Comprehensive Review of Digital Maturity Model and Proposal for A Continuous Digital Transformation Process with Digital Maturity Model Integration

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Abstract

In recent years, digital transformation is one of the most popular trends for enterprises worldwide. The global trend of digital technologies and the COVID-19 pandemic have made the growth speed of digital transformation steadier than ever. In this condition, practitioners and academic researchers believe that the digital maturity model is one of the most effective weapons helping managers and the workforce to manage to transform their businessesdigitally. However, the digital maturity model (DMM) is a type of maturity model (MM) that is relatively new in model development and digital maturity assessment methodologies, especially when integrated intoan extensive digital transformation process. By this paper,the authors aim to conduct a comprehensive review to clarify the current state of the DMM field, including its essential characteristics, popular elements belonging to its structures, number of methods, and techniques used in developing and applying them. In addition, these papers identify major areas being researched. Moreover, under the capture from reviewing results, the authors raise some challenges to the field, including i) a need for standardizations its component names, ii) the need for a contextualized but low budget DMM for SME can apply for their business, iii) the need for positioning DMM applied processes in a master digital transformation process and in a dynamics context that help applications of DMM more efficient. The authors proposed a solution for the third challenge by a conceptual model that integrates DMM into a continuous digital transformation process.

Key words:

digital transformation, digital maturity model, continuous transformation process, change management.

1. Research Background

1.1 The booming of Digital Transformation

Most modern-day enterprises are being confronted withdealing with digital transformation's challenges. Digital transformation (DT/DX) is defined as "the use of technology to radically improve performance or reach of enterprises" [1]. The DX is seen as a radical and complex type of Enterprise Transformation, commonly referring to a disruptive process that profoundly changes the companies' way of competing, interacting, and creating value. Moreover, Bordeleau & Felden [2] state that high levels of digitalization are presented as good for a country's economic performance to increase an organization's efficiency and productivity.

According to IDC [3], despite the challenges presented by the COVID-19 pandemic, global spending on DX investment continually grow from 10.4% in 2020 to $1.3 trillion. Even thoughthis is significantly smaller than the 17.9% growth in 2019, the growth remains one of the few bright spots in case overall technology spending reduces dramatically. The global consulting giant also reveals that the direct DX investment is growing at 15.5% annually, driving over 6.8 Trillion from 2020 to 2023 as companies struggle to become digital-at-scale future enterprises. By 2022, the Digitalized economy is about 65% of Global GDP [4].

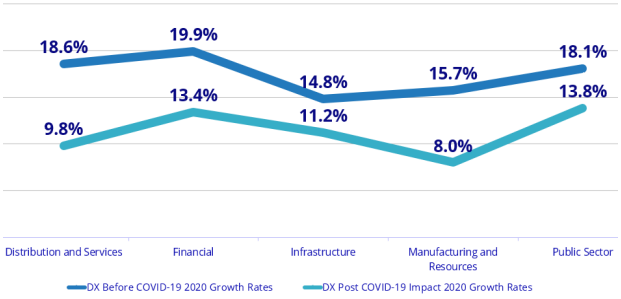

Fig. 1 Worldwide spending for DX in 2020. Source: [3].

1.2 Applications of Digital Maturity Model in Digital Transformation

The concept of maturity model (MM) first appeared in the 1970s and is dedicated to software engineering [5,6]. Since then, the MM concept has evolved into an important tool for improving business practices [7] by assessing their status-quos, establishing a desirable path for advancing them, and making internal or external benchmarking to realize gaps in competencies manner [8].

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Due to the broad range of potential applications, MMs have gained popularity in management and science [6,9]. There are lots of MMs that have been published focusing on different fields of organizations' capabilities such as Process Management [10], Six Sigma [11], "IT service capability, innovation management, program management, enterprise architecture, strategic alignment, or knowledge management maturity" [12]. The most well-known MM is the Capability Maturity Model (CMM) derived from Phillip Crosby's Quality Management Maturity Grid (QMMG) model, which aims to help evaluate the quality of the information systems and processes [13].
Meanwhile, the DX is a modern revolution where companies use new digital technologies such as SMACIT [14] to enable major business improvements like enhancing customer experience, advancing operations excellence, and innovating new business models [15]. It is a strategic change that needs to be aligned with several aspects [16], such as operational, functional, financial, and corporate strategy [17]. However, all previously mentioned MMs just applied in improving specific organizations' capabilities, which means there is a need to develop a type of maturity model that covers the number of capabilities required for the DX [18]. The Digital Maturity Model (DMM) is a type of MM that focuses on supporting firms to assess and develop their digital capabilities [9]. With the booming of the DX trend, DMM has become one of the most important fields for both academia and practitioners to research and pursue.

