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Digital transformation maturity model development framework based on design science: case studies in manufacturing industry

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Abstract

Purpose – This study aims to propose a novel maturity model development framework based on design science theory utilizing qualitative and quantitative methods for empirical evidence and develops a descriptive digital transformation maturity model by using the proposed framework.

Design/methodology/approach – Design science theory is deeply explored and extended to propose a novel maturity model development approach, including robust and rigorous validation processes. Thus, three consecutive discussion sessions and evaluations with experts are carried out iteratively to evolve and saturate the efficiency and utility of the maturity model, and consensus among experts at each session is validated by the intra-class correlation (ICC) coefficient. Furthermore, the Wilcoxon signed rank test is utilized to test whether there is a difference between consecutive sessions. Finally, prototype testing as a pilot study and two case studies in the manufacturing industry are carried out to validate the applicability of the developed maturity model.

Findings – A 3-phase maturity model development framework that includes the activities and outcomes in each phase emerge based on the design science theory. The comparative literature analysis and discussion sessions resulted in six dimensions, ten sub-dimensions, 39-capability items that circumscribe the digital transformation concept and five maturity levels that demonstrate conceptual consistency and a measurement tool for self-assessment. In addition, prototype testing and case studies show that the developed maturity model can measure the company's maturity level. Finally, it is proven that the digital transformation maturity model is developed by following the proposed maturity model development framework.

Practical implications – The maturity model draws a framework for practitioners that facilitate an initial roadmap and enhance the adoption rate, and it motivates the practitioners for frequent and efficient assessments, thus helping the continuous improvement of the digital transformation journey.

Originality/value – The originality of this paper lies in proposing a novel maturity model development framework based on design science and presents the activities and validation methods for this purpose. Furthermore, a comprehensive and rigorously validated digital transformation maturity model is developed based on the proposed framework.

Keywords Digital transformation, Digitalization, Industry 4.0, Maturity model, Design science, Digital maturity

Paper type Research paper

1. Introduction

The exponential pace of technological development and innovation dramatically affects organizations, processes and business culture and forces them to undergo digital transformation by causing disruptive changes and creating aggressive market competition. However, beyond being a threat, this situation may uncover new opportunities to increase competitiveness. In order to compete and survive, businesses have to realize the strategy and vision that puts the customer at the center for an enhanced value proposition.

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The utmost point of today's digital technologies is Industry 4.0, which offers technologically innovative tools and new concepts to create the highest value for the customer. These technological tools include big data processing and storage, information and communication technologies (ICT), the Internet of things and services (IoTS), cyber-physical systems (CPS), artificial intelligence (AI), additive manufacturing (3D printing) and many others. The concepts that emerge from these innovative digital technologies are product and service customization, digitalization of equipment/processes/products/services, flexible, lean and agile business structures and processes, supply chain integration and connectivity (Santos and Martinho, 2020). Therefore, digitalization and emerging concepts provide a value-adding supply chain network (Asdecker and Felch, 2018) to realize what it takes to be customer-focused.

Due to these innovative and disruptive digital technologies, businesses are exposed to cultural, organizational, economic and technological changes (Berger *et al.*, 2020), forcing all business functions to be reshaped (Porter and Heppelmann, 2015). While experiencing such dramatic changes, businesses should first adapt and then address their challenges through a concrete roadmap, vision and strategy that continuously review its current status as a first relevant step (Pirola *et al.*, 2020). Businesses achieve their goals step by step, and each step includes its holistic advances. These progress steps and process definitions are called maturity models. Therefore, the maturity model is a strategic tool to elucidate the improvement path through digitalization efforts and reveal the weaknesses and strengths to determine the actions.

Since digital transformation is relatively new, good-quality studies are rare in the existing literature, and most of them focus on a specific field, the manufacturing industry (i.e. Bibby and Dehe, 2018; Pirola *et al.*, 2020; Wagire *et al.*, 2021). However, digital transformation affects all business segments regardless of sector, size, location, etc. Therefore, the existing literature lacks a holistic and modular framework that includes all peripherals and concepts of digital transformation. Furthermore, although existing digital transformation maturity model studies refer to design science methodology, a rigorous approach lacks following the stages of design science and presenting model verification and validation. Besides, researchers mainly focus on validating the design artifact, however, a holistic approach is missed, and validation of the design process is lacking and remains questionable. Since design science combines the design process and design artifact (Hevner *et al.*, 2004), it requires a holistic approach.

The development of a maturity model is the subject of design science research (Pöppelbuß and Röglinger, 2011), a set of processes to devise artifacts to solve the specific problem (March and Smith, 1995; Hevner *et al.*, 2004). However, design science research alone falls short of developing a maturity model since it is a set of processes for solving a specific problem and creating a design product and a guide for researchers. Therefore, a robust methodology needs to be developed and empirically tested by qualitative and quantitative means, clearly communicated and well-documented. Since the aim is to propose a maturity model development framework based on the design science, this study demonstrates a descriptive digital transformation maturity model as a sub-objective to prove the applicability of the framework. Pöppelbuß and Röglinger (2011) classify maturity models as the descriptive purpose, which measures the current state as a diagnostic tool, the prescriptive purpose, which provides improvement measures through maturation and the comparative purpose for benchmarking. Thus, the developed maturity model serves a descriptive purpose, focuses on businesses regardless of the sector and company size, addresses the need of both management and technology-oriented audiences with a self-assessment measurement instrument (Mettler, 2011). Therefore, this study contributes to and fills the gap in the literature by following ways:

(1) Proposing a novel maturity model development framework based on design science procedures,

(2) Developing a descriptive digital transformation maturity model by following the proposed framework,

(3) Proposing both qualitative and quantitative methods to verify each design process and to validate the developed artifact by utilizing iterative evaluation processes,

(4) Communicating both model development process and developed maturity model dimensions and measurement instrument.

