A Digital Maturity Model for Electronics Manufacturing Firms Toward Servitization with Integrated Approach

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Abstract. The growth speed of top trending for global firms, the digital transformation (DT), has become steadier than ever by the advancement of digital technologies as well as the COVID-19 pandemic. In order to implement a digital evolutional path appropriately, the Digital Maturity Model (DMM) has been seen as a handy tool since they help companies evaluate their initial states and plan development road maps. So far, several DMMs have been developed for both cross-industry and/or specific sectors, including manufacturing. However, none of them is developed for the Electronics Industry (EI) firms despite the vital importance of the EI sector, especially in developing countries like Vietnam. These companies contribute a significant proportion of Vietnam's GDP, up to 40% in 2021. Moreover, none of them guide EI firms to embrace the Servitization model. This article presents a new DMM to digitally transform EI companies to align with the Servitization model by applying both the Product Service System (PPS) and Service Design approach. The DMM is developed with on the design science research methodology and uses its strategy of combining related models to form a new one to gain high quality. Experts from a joint-venture telecom equipment company under VNPT, the biggest telecommunication service provider in Vietnam, were chosen to join the DMM pre-evaluation phase of the development process. For further research, the authors expected that the newly developed DMM should be transferred and evaluated by more EI incumbent firms and then become a standardized DMM for the EI sector.

Keywords: Electronics Industry · Digital Maturity Model · Digital Transformation · Servitization · Product Service System · Service Design · Change Management

1 Introduction

The fourth industrial revolution with digital technologies disruptions transforms traditional manufacturing companies into Smart Factories with capabilities of communicating

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with physical (humans, products, and machines) and virtual worlds, insight of production process, autonomous decisions making across their devices, machinery, warehouse systems, etc. [7]. Indeed, digital transformation (DT) helps companies [18, 21]: i) Improve vertical integration (between all internal departments within a firm in all levels in hierarchy); ii) Improve horizontal integration (between entities across a value chain); iii) Improve end-to-end digital integration (between entities across product life cycle).

The complexity of adopting Industry 4.0 drives to follow a customized Digital Maturity Model (DMM) to help companies evaluate their initial states and plan development road maps [45]. The DMM should perfectly fit particular sector characteristics [42] and the distinctive context of the incumbent firms [9]. However, even though most existing DMM is for the manufacturing industry, there is no evidence of a specific DMM aimed at the Electronics Industry (EI) sector, a sub-sector of manufacturing that plays a substantial role globally economy. Hence, EI firms lack the guidance to embrace Industry 4.0 technologies and digitally transform their product and business models to gain competitiveness over rivals. Accordingly, this article has the purpose of filling this gap by building a DMM for the EI sector, called EI-DMM, by following the well-known procedure of MM development from [3].

The remainder of this article is organized as follows. To provide the theoretical background that underpins the research, Sect. 2 outlines the characteristics of the EI sector in the Industry 4.0 wave and their concerns in the implementation of Industry 4.0. Section 2 also reviews the existing DMMs and states the need and opportunity to develop a DMM for the EI sector (the EI-DMM). Section 3 explains the research methodology and development process to implement the EI-DMM. The targeted DMM will be pre-evaluated in focus groups of scholars underpinned by a telecom electronics equipment manufacturer from the most prominent telecommunication group in Vietnam, VNPT. Section 4 shortly describes the EI-DMM's main characteristics. Lastly, Sect. 5 summarizes the main content of the research, including contributions and suggestions for possible future issues.

2 Theoretical Background

2.1 Electronics Industry (EI) Sector in Industry 4.0

Introduced by a German initiative in 2011, the Industry 4.0 (I4.0) evolution was expected to increase the productivity and efficiency of the national industry of countries [16]. In addition, the I4.0 also innovates business models by supporting a transformational environment, knowledge management, and supply chain capacity building. I4.0 involves not only designing a new strategy; the role of information technology (IT), working environment, and changing traditional skills, but also innovation engines, management approaches, corporate culture [50]. It also makes firms attain operational excellence to have the ability to reduce production time to move products to the market more rapidly and efficiently than competitors [1, 33]. It also makes employees' survival depend on their adaptability to new job requirements (e.g., non-technical skills and data analytics) [35, 57].

In the electronics manufacturing sector, The I4.0 nowadays has a strong effect on the E&E manufacturing companies. Today E&E manufacturing companies face pressures to

improve their operations, such as ensuring cost reduction, short lead-time delivery, legal, environmental, and flexibility e.g. [1]. A critical strategic issue pursued by these companies is concentrating on investing in new products, technology, and services, enhancing their other competitive advantages than price [28]. As the demand for high-performing electronics equipment increases, electronics manufacturers are adopting emerging technologies like SMACIT [62] and intelligent devices to improve efficiency, connectivity, and productivity and satisfy complex customer needs [20]. In addition, such new technologies give firms more opportunities to offer more services. Regarding services, the Servitization is typically a strategic response by electronics manufacturing companies to transform them from only selling products to adding additional value by including various services within the product offerings [61]. Servitization helps manufacturers reach the maturity phase in the product lifecycle and gain profit over the entire product lifecycle [32]. In the Servitization model, the Product-Service System (PSS) approach and Service design approach is recommended to be implemented in an integrated manner [10] to combine the human-centered and co-creative perspectives of Service Design [64] and the product and organizational networks perspective from PSS.