1.3 Research questions

Understanding the importance of DMM in helping companies transform them to become digital-at-scale enterprises in the future, this paper aims to investigate research papers to gain insights into DMMs in general and DMM applications in particular. To this end, we raise and research answers for the following research questions:

- What are the different types of models, approaches, methods, and techniques, dimensions, maturity levels are used in the development and applications of DMMs?
- What are the potential research areas in the field of DMM development?

2. Research Methodology

2.1 Data collection

The authors collected peer-reviewed papers that were peer-reviewed and published between 2000 and May of 2021 through of structured keywords search and cross-referencing to ensure the quality and reliability of this review. The keywords applied to search for articles in the database of Google scholar were: "Digital transformation" OR "digital maturity" OR "maturity model" OR "readiness index". The authors limit sources of papers in several well-known databases, including Elsevier, EBSCOhost, Emerald, Taylor & Francis, AIS eLibrary, IEEE, ResearchGate. We also only considered results are articles in English, not literature review ones, and for enterprises.
Within our research, characteristics, structured elements, methods and techniques, focus, and challenges of DMM research are defined and classified. To this end, our review analysis research papers that have new contributions to this research field, such as:
- Specify functions and roles of DMMs in the DX process.
- Develop and/or implement a new DMM for a firm.
- Empirically investigate how firms from specific sectors apply their DMMs.

After carrying out screening titles, abstracts, and conclusions to choose the appropriate papers to review, we selected and reviewed 96 papers altogether.

2.2 Data analysis

The authors used the content analysis method in investigating the collected papers. The content analysis method was defined by Berelson [19] and developed by Mayring [20]. This method is very good at combining rich meaning qualitative approaches with robust quantitative analyses through enabling manifest content of text and documents and uncover latent content and more profound meaning embodied in the text and document [21,22].

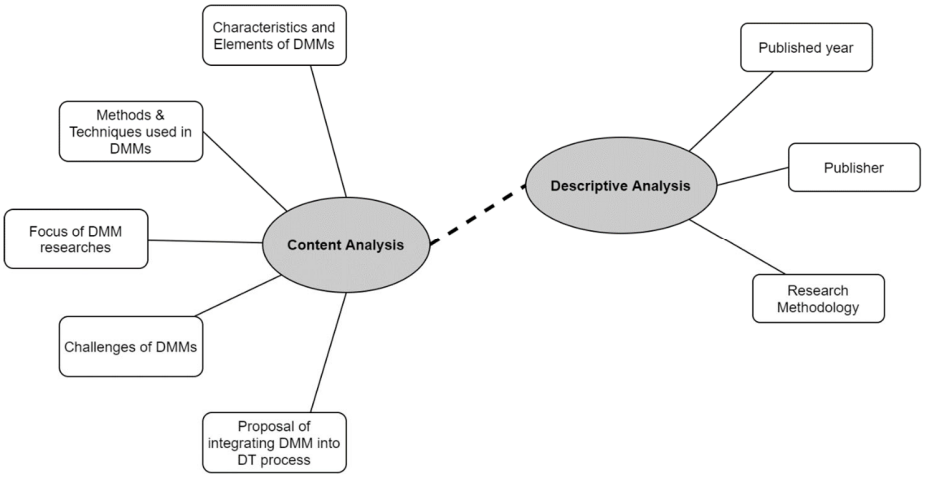

Fig. 2 Categories to analyze reviewed papers.

Firstly, we coded selected papers according to a number of categories that were also revised during the coding process. Figure 2 presents our analytic categories that include two groups, namely descriptive analysis and content analysis. Secondly, in the analysis phase, we synthesized and linked two groups to gain insights into critical points and trends of DMMs applications in the DX space.

3. Results and Discussion

3.1 Descriptive analysis of reviewed papers

Our review investigated research papers in both theoretical-based (77 papers) and empirical-based (19 papers). Figure 3 shows the distribution by published year of reviewed papers. In line with the prevalence of DMM in particular and DX in general, the number of papers has increased over time. Figure 4 shows the distribution of reviewed papers by publishers.

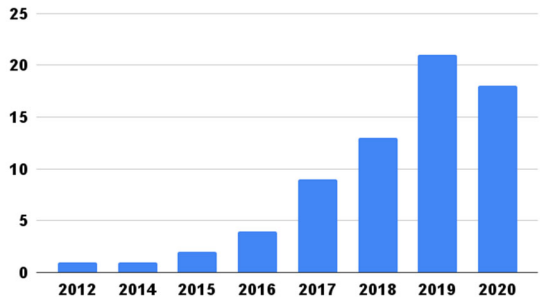

Fig. 3 Distribution of papers by published year.