This study is structured as follows: Section 2 presents the theoretical roots of the maturity model concept and design science theory. Besides, the characteristics of existing digital transformation maturity models are explored and analyzed to reveal the research gap. Section 3 is devoted to proposing a thorough and rigorous design process and a maturity model in which dimensions, maturity levels and measurement instrument are designed. Finally, sections 4 and 5 are devoted to the discussions and conclusions of this research.

2. Systematic literature review

2.1 Maturity model concept and design science approach

Maturity is the state of being at the desired level as a dictionary definition (Merriam-Webster, 2020), and the maturity model is a diagnostic tool to evaluate the current level (descriptive) and is a guiding tool to create a roadmap for desired level (prescriptive) (Becker *et al.*, 2009; De Bruin *et al.*, 2005). Since maturity models have evolutionary characteristics (Colli *et al.*, 2019), levels are successively developed for each concept that requires a number of capabilities (Schuh *et al.*, 2017). A maturity model has a conceptual structure that includes concepts of the related domain and incremental levels and aims to measure the ongoing efforts through maturation (Santos and Martinho, 2020). The maturity levels are defined as the increase in the capabilities of the related domain and can be evaluated either qualitatively or quantitively (Wagire *et al.*, 2021). Companies gain a strategically competitive advantage by measuring the digital transformation maturity levels (De Bruin *et al.*, 2005).

The development of a maturity model is the subject of design science research (Pöppelbuß and Röglinger, 2011), a set of processes to devise design artifacts (March and Smith, 1995; Hevner *et al.*, 2004). The success of the developed artifact lies in the ability to effectively address the design process and design product (Hevner *et al.*, 2004). Design science research on information technologies and maturity model development in the literature is examined conceptually. March and Smith (1995) create the research methodology on information technologies and depict the conceptual relationship between design and natural science. Hevner *et al.* (2004) expand the concept of design science in information systems and introduce valid and reliable research guidelines. Design-oriented processes and product design are tackled effectively and efficiently by these guidelines. De Bruin *et al.* (2005) aim to generalize maturity model development processes in any domain and establish a generic procedure. Becker *et al.* (2009) establish the maturity model development procedure for IT management by considering these guidelines. Van Steenbergen *et al.* (2010) developed a generic IS focus maturity model development method based on design science processes. Mettler (2011), unlike the others, identifies the decision parameters of each process with a taxonomy from both the developer and the user's point of view. Although design science studies conceptually define the methodology of developing an artifact in detail and emphasize the importance of model evaluation, how to perform each step of the developed procedure and model evaluation techniques remain superficial and deficient.

2.2 Existing digital transformation maturity models

This study follows the guidelines mentioned by Webster and Watson (2002) and vom Brocke *et al.* (2009) for a systematic literature review focusing on the digital transformation maturity models. The search process includes peer-reviewed articles, conference papers and theses in ABI/Inform, EBSCO Academic/Business, Emerald-Insight, IEEE, Science Direct, SCOPUS, Taylor and Francis, Web of Science, ProQuest Dissertations and Theses Global databases. Besides, company reports are included by searching the selected articles (backward search). The search process is conducted until March 2021 without a start date to include all possible sources, and the search string is defined as ("Digital Transformation" *OR* Digitalization *OR* "Industry 4.0") *AND* ("Maturity Model" *OR* "Capability Model" *OR* "Process Improvement Model" *OR* "Maturity Grid" *OR* "Competency Model" *OR* Readiness). The search process includes the studies whose scope is to develop and validate the maturity model with a rigorous methodology, which provides dimensions of digital transformation in people, process and technology triage in a business environment. The enterprise-centric studies written in English are included, other languages and government-centric maturity models are excluded. Besides, maturity models focusing on a specific side of digital transformation, such as AI, additive manufacturing, etc., are excluded. By employing search strings, inclusion and exclusion criteria, the search process results in 613 journal articles and 354 conference papers. Duplicated search results are eliminated and, the first relevancy scan in terms of title, abstract, keywords is conducted. Therefore, 65 journal articles and 31 conference papers are resulted in for further analysis. Besides, five company reports are included in the backward search process. The second screening process with full-text read is carried out and finally results in seven articles, ten conference papers, one book chapter and three company reports. Webster and Watson (2002) suggest that the literature review is structured with a concept-centric approach. Therefore, the developed classification methodology, which includes the common concepts of the articles, is presented in Table 1, and the analysis of the selected publications according to the classification methodology is presented in Table 2.

Category	Sub-category	Description
Research principle	Conceptual	The model development procedure solely follows theoretical literature review and case study approach
	Design-oriented	The model development procedure additionally follows one of the maturity model development designs in the literature (Hevner *et al.*, 2004, etc.)
Model development method	Prescriptive literature review Systematic literature review	The literature search process for existing maturity models is conducted either arbitrarily and selective or systematically
	Comparative literature review	The existing maturity models are analyzed comparatively
	Interview Focus group Delphi Prototype testing	Qualitative and quantitative methods used in the model development process
Documentation quality	Research principle Lit. review of maturity models Model development method Description of model dimensions Description of maturity levels	Presents whether the model development procedure is well-documented in every aspect. Each article is scored from one to three points by the authors