In particular, the Vietnam electronics industry (EI) is an increasingly important sector of the country's economy when taking the lead in export turnover among sectors. The export volume steadily climbed from nearly $47.3 billion in 2015 to $96.9 billion in 2019 [39], accounting for almost 40% of the national GDP in recent years [37]. Vietnam is one of the world's key electronics exporters, ranking 12th globally since 2015 [37]. Vietnam's electronics exports continue to grow despite the negative impact of the COVID-19 pandemic, climbing 12% to nearly 100 billion in 2020 [37]. However, Vietnam's EI sector faces significant challenges in maintaining growth with competition from top global EI firms from Taiwan, Singapore, China, and other Asian countries. Incredibly, most Vietnamese electronics manufacturers operate as Electronic Manufacturing Service (EMS) companies, focusing on providing outsourced production procurement services, labor, and facilities for international EI producers [38]. Hence, they show low production efficiency and poor value-added services, with the profitability of those sectors ranging relatively low, from about 5 to 10% [38]. Therefore, Vietnamese EI enterprises need to have new capabilities to pursue digital transformation toward the Servitization to ensure their survival and growth in the market. However, there is a lack of a proven DMM for the EI with the previously mentioned requirements. Therefore, it would be significance beneficial to develop a DMM targeted at the enabler sector.

2.2 Foundation of the Digital Maturity Model

The concept of the maturity model (MM) first appeared in the 1970s and is dedicated to software engineering [45]. It has evolved broadly to improve other business fields [54] by assessing their status-quos, establishing a desirable path for advancing them, and making internal or external benchmarking to realize gaps in competencies manner [47]. MMs have gained popularity in science and management [3] with many potential applications. There are lots of MMs that have been published focusing on different fields of organizations' capabilities, such as "IT service capability, innovation management, program management, enterprise architecture, strategic alignment, or knowledge management maturity", Process Management [27], Enterprise Integration [26]. The most

well-known MM is the Capability Maturity Model (CMM), which aims to help improve the quality of information systems and processes quality [65].

Meanwhile, the DT is a modern revolution where companies use new digital technologies such as SMACIT [62] to enable significant 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 [55], such as operational, functional, financial, and corporate strategy [36]. However, all previously mentioned MMs just applied to improve specific organizations' capabilities, which means there is a need to develop a maturity model that covers the number of capabilities required for the DT [29]. The Digital Maturity Model (DMM) is one MM type that focuses on supporting firms to assess and develop their digital capabilities [3]. MMs are reference models that deal with identifying the organizations' current state (AS-IS) and the evolution of maturity to the target state (TO-BE) [44]. Development states are synonymous with maturity levels. The change to a higher level of maturity is equivalent to an improvement in DT [34]. With the booming of the DT trend, DMM has become one of the most important fields for both academia and practitioners to research and pursue.

The components and characteristics of DMMs are depicted in Fig. 1. The most important characteristics of DMMs are purposes, scope, approach type, and source. The purpose attribute includes "descriptive, prescriptive, and comparative functions" [47]. The descriptive function is suggested to conduct in a contextualized context so that the prescriptive function can give context-specific recommendations for firms that have similar digital maturity assessment levels [9]. The comparative purpose enables benchmarking across companies or capabilities between business units and organizations [14]. 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 specific capabilities that the firms are concerned with or all capabilities (multi-dimensions) they need to advance to digital enterprises [53]. There are four primary sources of DMMs creation [49]: Consultancy, Associations, Scientific, Big companies, where 70% of models are developed by Practitioners [8].

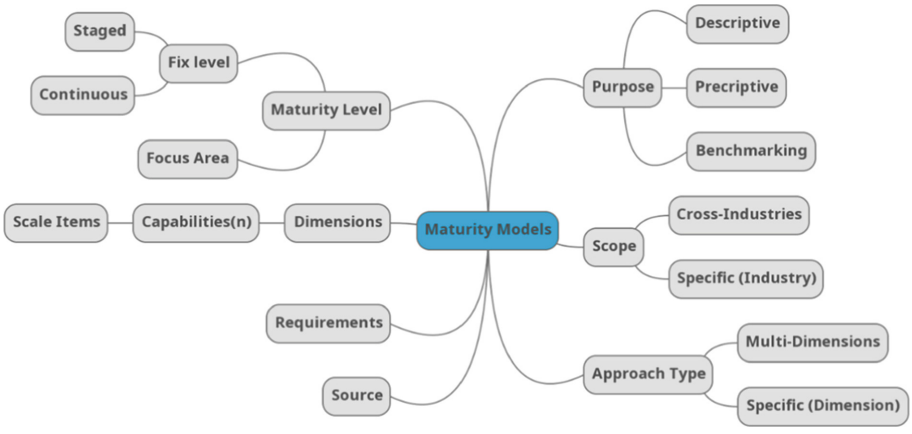

Fig. 1. Components and characteristics of maturity models. Source: [23]

Table 1. Comparison of well-known digital maturity models.