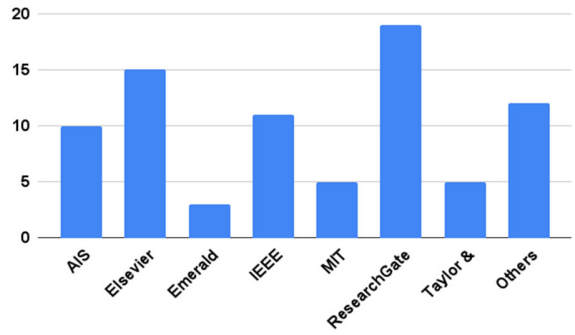

Fig. 4 Distribution of reviewed papers by publisher.

3.2 Content analysis of reviewed papers

Concerning the research questions, the content of reviewed papers is analyzed i) to clarify the characteristics, structure, methods, and techniques used in the DMM field, and ii) to find potential research areas. Firstly, to gain insights into the DX phenomenon, one needs to understand the characteristics and structure of DMMs [5,6,23,24]. The characteristics of DMMs are analyzed and synthetics in Table 1. From the table, the most important attributes of DMMs are purposes, scope, approach type. The purpose attribute includes descriptive, prescriptive, and benchmarking functions. The descriptive function is suggested to conduct to a contextualized context so that the prescriptive function can give context-specific recommendations for firms that have similar digital maturity levels. DMMs' scopes can cover a specific industry or cross-industries so that firms decide to select an appropriate DMM for them. DMMs' approach can

cover a specific capability that the firms' concern with or all capabilities (multi-dimensions) they need to advance to digital enterprises. Table 2 shows the popular components used to construct DMMs: dimension, scale items, weighting factors, maturity level, assessment tools, and evolution path. A comprehensive comparison of well-known DMMs is shown in Table 3, showing that the most important dimensions are Organization, Process, Strategy, Customer, People, Culture, IT Technology. The table also reveals that only a few but rather complex DMMs use weighting factors used for firms to prioritize their initiatives on reducing digital gaps as addressed from assessments. The assessment tools are built based on assessment methods & techniques that are detailed in Table 4. Table 4 shows various methods used in these actions ranging from qualitative to quantitative and mixed methods, cover different techniques, and use different types of data and supported tools. And these methods & techniques are used in the assessment process and model development projects. In terms of its evolution path, most DMM developstheir evolution path based on maturity levels and implies a linear path to the next maturity level. This implication is criticized for its oversimplification of the current context of firms and cannot give them context-specific and particular paths to their next levels [25].

Next, from the reviewed papers, the authors can find potential research areas that are researched ongoing and could be embedded into DMMs in the future. They are Change Management, Dynamics capabilities, Firm size, Non-linear evolution path, Evaluation methods, Dynamics of DMM. From Table 3, the Transformation Management dimension is the least popular one, but due to DX is a type of complex change, it should not only focus on what capabilities need to be changed but also on how these changes are managed [2]. For this reason, Change Management, Dynamics capabilities should be seen as capabilities that need to be assessed by DMMs. The firm size is another factor that should be considered because big companies tend to create their DMM for their specific & frequent use [26]. The non-linear evolution pathis also a potential research area due to giving context-specific recommendations for firms to escalate their digital maturity [25]. The firms' evaluation methods to select a suitable DMM for their digital visions need to be researched due to currently not having any guidance for this activity [27]. The last one is the dynamics of DMMs means that DMMs are currently seen in a one-time static manner rather than gradually enhanced & accessed to reflect the fast pace change of external environments [28].

Table 1: Characteristics of digital maturity models

Characteristics	***Components***	***Sub-component***	***Description***
Purpose	▪ Descriptive ▪ Prescriptive ▪ Benchmarking	▪ Impacted realization ▪ Contextual identification	MMs are reference models that deal with identifying the organizations' current state (AS-IS) and the evolution of maturity to target state (TO-BE) [29]. Development states are synonymous with maturity levels. The change to a higher level is equivalent to an improvement in DX [30].
			There are three main purposes of MMs [8,28,31]: ▪ Descriptive purpose: MMs help to assess organizations' current situation (AS-IS). ▪ Prescriptive purpose: MMs focus on indicating how to approach maturity improvement. ▪ Comparative purpose: MMs enabling conduct across-companies benchmarking.
			Descriptive models are the majority with 72%, thus limiting their scope to provide companies with some insights about their level of adoption of Industry 4.0 technologies [31]
			Prescriptive use of maturity models requires the ability to adapt to "organization-specific situational characteristics" [32] for conceiving tailored roadmaps consisting of context-specific improvement recommendations for the firms in their DX [33].
			Comparative use of maturity models is an adequate tool for comparing capabilities between business units and organizations [27], in which standardized maturity levels are the basis of a benchmarking approach between them [34]. Only a few models can provide this function [5].
Sector scope	▪ Cross-Industry ▪ Specific (sector)	▪ SMEs ▪ IT Industry ▪ Manufacturing	▪ The most recognized model within the area of information systems is the Capability Maturity Model (CMM) [35]