Table 1.
Description of concepts

Table 2. The analysis of the existing digital transformation maturity models

Reference	Application focus	Research principle: Conceptual	Research principle: Design oriented	Model development method: Prescriptive Lit.Rev	Comparative Lit.Rev	Systematic Lit.Rev	Interview	Focus group	Delphi	Prototype testing	Documentation quality: Research principle	Literature review	Model development method	Model dimensions	Maturity levels
Lichtblau *et al.* (2015)	Manufacturing	X		X				X				N/A		3	3
Schumacher *et al.* (2016)		X			X	X				X	2	1	1	1	
De Carolis *et al.* (2017a)		X		X			X				1	1	1	1	1
Gökalp *et al.* (2017)			X		X	X					2	3	2	2	2
De Carolis *et al.* (2017b)			X				X				1	1	1	1	2
Schuh *et al.* (2017)		X						X			2	N/A	3	3	X
Bibby and Dehe (2018)		X		X				X	X	X	3	1	2	2	1
Colli *et al.* (2019)			X	X	X		X				1	1	N/A	1	2
Schumacher *et al.* (2019)			X	X			X			X	2	2	3	2	2
Pirola *et al.* (2020)		X			X		X			X	3	3	3	1	3
Santos and Martinho (2020)			X	X		X	X			X	3	1	3	3	1
Rafael *et al.* (2020)		X			X	X	X			X	3	3	3	1	1
Wagire *et al.* (2021)			X		X	X	X				3	3	3	3	1
Geissbauer *et al.* (2016)	General	X		N/I								N/A		3	3
Akdil *et al.* (2018)		X			X						1	2	1	3	3
Aguiar *et al.* (2019)			X	N/I							3	1	3	1	1

(*continued*)

Table 2.

Reference	Application focus	Research principle: Conceptual	Research principle: Design oriented	Model development method: Prescriptive Lit.Rev	Comparative Lit.Rev	Systematic Lit.Rev	Interview	Focus group	Delphi	Prototype testing	Documentation quality: Research principle	Literature review	Model development method	Model dimensions	Maturity levels
Mittal *et al.* (2018)	SME	X		X							1	2	1	2	1
Trotta and Garengo (2019)			X			X					2	2	1	1	1
Asdecker and Felch (2018)	Delivery process		X		X	X					3	3	3	3	3
Bandara *et al.* (2019)	Banking sector	X		X							1	1	1	1	2
Gollhardt *et al.* (2020)	IT		X	X			X				3	3	3	3	N/A

Note(s): *NOT Included (N/I)*: The article does not include a part related to the concepts
NOT Applicable (NA): The concept does not apply to the scope of the article

A classification shown in Table 2 reveals the current trends and the basic characteristics of the maturity model design process in the existing digital transformation maturity models with three main and 14 sub-concepts. In order for the maturity model development process to be more rigorous and reliable, it is important to present the strengths and potential development areas. As a result of the systematic literature review, 21 studies are found, with publication years between 2015 and 2021 presenting that the digital transformation maturity model development is a new field.

The first concept is the research principle, categorizing the studies as conceptual or design-oriented. The model development procedure in conceptual studies solely follows theoretical literature review and case study approach. However, design-oriented studies additionally follow one of the maturity model design approaches in the literature. Design science is a methodological approach that includes guidelines for developing more stable, reliable and validated artifacts, a maturity model in this research. Articles that follow a design-oriented approach (e.g. Hevner *et al.*, 2004; Becker *et al.*, 2009; De Bruin *et al.*, 2005) include a good number of existing maturity models as a reference that is systematically and comparatively evaluated and implement multi-methodological processes for model development. Besides, case study applications are dominant in the design science approach to prove the validity of the developed product.

The second concept aims to explore the maturity model development methodology. The selected articles present that the literature review process focusing on existing maturity models is at the center of novel model development. Besides, interviews, focus groups, Delphi and prototype testing are included in applying a multi-methodological approach to realize the validity of the developed maturity model. Since digital transformation is an ever-growing concept, the researchers mainly benefit from interviews with experts and practitioners. The pilot study is rarely preferred for the maturity model development process. The last concept is to analyze the documentation quality of the selected articles in five categories. Hevner *et al.* (2004) and Becker *et al.* (2009) suggest that the development process should be well-documented and communicated. Therefore, documentation quality of research principle, the literature review process, model development method, detailed explanation of model dimensions and maturity levels are critically evaluated by authors within consensus for each study in terms of three grades according to the granularity of the detailedness: 1- Slightly explained, 2- Moderately explained, 3- Significantly explained. It is observed that journal articles demonstrate a satisfying documentation quality while conference proceedings and company reports lack a clear description of maturity model procedures and features.

3. Methodology

This research aims to develop a descriptive digital transformation maturity model by recalling the design science theory in which March and Smith (1995) and Hevner *et al.* (2004) strongly emphasize the build-and-evaluate iterations for developing system artifacts. The build process refers to understanding the domain peripherals comprehensively and addresses the question of "Does the built artifact work?" The evaluation process refers to the performance of the artifact in terms of evaluation criteria and seeks to address the question of "How well does the developed artifact perform?" The success of the developed artifact lies in the ability to effectively address the design process and design product (Hevner *et al.*, 2004).

When maturity model development studies supported with a design science theory are evaluated, common processes have different titles but similar meanings. These common processes and features in maturity model development include a multi-methodological approach, a systematic and comprehensive literature search, an iterative design solution, rigorous and well-documented research that is clear, comprehensible and reproducible. Therefore, existing knowledge is utilized to propose the digital transformation maturity model development framework, which presents the activities of previous design science methodologies. Therefore, the maturity model development framework based on design science is constructed with three phases, as shown in Figure 1.