No.	DMM	Author/s	Year	Source	Scope	Dimensions													
						Size	Culture	Customer	Data	Digital Technologies	IT Technology	Innovation	Organisation	Partner	People	Process	Products	Strategy	Transformation Mgmt.
1	Product-Service Systems Maturity Model	Häckel et al. [24]	2021	A	S	4	x	x	x		x		x	x	x	x	x	x	
2	Maturity Model for Machine Tool Company	Rafael et al. [45]	2020	A	S	6			x				x		x	x	x	x	
3	Smart Industry Readiness Index*	SIRI [48]	2019	O	S	5			x		x		x		x	x	x		
4	ACATECH Industries 4.0 Maturity Index	Schuh et al. [51]	2018	A	S	6	x		x	x	x		x		x	x			
5	Maturity Model for Leveraging Digitalization in Manufacturing	Sjödin et al. [56]	2018	A	S	3	o		o		o			o	o	o			
6	Maturity Model for Assessing the Digital Readiness of Manufacturing Companies	De Carolis et al. [11]	2017	A	S	4	x				x		x			x			
7	IMPULS	Lichtblau et al. [35]	2017	A	S	6			x	x			x		x	x	x	x	
8	Model for Industry 4.0 Readiness and Maturity	Schumacher et al. [52]	2016	A	S	7	x	x			x		x		x		x	x	
Total (Manufacturing sector)							**5**	**2**	**6**	**2**	**6**	**0**	**7**	**2**	**7**	**7**	**5**	**4**	**0**
9	TM Forum's Digital Maturity Model (4.0.3)	TM Forum [58]	2021	O	C	10	x	x	x	x	x		x	x	x	x	x	x	
10	Multi-dimensional Maturity Model	Berger et al. [4]	2020	A	C	7	x	x	x	x				x	x	x		x	
11	Structuring Digital Transformation	Gimpel et al. [19]	2018	A	C	8		x	x	x			x	x		x	x	x	x
12	Digital Maturity	Rossmann [46]	2018	A	C	7	o		o		o		o		o	o	o	o	
13	Open Digital Maturity Model (ODMM)*	Open ROADS [41]	2017	O	C	10	x	x	x	x	x	x	x	x	x		x	x	
14	Digital Business Transformation Stages	Berghaus and Back [5]	2016	A	C	10	x	x	x		x	x	x		x	x	x	x	x
Total (Cross-industry)							**5**	**5**	**6**	**4**	**4**	**2**	**5**	**4**	**5**	**5**	**5**	**6**	**2**
Total (Manufacturing sector & Cross-industry)							**10**	**7**	**12**	**6**	**10**	**2**	**12**	**7**	**12**	**13**	**11**	**10**	**2**

Legend: A: Academy, O: Organisation; C: Cross-Industry, S: Specific Industry; o/x – DMM (does not) have sub-dimensions; *: weighting. Source: [23].

The popular components used to construct DMMs compose maturity level, dimension, capabilities, scale items, and requirements. First, MMs are structured by dimensions and capabilities in a sequence of discrete levels [44] to support reporting to layers of management and enable maturity level improvements management. Dimensions (focus areas, action fields, or domains) are essential and fundamental business areas impacted

by DT [45]. The most popular dimensions are Culture, Customer, Data, Digital Technology, Innovation, IT Technology, Organization, Partner, People, Process, Product, Strategy, and Transformation Management [23], as depicted in Table 1. Sub-Dimensions, usually called capabilities, are prominent, independent aspects of a given domain that is important to domain maturity, e.g., strategic capabilities, critical success factors, and resistance to entry into higher maturity level. Scale Items of capabilities are specific characteristics of capabilities that provide further detail, enabling targeted maturity level improvements. Maturity levels are maturity states of a particular dimension [45]. Standardized maturity levels are the basis of a benchmarking approach between companies [43]. There are two scale types for maturity levels: fixed levels and focus area [43]: 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. In staged one, capabilities are assigned to precisely one maturity stage. On the other hand, in the continuous one, the specification of capabilities is required for all maturity stages [43]; In the focus area maturity models, each capability area has its number of specific maturity stages in terms of quantity and distance to each other [43]. About the requirements, DMMs should fulfil the normative defined for standardized MMs like [26, 27], such as clarity, completeness, and unambiguity to gain objective, consistent, repeatable, comparable, impartial, and representative [45].

3 Research Methods

The development applies the paradigm of design science research methodology (DSRM) that is well-accepted in IS research to provide a proven rigor methodology for developing novel artifacts to support organizations and [22]. To develop our DMM, we follow the eight-step procedure for the model development from [3] based on the DSRM paradigm (Fig. 2). The first four phases are this work's focus, concentrating on designing and developing the DMM (Table 2). They are Problem definition, Comparision of existing MMs, Determination of the development strategy, and Iterative MM development. The other phases that cover the transfer and evaluation will be in future research because it requires further continuous evaluation to ensure rigorous evaluation (Pöppelbuß and Röglinger [44]).