Characteristics	*Components*	*Sub-component*	*Description*
		▪ Banking ▪ Logistics/Supply Chains (SCM) ▪ Telecommunication	▪ The two largest groups of MMs concentrates on manufacturing, specifically concerning smart manufacturing, and on SCM [36] ▪ Product & Service Systems [37,38] ▪ Banking [39] ▪ Telecommunication [40,41]
Approach type	▪ Holistic / Multi-Dimension ▪ Specific dimension	▪ Corporate Culture ▪ Data-Driven ▪ Enterprise Integration ▪ IoT Technology ▪ IT Governance (ITG) ▪ Process Management	There are two groups of strategic guidance in Industry 4.0 [42]: holistic and specific approaches. ▪ Holistic approaches: aiming to assess elements of Industry 4.0 from all possible angles to derive encompassing success factors. ▪ Specific approaches – focusing on limited specific aspects (dimensions or capabilities) with greater detail such as Corporate Culture [43], Enterprise Integration [39], IT Governance model [44], Process Assessment Model [45]
Other characteristics	▪ Source	▪ Practitioners / Consultancy ▪ Academy ▪ Association ▪ Big Company	There are four main groups of DMMs creators [26]: Consultancy, Associations, Scientific, Big companies: ▪ Consulting firms like PwC [46], Forrester [47] use DMMs as a practical supporting tool for providing premium information and consultancy services to companies needing to improve their digital strategy. It shows that 70% of models are developed by practitioners [31]. ▪ Academic organizations consist of universities, and research institutes have the goal to educate and support the public, e.g., ACATECH [48], IMPULS [49], ▪ Associations like Open ROADS [50], SIRI [51], TM Forum [40] are representations of a sum of consultancy or academic organizations to inform and strengthen the industry sectors. Digital maturity should help create benchmarks and comparisons for the members. ▪ Big companies, e.g., Deutsche Telekom, sometimes require their own DMM for their maturity level improvement and market data collection [46].
	▪ Requirements		The DMMs should fulfil the normative defined for standardized [10,52] MMs [6] such as completeness, clarity, and unambiguity to ensure that gaining objective, impartial, consistent, repeatable, comparable, and representative results of the assessed organizational units [52]. Besides, they should be: ▪ Context-specific; Descriptive, prescriptive, or comparative; Consisting of mutually exclusive dimensions; Describe a maturity continuum in its dimension; Operationalizable (i.e., measurable levels) [28] ▪ Questionnaire's clarity; the modes of representation's transparency, understandability, comprehensibility, comprehensiveness, relevance, consistency, systematic structure, detail level, conceptual reliability, and applicability [27,53].

Table 2: Principles elements of digital maturity models

Elements	*Components*	*Sub-component*	*Description*
Action Fields (or Focus Areas or Dimensions)	▪ Capabilities (or Sub - Dimensions)		▪ The Actions Fields (Dimensions) cover essential and fundamental business areas impacted by DX [6,28]. ▪ The Actions Fields consist of specific capabilities as subcategories [38] or sub-dimensions.

Elements	*Components*	*Sub-component*	*Description*
			▪ The resource-based view defines organizations as configurations of resources that consists of both assets and capabilities; capabilities are could be defined as an organizational entity's ability to perform certain activities to achieve a particular outcome [38] ▪ Organizational capabilities were developed by assessing the current state as well as future requirements [54] and continue improving them [38]
			Two groups of capabilities are [55,56]: ▪ digital capabilities including strategy, technological expertise, business models, customer experience ▪ leadership capabilities, including governance, change management, culture
			Three groups of capabilities related to three realization phases towards Industry 4.0 are [42]: ▪ Enable (items that build the bases for Industry 4.0's realization), ▪ Implement (items that capture the enactment of Industry 4.0's concepts), ▪ Formalize (items that help to sustain targets states in Industry 4.0)
Maturity Levels	▪ Scale items ▪ Scale type ▪ Weighting factor	▪ Fix level: Staged, Continuous ▪ Focus Area	Represent archetypal states of maturity of a certain dimension or domain [6]. Maturity level is based on the principle of Capability Dimension of Industry 4.0-MM [57] and Capability Maturity Model Integration (CMMI)'s definition of maturity level [58], which specifies six levels of maturity for assessment [59].
			Standardized maturity levels are the basis of a benchmarking approach between companies [34]
			Each level should have Scale items which are descriptors providing the intent of the level and a detailed description of its characteristics. The characteristics of Scale items should be distinct, empirically testable, and have well-defined relationships to its predecessor and successor levels should be [6]
			There are two Scale types: fixed levels and focus area [28,38]: ▪ Maturity in the form of fixed levels is a rather classic approach, where the five-level scale is most common. These fixed levels can be either (i) staged or (ii) continuous. The staged one require an assignment of capabilities to exactly one maturity stage, while the continuous one requires the specification of capabilities for all maturity stages [38] ▪ In the focus area maturity models, each capability area has its number of specific maturity stages that have disparate levels of maturity in terms of quantity and distance to each other [38].
			Some models rely on a (dynamic) weighting of dimensions and related indicators [5], such as Deloitte's DMM [60], Open ROADS [50], SIRI [51]
Assessment Tools	▪ Qualitative ▪ Quantitative	Self-Assessment Expert-guided Assessment Continuous Assessment	Developed assessment tools aim to provide companies analytical frameworks that they could adopt to self-assess their conditions [31].
			Assessment tools can be qualitative or quantitative, using Likert-based [61] questionnaires and scoring models [6].
			Companies could adopt to self-assess their conditions by (online) questionnaires and online self-checks [46] or collaboratively analyze them in a guided interaction with the developers of the framework [31]
			Continuous assessment supported by integrating IoT technology help promote data transparency in existing processes. It is a solid basis for defining transformation actions and project plans [62].