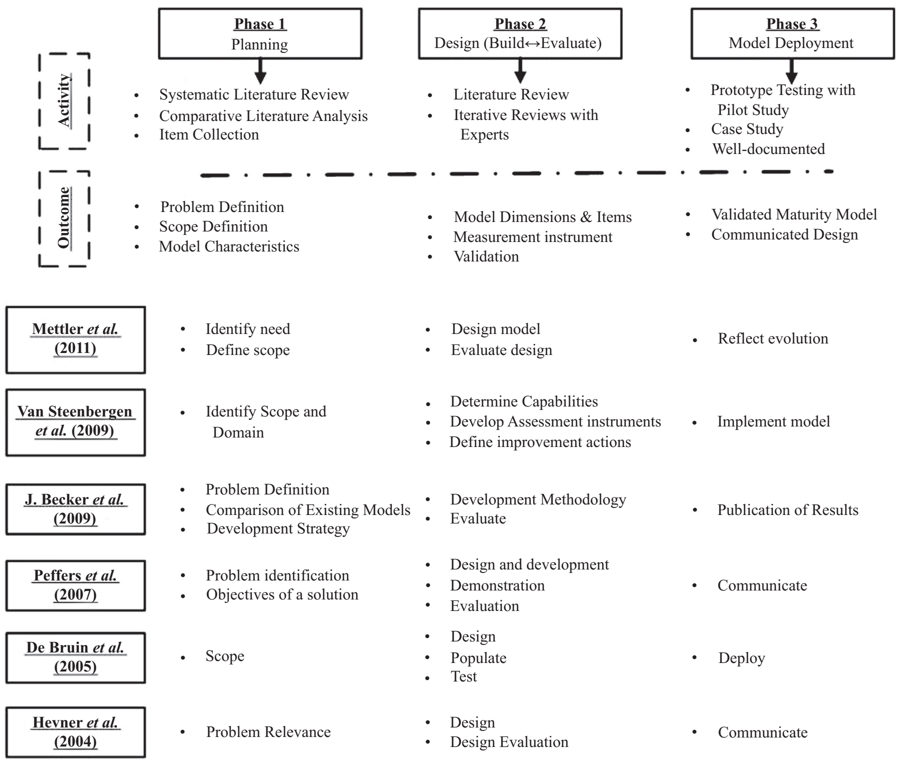

Figure 1.
Digital transformation maturity model development framework

3.1 Phase-1: planning

The planning phase focuses on developing the scope definition, problem identification and model characteristics. A comparative systematic literature review captures the gap in the existing studies and builds on the existing knowledge incrementally. In light of the literature review, the scope and objective of this study are to develop a rigorously tested, reliable and valid maturity model which has the following model characteristics (1) follows design science methodology, (2) employs a multi-methodological approach, (3) targets both management and technology-oriented people as an audience, (4) multi-dimensional, (5) includes both theory and practice-driven design process and proposes self-assessed measurement instrument as a design product. Thus, Figure 2 presents the details of the planning phase.

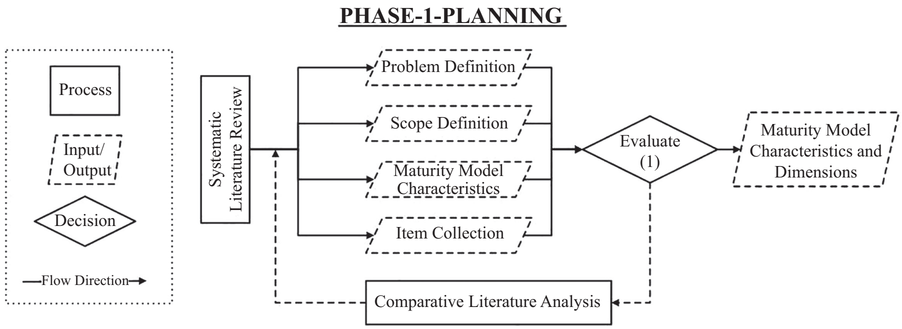

Figure 2.
Phase-1-planning

3.2 Phase-2: design process

The design process focuses on incrementally developing a maturity model and measurement instrument for quality and efficiency by including 14 industrial/academic experts whose profiles are given in Table 3 through in-depth discussion sessions. Experts are selected using judgmental sampling, "the deliberate choice of a participant due to the qualities the participant possesses" (Etikan *et al.*, 2016).

Hevner *et al.* (2004) define the design process as a sequence of expert activities. Build-and-evaluate iterations are frequently recalled providing feedback until saturating the model development process. As shown in Figure 3, the design process framework starts with the initial maturity model, including dimensions, capabilities, maturity levels and measurement instrument. Afterward, a series of expert reviews are iteratively conducted until the maturity model is saturated. Then, the first expert reviews and discussions are conducted, and feedbacks are collected to refine the maturity model and measurement instrument for the second iteration.

	Current job title	Experience (years)	Education
1	Smart solutions and IOT senior specialist, digital transformation researcher	13	Ph.D
2	Information technology and cyber security director, digital transformation consultant	34	M.Sc
3	ERP system manager and consultancy, assoc.prof. in information systems	20	Ph.D
4	General manager at business academy, ERP project manager	26	B.Sc
5	Lean coordinator, digital transformation consultant	21	B.Sc
6	ERP sales manager, managing partner of a company (ERP, business intelligent, digital transformation, management and process consultancy)	20	B.Sc
7	IoT projects coordinator	8	B.Sc
8	General manager of a company (Digital factories), University lecturer	24	B.Sc
9	Project, operations and industry coordinator	7	M.Sc
10	Digital transformation consultant, ERP project manager and consultant, chair of enterprise transformation platform	26	B.Sc
11	Researches about digital transformation and published Ph.D. thesis on digital transformation maturity model	15	Ph.D
12	Digital transformation project manager	4	M.Sc
13	Researches about digital transformation and published Ms.C. thesis on digital transformation maturity model	6	M.Sc
14	Digital transformation and business development leader	8	Ph.D