The Problem definition phase (The First phase) examines the motivation for the MM that comprises the determinations and problems of the application areas. The second phase, Comparing existing MMs, reviews existing publications to address research gaps. The third phase, Determination of Development Strategy, comprises four strategies, including i) design of a new model design, ii) enhancement of an existing model, iii) a combination of models to form a new one, and iv) the transfer of existing models to new application domains [3]. The Iterative Maturity Model phase (The Fourth phase) is the central one of the procedure models. Some additional techniques are recommended to develop a proper research and practice model within this phase. For example, the multi-methodological approach [60], including literature reviews, interviews with domain experts, and discussions of scientific focus groups, that go along conceptual-to-empirical approach [40] (Table 2). At the same time, the practical perspective and adjusting the artifact is mainly used in the inductive empirical-to-conceptual

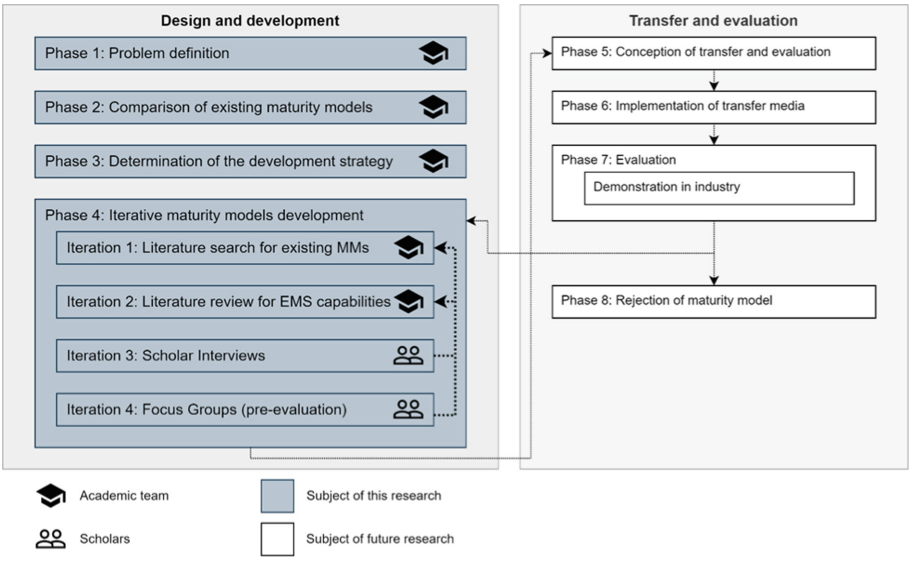

Fig. 2. The research approach for EI-DMM development based on [3]

Table 2. Iterations' activities and Deliverables of the model in the development phase.

Iteration	Approach	Activity	Deliverables
I1	Conceptual-to-empirical	Literature review of existing DMMs	The first draft of the capability framework
I2	Conceptual-to-empirical	Literature review for EI characteristics	The first draft of the digital maturity model with the most defined maturity levels of capabilities
I3	Empirical-to-conceptual	Interview scholars	The complete digital maturity model
I4	Empirical-to-conceptual	Focus group discussion (pre-evaluation)	The pre-evaluated digital maturity model

Source: Becker et al. [3]

approach [40]. The fifth one, the Conception of transfer and evaluation, focuses on model evaluation to ensure the proposal MM is evaluated to desired firms in the targeted sector. The sixth phase, the Implementation of the transfer media, helps deliver the MM to firms in the targeted sector. In the seventh phase, the MM is applied and examined how well the solution to the problem is delivered. Lastly, in the eighth phase, Decision about Rejection of Maturity Model, the MM is rejected if it is outdated or does not function well.

This work focuses on the first four DMM design and development phases. In Sect. 2 of the paper, three first phases are conducted: The need for EI sectors management

guidance is examined. The critical problem is that EI firms struggle to digitally transform toward the Servitization model with both PSS and Service Design approaches (Phase 1). While existing MMs for EI could not afford these holistic perspectives, the EI-DMM is proposed to be built to fill this gap (Phase 2). At the development strategy determination phase (Phase 3), there is no MM in the literature that identifies all relevant dimensions for the DT of the EI sector. However, several existing models were close enough to be combined (Strategy 3) that could be used to fulfill the gap.

Within the Iterative MM development phase *(the Fourth Phase)*, we conducted a multi-methodological approach to develop dimension-specific evolution paths for the DMM [60]. In *Iteration one* of the literature review, we searched for existing MMs focused on the manufacturing and/or EI sector and related to the research stream (Servitization, PSS, Service Design) as recommended by [3]. For this, we performed a Google Scholar search with the following search string: "*Digital transformation" OR "digital maturity" OR "maturity model" OR "readiness index."* The authors limit sources of papers to several well-known databases, including Elsevier, EBSCOhost, Emerald, Taylor & Francis, AIS eLibrary, IEEE, and ResearchGate. We only considered results as articles in English, not literature review ones and for enterprises. As a result, we found 82 papers where 35 related to MMs, of which 15 MMs are for manufacturing and 10 MMs are for cross-industry. Then, we compared these MMs and identified relevant capabilities for EI to understand and partly included them in the DMM of our existing work. We identified 180 capabilities from manufacturing MMs related to the EI sector. After classifying these capabilities into seven dimensions to enhance clarity and accessibility, we developed 155 capabilities. We refined the dimensions and capabilities iteratively until a general agreement among the research team was achieved. At the end of this Iterative, we release the first draft version of the EI-DMM.