Elements	*Components*	*Sub-component*	*Description*
Evolution path	▪ Boundary Conditions ▪ Stage Boundaries		▪ Development or maturation paths help to deal with the current state and the evolution of maturity in organizations [29] ▪ The evolution path is a linear and forward progression in which the organizations develop and improve their capabilities, value creation, performance, etc. [6].
			Each particular maturity level is composed of the respective characteristics of previously defined ones and their required characteristics [9].
			Boundary Conditions are particular conditions that organizations need to accomplish in order to progress from one level to another. They are considered as the essential condition of a particular maturity level [6].
			Stage Boundaries specific the point at which the organization advances to the next level [6].

Table 3: Comparison of well-known digital maturity models. (A: Academy, P: Practitioner; C: Cross-Industry, S: Specific Industry; o – DMM does not have sub-dimensions; x - DMM have sub-dimensions; *: weighting)

No.	*DMM*	*Author*	*Year*	*Source*	*Scope*	*Dimensions*											
						Size	*Culture*	*Customer*	*Digital Technologies*	*IT Technology*	*Innovation*	*Organization*	*Partner*	*People*	*Process*	*Products*	*Strategy*	*Transformation Mgmt.*
1	Multi-dimensional Maturity Model	[63]	2020	A	C	7	x	x	x				x	x	x		x	
2	OMDIA Digital Telco Maturity Map	[64]	2020	P	S	4		x		x	x				x			
3	Smart Industry Readiness Index*	[51]	2019	O	S	5				x		x		x	x	x		
4	Deloitte's Digital Maturity Model*	[60]	2018	P	C	10	x	x	x	x		x	x	x	x	x	x	
5	Structuring Digital Transformation	[65]	2018	A	C	8		x	x			x	x		x	x	x	x
6	Digital Maturity	[56]	2018	A	C	7	o			o		o		o	o	o	o	
7	ACATECH Industries 4.0 Maturity Index	[48]	2018	A	S	6	x		x	x		x		x	x			
8	Gartner's Digital Business Maturity Model	[66]	2018	P	C	7		x	x	x	x	x				x	x	
9	Maturity Model for Leveraging Digitalization in Manufacturing	[67]	2018	A	S				o	o				o	o			
10	MM for Assessing the Digital Readiness of Manufacturing Companies	[58]	2017	A	S	4	x			x		x			x			
11	IMPULS	[49]	2017	P	S	6			x			x		x	x	x	x	
12	Open Digital Maturity Model (ODMM)*	[50]	2017	O	C	10	x	x	x	x	x	x	x	x		x	x	
13	Digital Transformation Roadmap	[68]	2017	P	C	5				x			x	x	x		x	
14	TM Forum's Digital Maturity Model	[40]	2017	O	S	7	x	x	x	x		x		x	x			