Table 3.
The profiles of experts

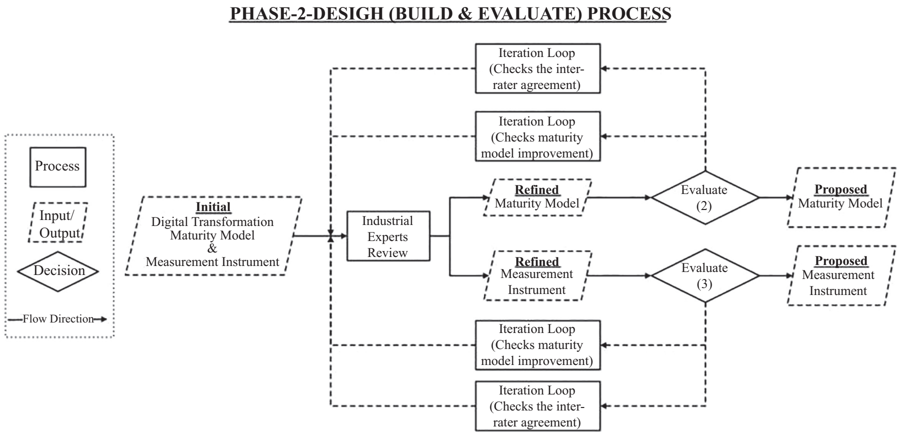

Figure 3.
Phase-2-design process framework

Experts review and evaluate the model at each iteration, and the improvement points are feedbacked. The iterative feedback loops ensure that the evolution of the maturity model is successful. The conceptual meaning of the iterations is based on the quantitative justification that utilizes the evaluation criteria given in Table 4. Experts are asked to score the evaluation criteria with a 5-point scale for refined maturity model and measurement instrument. Thus, if the average score for each quality criterion does not statistically differ from the previous evaluation score, it implies that the model is saturated and reached stability, and further iterations are interrupted, which ensures the proposed maturity model and measurement instrument is complete and effective (Hevner *et al.*, 2004). In addition, another iteration loop is considered to check whether the evaluation scores from experts agree, which ensures the inter-rate reliability.

Evaluation criteria	Definition	Reference
Maturity model		Hevner *et al.* (2004), De Bruin *et al.* (2005), Asdecker and Felch (2018)
CR-1: Comprehensibility	The maturity model is easily understandable	
CR-2: Comprehensiveness	The maturity model includes all relevant item	
CR-3: Relevance	The maturity model includes important and consistent content	
CR-4: Consistency	The structure of the maturity model presents logical connections	
CR-5: Detailedness	The maturity model describes all items in detail	
CR-6: Applicability	The maturity model supports to determine the maturity level of a company	
Measurement instrument		
CR-1: Comprehensiveness	The measurement instrument is easily understandable	
CR-2: Detailedness	The measurement instrument describes all items in detail	
CR-3: Applicability	The measurement instrument supports to determine the maturity level of a company	
CR-4: Ease of Use	The measurement instrument is intuitive to use and does not require a special training	

Table 4.
Maturity model and measurement instrument evaluation criteria

3.2.1 Digital transformation maturity model dimensions. Maturity model dimensions and capability items are highlighted through comprehensive and comparative literature analysis conducted in Phase-1 and developed through iterative expert discussion sessions. Table 5 presents the final maturity model dimensions comparatively with existing digital transformation maturity models. The comparison is carried out based on capability definitions in the cited articles to reflect the comprehensiveness accurately. The maturity models, which are well-documented for defining capability items and dimensions, are included. Therefore, most of the items in the strategy and governance dimension are represented in the existing maturity models. However, consultancy requirements, protection of data and information sovereignty, abiding by the government regulations are less represented, and corporate social responsibility for supporting training initiatives through the digitalization era and project management is introduced as new items. The literature focuses on innovative culture and training factors in the organization and corporate culture dimension, which the proposed model extended the dimension with 11 capability items. Smartness is the most represented dimension in the existing maturity models in which the majority of the items are identified. The employee dimension focuses on soft skills (collaboration, self-learning and technology acceptance) and hard skills (IT), while the existing maturity models mainly refer to hard skills. The capability items in process and customer dimensions are mentioned in the existing maturity model studies, yet not included as separate items for evaluation.

3.2.2 Digital transformation maturity levels. Five maturity levels are determined, each of which exhibits conceptual consistency based on dimensions and includes the rationality behind the model development process. *Level 1, Awareness*, is a strategic step for maturity improvement that stimulates and creates awareness and aims to inform the organization about what should be carried out during digital transformation. Stentoft *et al.* (2021) suggest that the higher awareness of industry 4.0 concepts enables companies to be more prepared for innovative technologies. *Level-2, Pilot*, focuses on rehearsing the digital transformation process with pilot applications. Thus, the organization can evaluate the digital transformation process by itself and sense the value it creates, and the employees can be motivated by experimentation. Pirola *et al.* (2020) indicate that companies start digitalization processes with a pilot project to explore the potential. Geissbauer *et al.* (2016) see pilot projects as proof-of-concept and a way of carrying out larger projects successfully and ensuring the right investment. *Level-3, Engagement*, represents that digitalization projects determined in the vision statement are realized with the experience, knowledge and confidence gained from pilot applications. *Level-4, Supply Chain Integration*, is devoted to network integration which is the most critical asset for competitive advantage in the digital era and this provides orchestration of supply chain partners (Bharadwaj *et al.*, 2013). *Level-5, Optimization*, represents a level in which the organization adopts digitalization, constantly engages in innovative ideas and actions, integrates each new function into digital processes and optimizes existing applications.