Next, within *Iteration two*, a literature review for EI and additional capabilities were carried out to ensure that existing MMs and EI domain-specific work cover the body of knowledge. Hence, we performed a Google Scholar search but limited sources in several domain-related databases, including Elsevier, EBSCOhost, Emerald, Taylor & Francis, AIS eLibrary, IEEE, and ResearchGate, with the following search string: "*Electronics Industry" OR "Electronics Manufacturing" OR "Electronics Manufacturer" AND "digital transformation."* As a result, we found 70 articles that identify maturity levels and capabilities required for EI in digital transformation. After carefully reading and screening these publications, with forward-backward reference searches to screen the field of research, we identified another 23 capabilities for EI from this literature.

So, 178 capabilities (155 + 23) were identified from these first two iterations. After coding, clustering, and reducing the duplicates or grouping similar ones, 38 capabilities were finally derived (32 from existing MMs and six from EI literature). These include different characteristics leveraging these capabilities along all their stages of maturation. The research team discussed and supplemented several characteristics at some high stages for specified capabilities. At the end of the second iterative, we release the second draft version of the EI-DMM.

After the second version of the EI-DMM was intensively discussed and released by the research team, *Iteration three* conducted two separate interviews with EI experts to clarify its dimensions, capabilities, and characteristics of capabilities for each maturity level. One expert is expertise in electronics equipment automation production (IP1), and the other is in digital business strategies for manufacturers (IP2). The interview partners (IP) for the model development phase are depicted in Table 3. After these interviews, the team critically discussed proposed model adjustments before agreeing on a relatively completed EI-DMM.

Table 3. The development team for the model in the development phase.

IP	Type	Job Title	Industry	Expertise	Experiences Level	Working years in the field
IP1	Interview Partner	Senior Manager Digitalization	Electronics Industry Manufacturing	PPS, CPS, IoT, Autonomous Operation	Senior manager	>25
IP2	Interview Partner	Head of Digital Business	Telecommunication Equipment Manufacturing	Supply Chain Management, Digital Marketing	Senior manager	>25
FG1	Focus Group	Deputy Dean of Economic & Management	Economic & Management	Business transformation, high-performance manufacturing	Senior researcher	>25
FG2	Focus Group	Deputy Director of Development Strategies Department	Business Administration	Transformation strategies for manufacturers; Planning and Investment	Senior researcher	>25
FG3	Focus Group	PhD student	Domain focus on Operation Excellence, Telecom	Digital Transformation, Change Management	Senior researcher	>25
FG4	Focus Group	ICT Expert	Domain focus on Digital Business	Enterprise Architect, Digital Technology	Senior expert	>15
FG5	Focus Group	Digital Transformation Consultant	Domain focus on Industry 4.0, Digital Transformation	DMM development	Senior expert	>15
FG6	Focus Group	PhD student	Domain focus on Industry 4.0, DMM, Manufacturing	Knowledge and Innovation Management	Junior researcher	>15

As there are no more significant recommendations from expert interviews, In *Iteration four*, discussions by focus groups with six domain-specific scholars specialized in EI and related fields like Operation Management, Digital Business, Economic & Management (FG1–6 in Table 3) were conducted to pre-evaluate the EI-DMM. Thereby, the focus group pre-evaluated the EI-DMM using the proposed criteria [3]: (1) comprehensiveness, (2) problem adequacy, and (3) consistency.

a. Comprehensiveness: the model was totally agreed that it was comprehensive and covered essential EI, Digital Transformation, Servitization, PSS, and Service Design aspects.
b. Problem adequacy: number of discussion iterations of the model has been made by the focus group, that improved specificity of the model for the application context.
c. Consistency: The model was seen as overall consistency. Minor adjustments for the name of dimensions and sub-dimensions should be made.

After focus groups definitely agree that the EI-DMM is comprehensive, concise, and robust, the development process (Phase 4) is complete, as explained in detail in Sect. 4

4 Digital Maturity Model for Electronics Industry (EI-DMM)

In the following, the core of this paperwork, we present the EI-DMM in two main themes: Maturity scale and Dimensions. Regarding the Maturity scale, the model uses the concept of capability maturity model (CMM) [59] and recommendations from giant practitioners like Cognizant, Deloitte, PwC, and Red Hat. Moreover, the development team expands it in several aspects to cover the scale of the most well-known TM Forum's DMM [58] as a de-facto standard. This means the development DMM has more chance of integrating with the DMM of the firm's parents and/or benchmarking with other peers. Using these principles, the authors define five maturity levels as in Table 4.