15	Maturity Model for Industry 4.0 Readiness and Maturity	[53]	2016	A	S	7	x	x		x		x		x		x	x	
16	Digital Business Transformation Stages	[23]	2016	A	C	10	x	x		x	x	x		x	x	x	x	x
17	Forrester's The Digital Maturity Model 4.0	[47]	2016	P	C	4	o	o		o		o						
18	Aligning the Organisation for its Digital Future	[69]	2016	A	C	5	x					x		x	x		x	
19	The Digital Transformation Playbook	[70]	2016	A	C	4		x			x	x					x	
20	SIMMI 4.0 – System Integration Maturity Model Industry 4.0	[71]	2016	A	S	5	x		x				x		x	x		
21	DMM for Telecommunications Service Provider	[41]	2016	P	S	7	o			o	o	o	o		o		o	
22	PwC's matutrity model	[46]	2015	P	C	9	o	o	o			o	o	o	o	o	o	
23	Cognizant's Digital Transformation Framework	[72]	2014	P	C	5		x				x	x		x	x		
24	Digital Transformation Roadmap for Bilion-Dolar Organisations	[73]	2011	A	C	6	o	o				o		o	o		o	
Total							**15**	**14**	**11**	**15**	**6**	**19**	**9**	**14**	**19**	**11**	**15**	**2**

Table 4: Methods & techniques used in digital maturity model applications

Methods	***Techniques***	***Application phases***	***Main findings and related papers***
A. Qualitative			
	Business model canvas (BMC)	Assessment	BMC [74] help to map out the current state of the business model is rather straightforward [75,76]
	Delphi	Model development	The Delphi method was used to capture expert input for building new concepts or frameworks in areas where having limited empirical evidence that well suitable for the development of reference models [41]
	Problem Based Learning (PBL)	Assessment	PBL helps to facilitate the contextualization of the assessed company that propose different improvement recommendations, even the cases at the same maturity stage [32]
	Value Chain Framework (VCF)	Assessment	VCF helpsto address competitive advantages and the level of development of digital initiatives in each of the core areas of the organization that facilitates the connection between digital maturity and their contribution to the firm's success [77]
	Value Stream Mapping (VSM)	Assessment	The VSM - Lean tool has been extended focus on the information flow to map the current state of the organization to consider logistics, product development, and other indirect business areas that related to how the transformation is capitalized [61]
	Others	Model development	▪ Conceptual Modelling [46,78] ▪ Case Study [46,78] ▪ Systematic literature review [46,78] ▪ Workshop [46,78]
B. Quantitative			
	Business Process Management (BPM)	Model development	BPM helps to address the requirements of digitalization [79]
	Discrete-Event Simulation (DES)	Assessment	The DES is used to simulate a firm's operation and analyze the firm's automation level (maturity index) [80]
	Fuzzy Analytic Hierarchy Process (FAHP)	Model development	Fuzzy Analytic Hierarchy Process (FAHP) is used to prioritize the maturity items and dimensions based on their importance levels resolution [81]

	Fuzzy Inference Systems (FIS)	Assessment	FIS help overcome the inaccuracy and uncertainty of previous MMs, addressing the complexity of digitalization level perception [36]
	Hierarchical Cluster Analysis (HCA)	Model development	HCA helps to build clusters of items that represent maturity stages [23]
	IoT integration	Assessment	IoT technology integration help promote data transparency in existing processes and then a continuous assessment [61]
	Monte Carlo Simulation	Model development	Input data from Monte Carlo simulation is used for evaluating the I4.0 maturity models that were designed with a probabilistic approach based on a fuzzy rule [36]
	Others		▪ Analytic Network Processing [78] ▪ Factory Design and Improvement [78]
C. Mixed-methods and Techniques			
	Design Science Research Method (DSRM)	Model development	Design Science Research Method (DSRM) [82] provides a rigor research methodology for resolving problems with newly developed IT artifacts, such as models or methods [28,45]
			A MM can be regarded as an artifact and is thus subject to the principles of design science research [9,12]. The theory founded by Becker et al. [9] for the development and evaluation of maturity models is followed by DSRM [30]
	Multi models assessments	Assessment	In case the company was in relatively low stages as assessment by an Industrial specific model, then the use of a second holistic MM would give us a better insight into the necessary improvements. If the company is in higher stages in the first assessment, no further evaluation would be necessary [80]
	Multi Techniques	Model development	Most MM development techniques are used in a combination context with others [78]
		Assessment	In case the company was in relatively low stages, besides using of second holistic DMM, Discrete-Event Simulation (DES) with recorded inputs from AS-IS operation process help find out activities that unnecessary, without value-added, technological upgradable as inputs for improvements recommendations [80]
	Template-based	Model development	▪ Template-based development help increased predictable quality and productivity; increased performance; decreasing error; increased employee involvement; increased return on investment, and increased customer satisfaction [57,83] ▪ Well-known templates [57] are CMMI-DEV [84], TOGAF [85], SPICE [10], and Mettler's template [86].