3.2.3 Measurement instrument. The measurement instrument (see Supplementary file) enables companies to self-assess their maturity level. The self-assessment approach is one of the application methods proposed by De Bruin *et al.* (2005) and Mettler *et al.* (2010) and preferred by researchers utilizing a 5-point scale (Santos and Martinho, 2020; Schumacher *et al.*, 2016; Trotta and Garengo, 2019; Wagire *et al.*, 2021). Assessment scores of the developed maturity model are assigned from 1 to 5 for each capability item that is coherent to maturity level definitions. The scoring with a 5-point scale for a broad and diverse content, *digital transformation*, might be seen as depending on perception. However, there are three effective actions to differentiate from perceptual assessment and provide a more realistic and factual assessment (Voss *et al.*, 2002) that overcomes the key informant bias (Mettler, 2011): (1) Each score refers to a maturity level that has conceptual consistency and design rationality,

Table 5. Maturity model dimensions

Dimension	Sub-Dimension	Capability Items	Operational Definition	R1	R2	R3	R4	R5	R6	R7	R8	R9	Total referred
Strategy&Governance	Strategy	**S1.1**-Digital vision&Roadmap	A digital vision and roadmap, which includes how the digital transformation is communicated, how the processes are carried out, and how the company structure looks after the transformation, is determined.	■	■	■	■	■	■	■	■		**8**
		S1.2-Investment planning	The project investment plan is prepared and prioritized to include internal and external digitalization projects.	■	■	■	■	■	■	■	■		**8**
		S1.3-Measurable objectives	Clear, comprehensible, and measurable goals are determined according to the vision, and communicated with stakeholders.		■	■			■	■	■	■	**6**
	Governance	**S1.4**-Top management participation	Top management eliminates bottlenecks at digitalization projects, motivates staff, and makes them believe in change.		■	■	■		■		■		**5**
		S1.5-Project Management	The assignment of the Chief Digital Officer (CDO) and the project team with technical and managerial abilities, the creation of project plans that include time, cost, scope, and the coordination of internal and external stakeholders administratively should be achieved with the project management philosophy.										**0**
		S1.6-Consultancy	The contribution of the consultancy services to success in digital transformation projects is important, and consultancy services should be taken in different processes.						■				**1**
		S1.7-Strategic collaboration	To realize know-how transfer and increase project success by strategically collaborating with digital leaders that have achieved digital transformation success.	■					■		■	■	**4**
		S1.8-Corporate social responsibility	Companies take responsibility and act proactively in raising the future workforce.										**0**
		S1.9-Regulations	The companies should follow and abide by the regulations (tax, incentives, labor rights, etc.) related to the digitalization efforts.		■						■		**2**
		S1.10-Data&Information Sovereignty	The companies should ensure that internal and external partners protect the critical data and information, and legal measures are taken to protect the data sovereignty						■			■	**2**
Organization and Corporate Culture	Corporate Culture	**S2.1**-Experiencing the fault and risk	Employees are not afraid of trying new practices, taking measurable risks, and making mistakes. Therefore, the organization can tolerate employees making mistakes.						■			■	**2**
		S2.2-Being in the same boat	To have a business culture with a transparent and open communication culture, where employees can see themselves as a part of the whole, have a relationship of trust with their managers, work in a team towards a common goal.										**0**
		S2.3-Supportive in change	In an organization where employees trust and adopt digital transformation, their fears and concerns are eliminated, they do not resist change, and on the contrary, they embrace change.									■	**1**
		S2.4-Open innovation	An organization where employees do not hesitate to declare, develop and experience innovative ideas internally and externally.	■		■	■		■	■		■	**6**
	Mid-Level Management	**S2.5**-Active support of mid-level managers	Mid-level managers embrace the digital vision, understand and effectively communicate the change, have a unified goal, actively engage in digitalization efforts.										**0**
		S2.6-Actions of mid-level managers	Mid-level managers follow best practices, examine the success/fail stories, communicate with employees, develop incentive systems for the motivation of employees, and follow digitalization activities within the unit they manage.										**0**
		S2.7-Required employee skill	Employee skills required for digitalization projects are determined			■				■			**2**
		S2.8-Training	Determining, planning, and realizing the training needed by the in-house employees and SC partners for successful digitalization projects.		■		■		■	■	■	■	**6**
		S2.9-Decentralized decision-making	An organization where decisions on repetitive/programmable functions are carried out autonomously or decision-making power is delegated to become decentralized					■		■		■	**3**
	Organizational Structure	**S2.10**-Lean	Efforts to continuously improve and increase productivity, eliminate waste in processes, promote the employees' creativity, and embed lean thinking and lean leadership concepts in the organization.										**0**
		S2.11-Agile	Establishment of an organizational structure that is flexible and responsive to the fast-changing market dynamics, where the organization is purified from hierarchical silos, where the employees are appointed based on their expertise, where employees are empowered.	■								■	**2**

(*continued*)