Regarding the model's structure components, the development teams address the required capabilities for the corresponding manufacturers [35, 45, 48, 51], PSS Provider, Service Provider [41]; [58]. Moreover, the development team supplements them in aspects to cover critical fields that typical firms must consider in DT, like Customer, Strategy, & Organisation [4, 5, 19, 63]. This means the EI-DMM can address the root cause of the incumbent firm's weakness without a need to perform any further assessment by other multi-dimension models [17]. Using these principles, the authors define seven dimensions for the EI-DMM as depicted in (Table 5) (the detailed sub-dimensions and attributes are depicted in Appendix 1).

Table 4. Maturity of development model for EI sector (EI-DMM).

Level	Name	Definition
1	Initiating	No Industry 4.0 or only "ad-hoc": There are some individual initiatives, but no person explicitly responsible for DT, no existing clear vision of I4.0 or DT; there are no processes or supporting systems that are well-defined
2	Emerging	Project level: There are few pioneer Projects. DT is seen as a technical or production problem, but there are still no processes or supporting systems that are well-defined
3	Performing	Departmental level (isolated silos): DT is seen as a technical or production problem for some departments; These activities are performed independently mainly by the IT or production/engineering departments
4	Advancing	Organizational level (cross-departmental): DT is seen as a business problem at the firm's level involving all departments, requiring an overall vision and integrative approach from the BoD level
5	Leading	Inter-organizational level (cross supply chain/value chain partners): DT is seen as a business issue at the overall value/supply chain level involving all partners of the value/supply chains that are beyond the organizational borders, to enable collaboration required to make appropriate decisions across product-life-cycle from the customer viewpoint

Table 5. Dimensions of the development model for the EI sector (EI-DMM).

Dimensions (Domains)	Definition	References
People & Culture	The technical and management skilled workforce is crucial for DT. They need to have Design thinking, and PPS knowledge, be open to innovative technologies and have flexibility and autonomy for fast changes in the VUCA environment. These are supported by the promotion and the dissemination of an innovative culture, digital workplace environment, and digital leadership.	Berghaus and Back [5], Bilgeri et al. [6], El Sawy et al. [12], Gimpel et al. [19], Häckel et al. [24], Kane et al. [29, 30, 31], Schuh et al. [51]

(*continued*)

Table 5. (*continued*)

Dimensions (Domains)	Definition	References
Data	Data to be the "new oil" in the digital economy, the foundation of success for many actions fields related to digital transformation. Data need to be collected and aggregated so that they become available in standard forms, unprecedented volume, variety, and velocity. By exploiting data via advanced analytics, an organization can gain insight into customers or operations, predict usage, and support decision-making. Those capabilities must be implemented across the value chain, not only inside the organization but integrated with ecosystem partners to provide the best experience to the customer.	Colli et al. [9], Gimpel et al. [19], Häckel et al. [24], Schuh et al. [51], Schumacher et al. [53]
Smart Products	Products with ICT addons enable data acquisition, continuous connectivity, and communication with customers and factories across the value chain. Value-added services with a result-based payment model will be an important source of the company's revenue.	Arnold et al. [2], Berger et al. [4], Holotiuk and Beimborn [25], Häckel et al. [24], Lichtblau et al. [35], Rafael et al. [45]
Smart Operation	The autonomous systems and processes of information are based on connectivity and interoperability between operation systems, devices, and equipment. These allow processes of self-configuration and self-optimization of production, maintenance, and logistics activities. It supports a fast pace of product development and continuous improvement.	Berghaus and Back [5], Colli et al. [9], El Sawy et al. [12], Gimpel et al. [19], Häckel et al. [24], Kane et al. [31], Lichtblau et al. [35], Schuh et al. [51], Schumacher et al. [53]
Smart Factory	The cloud-based factories with fully IT security activities and IT infrastructures form a digital network environment as the enabler of real-time production and communication between machines, installations, and people.	Berghaus and Back [5], Colli et al. [9], El Sawy et al. [12], Gimpel et al. [19], Häckel et al. [24], Rafael et al. [45], Schuh et al. [51]
Strategy & Organisation	The administration board formulated a new strategy in terms of the Offering and Pricing Strategy, product as point-of-sale vision, the adequacy of the partner networking and organizational structure, and the required resources to function PPS.	Berghaus and Back [5], Colli et al. [9], El Sawy et al. [12], Gimpel et al. [19], Häckel et al. [24], Kane et al. [31], Schumacher et al. [53]

(*continued*)

Table 5. (*continued*)

Dimensions (Domains)	Definition	References
Customer	In the digital economy, customer experience is vital to gain and sustain customer relationships. Customer insight and customer interaction are essential for improving and providing personalized service to the customer. The digital product welcomes customers as partners to co-creation new disruptions.	Arnold et al. [2], Berghaus and Back [5], Exner et al. [13], Fleisch et al. [6], Gimpel et al. [19], Holotiuk and Beimborn [25], Häckel et al. [24], Kiel et al. [2], Schumacher et al. [53], Westerman et al. [63]

