and included. The analysis conducted in this paper is going beyond the work presented in previously published papers mentioned above, since special attention has been placed on the type of dimensions used in the various digital maturity models.

The research results of this article provide strong evidence that all identified models pursue different approaches in describing digital maturity. There is no consistent definition of digital maturity available because all the different maturity models and their underlying definition of digital maturity show a heterogeneity in content and methodology. Even domain-specific digital maturity models examined in this paper – mainly reflecting the manufacturing sector – show significant differences in maturity-dimensions, nomenclature, levels and characteristics applied. The comparison of maturity-areas addressed in different models provides interesting findings. Firstly, the dimension "product & services" plays a clearly minor role in general models compared to domain-specific models. Secondly, the cultural aspect plays a significantly more important role in general digital maturity models than in domain-specific models. Other "soft" dimensions, more attached to transformational capabilities, like leadership, vision, and innovation culture, are also addressed more in general digital maturity models than in domain-specific models. Thirdly, it becomes evident, that in all examined models included in this review the maturity area "business model" is hardly addressed. It seems, that the digitalization of the business model is neglected in most digital maturity approaches. Just a few models address this aspect. This can be interpreted that most companies rather focus on the exploitation of digital technology than on the exploration of digital innovation and development of new digital products and business models to generate new digital revenues. Fourthly, "customer insight and experience" as a characteristic of digital maturity plays a minor role in domain-specific models. Hence it can be argued that general digital maturity models more comprehensively address transformational capabilities, and domain-specific models more strongly address digital-technological capabilities in the assessment of the digital maturity of a company. Also, general models tend to show more external orientation and therefore take customer experience as criteria for digital maturity much stronger into account than domain-specific models. The comparison of all maturity dimensions represented in various models makes evident that the majority of models provide an incomplete picture of digital maturity. Either transformational management capabilities (e.g. vision, culture, leadership, governance, innovation, agility, …) or an organization's digital foundation (e.g. technology, digital skills, organization, strategy, customer experience, …) are not addressed sufficiently and systematically.

In this context, a special light has been shed on the dimension of "culture" because organizational culture is seen more and more as the number one hurdle to digital transformation (Buvat *et al.*, 2017; Solis, 2017) and as the most significant barrier to digital effectiveness (Goran *et al.*, 2016). What separates digital leaders from the rest is a clear digital strategy combined with a culture and leadership focussing on driving the transformation. Employees in digitally mature organizations describe their culture as more collaborative and innovative compared to other organizations and they state that leadership has sufficient digital skills (Kane *et al.*, 2015). Digitally mature companies also have cultures that embrace an expanded appetite

for risk, rapid experimentation, heavy investment in talent and recruiting and leaders excelling in soft skills (Kane *et al.*, 2016). More than half the examined digital maturity models include "culture" as a separate dimension. Within the models, attributes like "collaboration", "agility & flexibility", "organizational learning", "change-ability" and "customer centricity" are among the most represented cultural attributes across all models. Innovation is addressed indirectly by attributes like "failure tolerance", "risk tolerance" and "ideating new digitalized working methods". When comparing the identified cultural attributes with the attributes proposed by popular culture models like Buvat *et al.* 2017 and Denison and Mishra 1995, it becomes evident that to some extent there is conformity. Other proposed attributes describing a digital culture (Buvat *et al.*, 2017), like "digital-first mindset", "data-driven decision making" and "open culture", are clearly under-represented in the examined digital maturity models. Hence, there is a clear need to consistently define attributes of a digital culture enabling digital transformation and to systematically include these cultural attributes in digital maturity models.

Furthermore, the findings of this paper reveal a lack of digital maturity models reflecting domains other than manufacturing, taking the context and challenges of other industries into account.

Driven by Industry 4.0, the majority part existing models address the domain of manufacturing. More specific and granular model approaches providing additional layers of detail are required in order to reflect industry-specific capabilities and characteristics and give companies effective guidance towards digital maturity in different industrial and functional contexts. Especially the service industry needs stronger attention in the future, because more and more manufacturing companies recognize aftermarket services as a revenue driver, and digital technologies are opening up new opportunities especially in service (Baines *et al.*, 2009; Falk and Peng, 2013; Ardolino, 2018; Benjamin, 2019).

With regards to the design of the models, an inconsistency of levels and characteristics describing digital maturity can be found across all examined models. There is no standard approach for describing digital maturity levels, not even within a domain like manufacturing. In most cases, the description of digital maturity levels and consequently the classification of companies is too vague. Therefore, an assessment does not give clear reference points for new digital initiatives and does not provide a clear map of potential actions for management. Thus, more granular assessment approaches with specific characteristics for each defined maturity level would be required.

CONCLUSION

The main objective of this extensive systematic literature review was to provide a better understanding of the contemporary development in the field of digital maturity and related models. This could be achieved by identifying, examining and comparing 22 digital maturity models in detail. The research results of this paper indicate that most models provide an incomplete picture of digital maturity and that the description of digital maturity stages is inconsistent across all models. Furthermore, the review reveals that the majority of existing digital maturity models addresses just the manufacturing domain. Other domains like service are clearly under-represented. Special attention was placed on the role of culture playing in digital transformation and in which way it is reflected in digital maturity models. It is schown that attributes of a digital culture which enhance digital transformation efforts are not systematically incorporated in contemporary digital maturity models.

Overall, the findings of this paper indicate that research in this domain is not sufficient and future research has to place more attention to the issues highlighted above: (1) Incomplete digital maturity models need to be extended to "digital transformation maturity" models which are holistic and specific, respectively granular, at the same time. (2) Furthermore, models addressing other domains than manufacturing have to be developed. In this context the domain of service needs more attention. (3) Clearly defined attributes of a digital culture have to be integrated systematically in digital maturity models.

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