Dimension	Sub-Dimension	Capability Items	Operational Definition	R1	R2	R3	R4	R5	R6	R7	R8	R9	Total referred
Smartness	IT Cyber Security	**S3.1-**IT Cyber Security	IT Cyber Security									■	**1**
		S3.2-IT cyber security applications	IT system security is carried out by the company internally and ensured by SC partners to establish trust.				■	■		■	■	■	**5**
	Data Analytics	**S3.3-**Data Collection	Data Analytics	■	■	■	■	■	■	■	■	■	**9**
		S3.4-Data analytics	It is aimed to propose the highest value to the customer by analyzing the collected data in real-time utilizing technological tools such as AI, ML, cloud computing, big data processing, etc., for better decision-making and optimizing processes.	■	■	■	■	■	■	■	■	■	**9**
		S3.5-Data analytics team	The company's vision is to see the dedicated data analytics team as a strategic asset to perform data analysis in-house.								■		**1**
		S3.6-Decentralized data analytics	The ability to analyze the data using smart sensors or CPS with its own microprocessors and control manufacturing or business processes by making autonomous decisions with the generated information.			■				■		■	**3**
		S3.7-Data management	Combining data sources in a scalable, autonomous, and central database system within a data management plan and strategy.	■							■	■	**3**
Employee	Talented Employee	**S4.1-**Talented Employee	Talented Employee									■	**1**
		S4.2-Self-learning for digital knowledge	Employees have a self-training plan, self-develop in digital literacy, follow recent technological innovations, and have sufficient IT/technology knowledge.	■	■					■		■	**4**
		S4.3-Digital collaboration	The ability of employees to cooperate and collaborate, take a participatory approach to innovative processes, share knowledge, and work as a team.								■		**1**
		S4.4-Technology acceptance	Employees believe that the company benefits from digital technologies, which increase their performance. Besides, digital technologies are user-friendly and easy to use.										**0**
		S4.5-Skilled IT team	The skilled IT team is a strategic asset for successfully executing digitalization projects.					■	■		■		**3**
Processes	Smart Processes	**S5.1-**Smart Processes	Smart Processes					■	■	■			**3**
		S5.2-Process flexibility	The flexibility of operations, processes, and business functions enables companies to respond to the fast-changing market environment and provides strategic superiority and competitiveness.										**0**
		S5.3-Process automation	The ability to automate repeatable processes to accelerate and standardize daily tasks and prevent user-induced errors by utilizing digital tools such as AI,ML, etc.			■			■				**2**
		S5.4-Horizontal&Vertical integration	Business functions, processes, and operations are digitally integrated within the company (vertical) and across supply chain stakeholders (horizontal).				■	■	■	■	■	■	**6**
Customer	Customer Integration and Value	**S6.1-**Customer Integration and Value	Customer Integration and Value						■		■		**2**
		S6.2-Digital value proposition	The ability to propose added value and create a digital revenue stream by including complementary digital products and services to existing ones.			■	■		■	■		■	**5**

R1-Bibby and Dehe (2018)	**R2**-Pirola *et al.* (2020)	**R3**-Santos and Martinho (2020)	**R4**-Wagire *et al.* (2021)	**R5**-Gökalp *et al.* (2017)
R6-Gollhardt *et al.* (2020)	**R7**-Lichtblau *et al.* (2015)	**R8**-Geissbauer *et al.* (2016)	**R9**-Schuh *et al.* (2017)	

Table 5.

(2) Scoring for each capability item is carried out by managers responsible and knowledgeable for that capability, (3) Scoring for each capability item is carried out by at least two managers with a consensus. Therefore, perceptual and subjective maturity assessment is minimized by applying an effective evaluation strategy.

3.3 Phase-3: model deployment

Model deployment is achieved through prototype testing with pilot studies and case applications, as shown in Figure 4. First, a pilot study is carried out to overcome the shortcomings encountered in practice. It provides an opportunity to explore and improve the developed maturity model and gives another perspective from practitioners. Then, the operational definitions of the dimensions and maturity levels are discussed with the participants in the company and revised if necessary. Besides, the clarity and comprehensiveness of the developed maturity model and the measurement instrument are also reviewed. Finally, prototype testing is realized in the pilot study, and the initial usability and applicability of the maturity model are observed. Afterward, a case study is conducted to explore the real-life applicability of the developed digital transformation maturity model in companies. Bibby and Dehe (2018) imply that a case study is useful for exploring a phenomenon and extracting knowledge deeply. Besides, Pirola *et al.* (2020) suggest a case study for complicated systems as a suitable approach for development and validation. Another case application within a suitable time frame that the assessor forgets the first evaluation and the company cannot improve in maturity levels is conducted in the same company to test the reliability and stability of the measurement instrument with Pearson's correlation coefficient.

3.4 Validation and evaluation of design process and product

Maturity model evaluations are carried out for research rigor to verify and validate the design process and product (Mettler, 2011). Hevner *et al.* (2004) and Peffers *et al.* (2012) propose various evaluation types for designed artifacts and recommend that researchers apply the appropriate type that proves a logical justification. However, clear guidance on empirical evaluation of maturity model design with quantitative methods lacks, to our best knowledge, in both design science and existing maturity model research. Therefore, this study utilizes several evaluation types mentioned in design science research and proposes qualitative and quantitative approaches for each phase to ensure appropriateness, as shown in Figure 5.

The planning phase utilizes the descriptive evaluation type, referring to existing knowledge to extract the relevant research question (Hevner *et al.*, 2004). Therefore, this study utilizes a systematic and comparative literature analysis to identify the research problem and scope, the characteristics and dimensions of the maturity model. The design phase utilizes expert evaluation for incrementally building the design artifact (Peffers *et al.*, 2012) and static analysis, which compares one design product from the other (Zelkowitz and Wallace, 1998). Expert evaluations are conducted through in-depth discussions in each iteration. Static analysis is achieved by two evaluation methods: (1) Wilcoxon signed-rank test and (2) intra-class correlation (ICC) coefficient. The expert reviews are continued iteratively until the last evaluation for quality criteria do not statistically differ from the previous evaluation.