5 Conclusion

This paper addresses the need and develops EI-DMM, a DMM to guide electronics manufacturers digitally, transforming them toward Servitization. The authors have reviewed DMM theory to structure the EI-DMM, addressing Servitization as a business model that electronics manufacturers should pursue with an integrated PSS and Service Design approach. The EI-DMM has been iteratively developed by using the strategy of combining related models to form a new one and being upon the literature, pre-evaluated with domain-specific scholars in expert interviews and focus group discussions, as follows DSRM based procedure from [3] to gain high quality (i.e., comprehensiveness, problem adequacy, consistency) for the EI sector. By developing the EI-DMM, the authors contribute several practical and research outcomes. Regarding the practice aspect, within Vietnam's particular context, the paperwork has extended [38] research in improving the efficiency and profitability of Vietnamese EI firms that are relatively low. It points out that these firms should consider and digitally transform them toward the Servitization model under an integrated PSS and Service Design approach.

Regarding the research aspect, this work seriously provides a foundation for future research on performing a massive evaluation of more companies to improve and make it a standardized DMM for the EI sector.

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Appendix

Domains	Capabilities	Maturity Levels				
		1-Initiating	2-Emerging	3-Performing	4-Advancing	5-Leading
People & Culture	Digital Skills	No Digital Skills	Recruiting Digital Skills	Educating Digital Skills	Developing Digital Talents	Developing Digital Leaders
	PSS vision engagement	Product-oriented way of thinking	Thinking of offering complementary services	Thinking in terms of customer usage;	Thinking of providing PSS solutions	Thinking of delivering results as a service
	Workplace Environment	Desk Space	Meeting and Social Space	Collaborative Space	Spaces beyond the Building	Digital Workplace
	Innovation Culture	Inhibition of Innovation	Openness towards Change	Acknowledgment of Experimentation	Aspiration to Improvements	Entrepreneurial Thinking
	Leadership	Top-Down Governance	Transformational Leadership	Servant Leadership	Coaches & Sponsors	Digital Leadership
Data	Data Collection	No Collection	Manual Collection	Partially Automated Collection	Fully Automated Collection	Automated Collection with ecosystem partners
	Data Aggregation	Raw Data	Target Data	Pre-processed Data	Transformed Data	Enrichment Data
	Data Analysis	No Analysis	Descriptive Analysis	Diagnostic Analysis	Predictive Analysis	Prescriptive Analysis
	Data Integration	No Integration	Partial Integration	Integration with Major Business Entities	Integration with Whole Enterprise	Integration Beyond Enterprise

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Domains	Capabilities	Maturity Levels				
		1-Initiating	2-Emerging	3-Performing	4-Advancing	5-Leading
Smart Products	Digital Twins	There are some implementation projects	There are virtual models in the PLM	Virtual models of the PLM are well updated	Well updated Virtual models of the PLM used product improvement	Well updated Virtual models of the PLM used product improvement, and SAT (Servitization Business Models)
Smart Products	Tracking the product	No products are tracked	Products are tracked within manufacturer	Route of products are tracked until delivery to the customer	Products are tracked throughout their lifecycle	Products routes status is tracked
	ICT addons functionalities	Products have little add-on functionalities	Products feature initial add-on functionalities	Products feature multiple, interrelated add-on functionalities	Products feature add-on functionalities in different areas	Products feature extensive add-on functionalities
	Connectivity and Data Access	No access to product after point of sale	Indirect, situational data, manual customer data exchange	Continuous interconnectivity; mainly reading rights	Continuous interconnectivity; full access to product	connectivity of the product is a substantial component
	Product-Service System Model	Product offers basic services based on data, without revenues	Product offers services based on data with a periodical payment	Offers a service by pay per use	Offers a service by pay per results	Offers services based on data for improving the result

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Domains	Capabilities	Maturity Levels				
		1-Initiating	2-Emerging	3-Performing	4-Advancing	5-Leading
Smart Operation	Process Control	Instinct-driven Decisions	Data-based Decisions based on data from some functions	Data-based Decisions based on data from across organization	Autonomous Decisions for all functions of organization	Autonomous Decisions for organization and ecosystems partners
	Production Flexibility	Rigid Production Systems	Adaptive Production Systems	Component-driven Production	Modular Production	Modular Production across Value-adding Network
	Product Assembly	Small Proportion of Identical Parts	High Proportion of Identical Parts	Modular Construction of Products	Modular Products	Modular Products across Value-adding Network
	Business Processes Flexibility	Rigid Processes	Flexibility within Individual Processes	Interaction of Processes	Interaction across the Value-adding Network	Interaction across the Value-adding Network
	Inter-organizational Collaboration	Linear Supply Chain	Provider Network	Partner Network	Digital Value-Chain	Digital Ecosystem with Knowledge protection
Smart Operation	Life Cycle Management	Development, production, sale, and shipment; no responsibility for operation	no responsibility for operation but reactive provision of services	Development, production, sale, shipment, maintenance, and usage phase	Responsible for guaranteeing the usability of the product	Managing everything until the end of the product life cycle; responsible for delivering results and productivity