Table 5: Focuses in the field of Digital Maturity Model

Focuses	***Sub-objectives***	***Main findings and related papers***
Change Management	▪ value creation ▪ organizational structure	Two subject areas should be explored in addition to the stages of DX: capabilities and change management [2]
		DX strategy needs to be aligned with the operational, functional, and corporate strategy. Considering financial aspects, Matt et al. [87] propose changes in value creation and organizational structure to exploit the emerging digital technologies' full potentials.
Dynamics of DMM		Digital maturity is a goal that is always changing and improving [40]
		MMs becomes outdated if reality changes, so DMM needs to be changed over time, especially due to the fast pace of the DX [28]
		The need for the organisations to develop their own transformation roadmap [2]

Focuses	*Sub-objectives*	*Main findings and related papers*
Dynamics capabilities		Most maturity models cannot identify an organisation's dynamic capability or examine this capability in a dynamic and competitive environment during the transition as well as not provide dynamic capability-based guidance for enterprises to reevaluate their strategies and strengthen the capabilities they require to face a changing environment [88].
Non-linear evolution path	Impact of digital technology	▪ In cases the phenomenon of DX is context-specific and can take idiosyncratic paths, the logic of a linear DX pathseems critically oversimplifiedthinking that is possibly resulting in wrong management decisions [25]. ▪ the impact that DX has on a specific firm should be a scale that describes a firm's digital maturity [25]
Firm's size		▪ Big companies sometimes create their own DMM to improve their maturity level and to collect market data [46]; ▪ Large companies are a step ahead in implementing Industry 4.0 than small and medium enterprises (SME's) [6,87]; SME's are waiting to see the advantages; lack of competence and resources; uncertainties about risks/opportunities [89]
Evaluation	NPS	NPS is suggested as an appropriate key performance indicator for MM satisfaction, which helps decision-makers select the most well-suited MM from the many available ones [27]

3.3 Challenges in Digital Maturity Model development

Although DMM brings huge benefits to DX activities, the development of these models in academia and industryfaces many challenges. Firstly, it lacks standardizations in naming, especially in the name of structured components of models. Different authors used these terms in different contexts with different meanings, including the dimensions [41,47-51,64,90-92], action fields [65,93], focus areas [58,72], capabilities [56,73], congruence [69], domain [70], track [68]. Due to the majority used of "dimensions" in recent years, and with the popularity of this term in other management frameworks like ITIL 4 [94], the authors suggest that "dimensions" should be used as a standard name for the first level components of DMM. Similarly, the authors suggest that "capabilities" should be used as a standard name for the second-level components.

Secondly, the majority of the models (72%) have a descriptive purpose [31], thus limiting their scope to provide companies with some insights about their level of adoption of Industry 4.0 technologies [31,95]. In addition, multi-dimensional models are usually too high-level [17], i.e., provide too little detail, or too general, i.e., do not consider industry-related characteristics [23] to deliver necessary insights for organizations. Meanwhile, specific models only focus on particular isolated dimensions or functional areas resulting in potential risks [42]. These limitations raise rather high requirements for both sides of DMM application contexts. From the development side, they require establishing development teams who can conduct multi-discipline approaches to build multi-dimensional models for their clients. As depicted in Table 3, the team must be experts in diverse domains such as Organizations Developments and Design, Operation & Quality Management, Strategic Management, Business Management, IT Technology, Digital Technologies, Human Resource Management, Service Management, Change Management, ... On the flip side, firms who use DMMs should make serious investments in DMM assessment missions to obtain significant results that are context-specific to their companies. The context-specific DMM assessment can lead to the application of multi-model assessments and multi-method assessments, including 360 degrees (expert survey and interview) assessment [32], IoT integration [62], DES simulation [80], Fuzzy analysis [36,81], etc. These serious deployments of DMM assessment will lead to only some big companies paying for these types of assessments to achieve particular recommendations. The challenge of providing cheaper ways for SME firms to assess their own digital maturity should be an outlook for future research.