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Domains	Capabilities	Maturity Levels				
		1-Initiating	2-Emerging	3-Performing	4-Advancing	5-Leading
	PSS Design Methods and Tools	No approach for service or PSS development;	Partial use of PSS methods and tools	Selected approaches and formalized development processes for PSS; appropriate tools for development and implementation	Company-specific and individualized PSS approaches plus fast development cycles and prototyping; continuous improvement and use of methods	Company and ecosystem partners PSS approaches plus fast development cycles and prototyping; continuous improvement and share of methods
	Autonomous processes	Machine level: Partial mainly loading/unloading solutions	Machine level: Robots and assistants with more applications	Some production lines are partially automated	Some production lines are highly automated	All production lines are highly automated across the Value-adding Network
	Product Performance Measurement	Only measuring product quality by internal tests	Occasional insights measuring product performance but through maintenance services	Measurement of product performance and usage to guarantee and optimize product availability	Well-defined measures and feedbacks are systematically used for payments, maintenance	Well-defined measures and feedbacks are systematically used for new service development

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Domains	Capabilities	Maturity Levels				
		1-Initiating	2-Emerging	3-Performing	4-Advancing	5-Leading
Smart Factory	IT Infrastructure	Function-specific Infrastructure	Service-oriented Architecture	Cloud based infrastructure is used by some functions	effectively uses cloud-based infrastructure for all functions	effectively use cloud-based infrastructure with ecosystem partners
	IT Security	Isolated IT security activities	Security of Highly Critical Assets	Security of Processes	Intra- and inter-organizational IT security activities	Security by design in product development process
Smart Factory	IT Role	Functional IT	Business Integrated IT	IT as Service Provider	IT as Driver of Change, enabler of product-availability	IT as Driver of Change, enabler of product-performance
	Digital Modelling	Implementation project in a concrete area of the organization	Virtual model of the manufacturing plant is not used or updated	Updated virtual model of the manufacturing plant, it is used to make some incidental simulations	The plant has a digital model for simulations and improvement	The plant has a digital model for simulations and improvement; integrated with the ICT of the organization
	Adaptive & learning capabilities	machinery has a system of alarms	machinery has an alarm and can give some advice to the operator	machinery triggers an alarm and can automatically correct the problem, but with reduced performance	machinery triggers an alarm and can automatically correct the problem and maintain the performance	machinery triggers an alarm and can automatically correct the problem maintaining or improving the performance

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Domains	Capabilities	Maturity Levels				
		1-Initiating	2-Emerging	3-Performing	4-Advancing	5-Leading
Strategy & Organisation	Offering	Product	Standard Service	Novel, additional Services	Product-as-a-Service	Result-as-a-Service
	Pricing Strategy	(Fixed) one-time Price (pay for product)	One-time payment for product and situational service fee	Periodic Fee	Usage-based Billing (pay on availability)	Performance-based Billing (Customer-specific, result-based payment based on service level agreement)
	Sale Channel	Traditional Channels	Traditional and web-based channels for product sales	Traditional and web-based channels for product and service sales	Traditional and web-based channels or product as point of sale	Traditional and web-based channels and product as point of sale for integrated view on results
	Resource Allocation for PSS	No budget for PSS development and implementation	Little effort for creating additional services to the product; ad hoc investments in organizational changes	Medium effort for creating well-functioning PSS; continuous investments	Great efforts for maintaining well-functioning PSS; substantial and continuous investments	Great efforts to achieve a high-performance PSS; substantial and continuous investments

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Domains	Capabilities	Maturity Levels				
		1-Initiating	2-Emerging	3-Performing	4-Advancing	5-Leading
Strategy & Organisation	Partner Integration	Only suppliers as value-adding partners; clear organizational boundaries	Additional value-adding partners for service-creation and initial involvement of customer	Blurring of boundaries between company and suppliers as well as service-creation involved partners; close cooperation with customer as partner	Strong collaboration and integration of value-added partners and customer for PSS co-creation	Deeply integrated into partners and customers' processes, and business model
	Organizational Structure	Function-oriented hierarchical	Structures Cross-functional Projects	Product-/Process-oriented	Organization Independent, self-organized Teams	Organization Independent, self-organized Teams with ecosystem partners
Customer	Customer Insights	No Information	Anonymous Information	Segment-specific Information	Personalized (expectations, preferences) Information	All Personalized Information are actively considered across the Value-adding Network
	Customer Integration	Integration of Feedback	Integration in Early Design Process	Design Process as Co-Creation	Ideation Phase as Co-Creation	Partner-like Collaboration

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Domains	Capabilities	Maturity Levels				
		1-Initiating	2-Emerging	3-Performing	4-Advancing	5-Leading
	Customer Interaction	Interaction focuses on product purchase	Self-Service	PSS provider initiates services and is responsible for ensuring the perpetual availability; planned interactions	Digital, Semi-automated Interaction	Proactive and automated service interaction; connected through pre-defined touch points and processes; result as continuously monitored parameter for service initiative
	Customer Experience	There is no or little personalisation	Some aspects of the customer experience are personalized	Almost aspects of the customer experience are personalized	All aspects of the customer experience are personalized	All aspects of the customer experience are personalized based on collected customer insights and context from both the organization and its ecosystem partners.

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