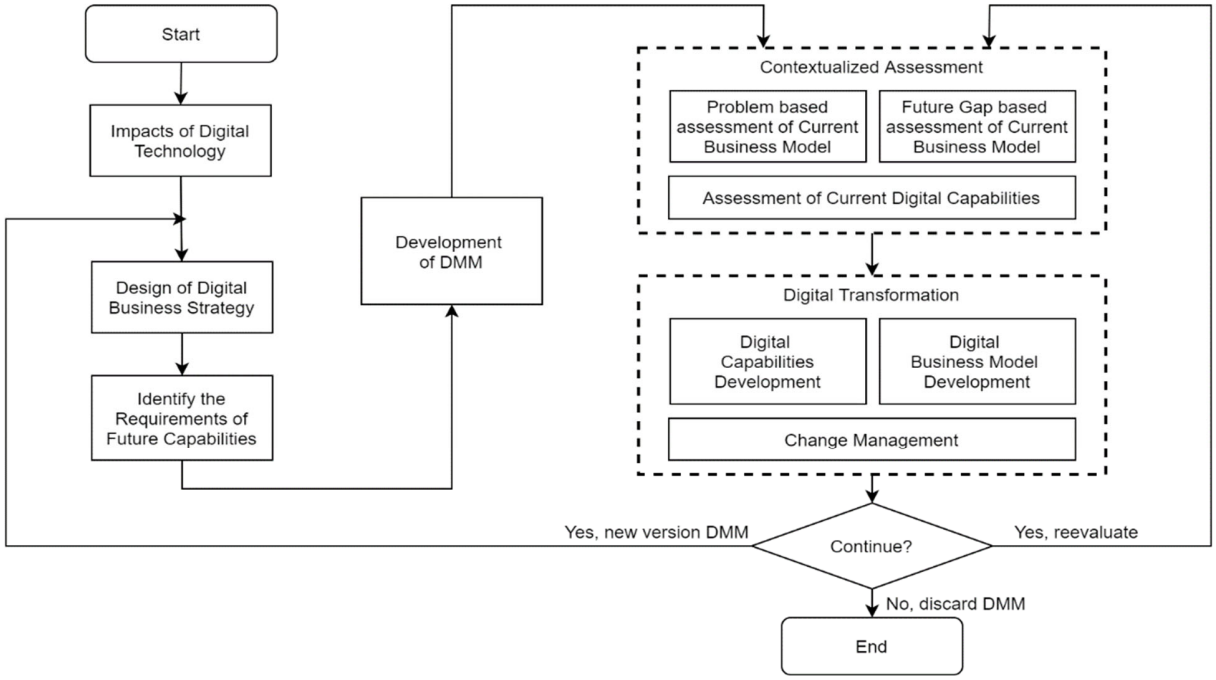

Fig. 5 Proposal of integrating DMM into a continuous digital transformation process.

Thirdly, due to the DX are integrated into firms' strategies that are gradually revised to respond to the dynamic context of the environment, the DX is suggested to be implemented in an incremental and continuous manner [69,96]. Hence, the DMM that reflects the impacts of digital technologies on the firms should be applied to the DX process in a closed-loop manner. However, few models mentioned about their assessment process [32], and in case of that, they only introduce one-time assessment context like Deloitte's DMM [61]. These limitations raise a critical requirement for guidance that shows DMM actions in its whole lifecycle regarding the continuous DX process. The next section presents a suggestion for this challenge.

3.4 Proposal for a continuous digital transformation process with digital maturity model integration

As theanalysis in previous sections, it should be critical for the need of guidance on how to apply DMMs in an integrated manner with DX processes, to reflect the frequent changes of customer expectations [97] and dynamics of external conditions, including digital technologies disruptions [98,99].

In this section, the paper's authors propose a conceptual model of integrating DMMs in the DX process that respects the above requirements. The proposed model is based on the DX process suggested by Vial [98] and focuses on showing the applications of DMM in its Strategic Response block, as presented in Figure 5. Process in Figure 5 shows that, after realizing the disruptions from markets, firms should redefine their business strategy that should base on the advancement of digital technology [100,101], and then identify capabilities need to implement the newly adjusted strategies [76]. Then the firms develop suitable DMM that reflect firms' strategic visions and future needed capabilities. The DMM then assesses the firms in contextual manners to consult their weaknesses that need to heal in the short-term and their gap from the current business model to visions' business model [32,102]. The DMM assessment also helps firms understand their gap in digital capabilities [103]. The assessment outputs will be used as guidelines for firms to plan and implement their transformations that consist of transformations in business models in parallel with the development ofdigital capabilities [76,104]. The change management should be considered [2,65] due to transformation is a type of radical strategic and cultural change [55], being a type of strongest and riskiest change of any organization [104]. After each incremental loop within transformation action plans, the firms make a revision to the current DMM in respect to its performance [27] and the newest disruptions from outside and make decisions to reuse them or build new ones [28].

4. Conclusion

This paper used keyword search and cross-references to collect units of analysis and the method of content analysis to review gathered research papers from 2000 to 2021. This paper provided an overview of characteristics and components of DMMs, methods and techniques used in DMMs development and assessment. Moreover, besides the major focus subjects that are currently under development, the paper raises a need for further considerations in challenges. One of these challenges that show the need to address the position of DMM in the DX master process, the authors propose an integration of DMM development and assessment steps into the DX process in a continuous context. The integration is supplementary for reviewed studies of DMMs and, together with them, provides to both development and applications sides (enterprise) of DMMs clearer functions and position of DMMs in DX process. The continuity of the integration model suggests that not only the assessment but the development of DMMs should be continuously conducted. Other challenges, especially the need of studying appropriate development methods for multi-dimensional DMMs that SME firms can freely customize and apply effectively by themselves for their own businesses without serious investment expense, is also an outlook for future research.

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