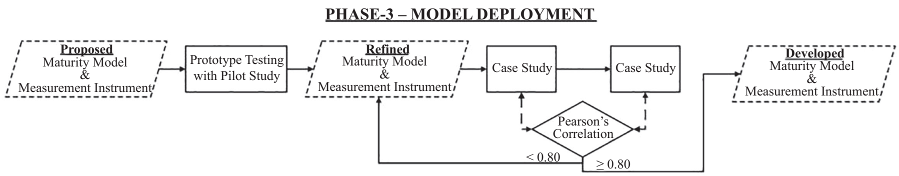

Figure 4.
Phase-3-model deployment framework

This implies that the model is saturated for further developments. Therefore, the Wilcoxon signed-rank test, a non-parametric alternative of paired-sample t-test, shows whether the quality of the proposed maturity model in the last iteration and previous iteration statistically differ.

The maturity model evaluation scores are compared for the first and second review sessions and the second and third review sessions. The results as shown in Table 6 indicate that the differences for evaluation scores of the first and second review sessions are statistically significant where each $p < 0.05$, and the differences for evaluation scores of the second and third review sessions are not statistically significant for Comprehensiveness, Relevance, Consistency and Applicability where each $p > 0.05$. However, the maturity model shows the statistical difference for comprehensibility and detailedness between the second and third review sessions. The average score of the Comprehensibility improved from 4.6 to 4.82, and the average score of the detailedness improved from 4.18 to 4.68. Since the final scores of the two quality criteria are satisfactory, further iterations of the review sessions are interrupted. As for the measurement instrument evaluation scores, the differences between the first and second review sessions are statistically significant, where each $p < 0.05$. The difference for the "Ease-of-Use" of the second and third review sessions is not statistically significant, reflecting the maturation. However, the measurement instrument shows the statistical difference for Comprehensiveness, detailedness and Applicability between the second and third review sessions. The average score of the Comprehensiveness improved from 3.96 to 4.32, the average score of the detailedness improved from 4.32 to 4.64, and the average score of the Applicability improved from 4.29 to 4.375. Since the final scores of three quality criteria are satisfactory, then further iterations are interrupted.

The agreement among experts is tested by ICC analysis for each iteration, as shown in Table 7 since the collected data is continuous and more than two raters exist. Each expert evaluates the maturity model and measurement instrument two times during the discussion session. One evaluation is conducted after the authors finalized the presentation, and another is conducted after the expert has given the feedback. Therefore, the average score is used to measure the interrater agreement. It is important to use the correct form of ICC Shrout and Fleiss (1979). Therefore, this study follows the guidelines of Koo and Li (2016) to select the appropriate model, form and type of the ICC. Thus, the two-way mixed effect model implies that the same raters are utilized to evaluate each subject, and the raters are not randomly selected from a population since they are purposefully selected in terms of their experience and knowledge. The average measures are used as a form since two evaluations are taken from each expert in each session. Absolute agreement as type is used to observe the extent to which raters agree. Therefore, as presented in Table 7, the results suggest that experts are in

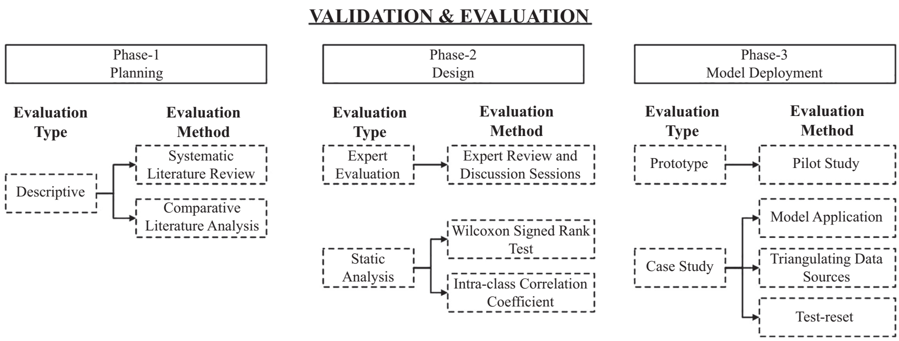

Figure 5.
Model validation and evaluation methods

Table 6.
Wilcoxon signed rank test results

Maturity model evaluation

Criteria	Wilcoxon signed-rank test	Iterations 1–2	Iterations 2–3	Criteria	Wilcoxon signed-rank test	Iterations 1–2	Iterations 2–3
Comprehensibility	Average score	3.39–4.6	4.6–4.82	Consistency	Average score	3.89–4.71	4.71–4.89
	Median	3.5–4.5	4.5–5.0		Median	4.0–5.0	5.0–5.0
	p-value	0.001	0.014		*p*-value	0.002	0.059
Comprehensiveness	Average score	3.32–4.32	4.32–4.46	Detailedness	Average score	3.46–4.18	4.18–4.68
	Median	3.5–4.5	4.5–4.5		Median	3.5–4.0	4.0–4.5
	p-value	0.003	0.102		*p*-value	0.002	0.002
Relevance	Average score	3.29–4.75	4.75–4.86	Applicability	Average score	3.39–4.79	4.79–4.93
	Median	3.25–5.0	5.0–5.0		Median	3.5–5.0	5.0–5.0
	p-value	0.001	0.180		*p*-value	0.001	0.157

Measurement instrument evaluation

Criteria	Wilcoxon signed-rank test	Iterations 1–2	Iterations 2–3	Criteria	Wilcoxon signed-rank test	Iterations 1–2	Iterations 2–3
Comprehensiveness	Average score	3.25–3.96	3.96–4.32	Applicability	Average score	3.71–4.29	4.29–4.75
	Median	3.25–4.0	4.0–4.5		Median	3.5–4.5	4.5–4.75
	p-value	0.001	0.004		*p*-value	0.002	0.008
Detailedness	Average score	3.61–4.32	4.32–4.64	Ease of use	Average score	3.71–4.5	4.5–4.78
	Median	3.5–4.5	4.5–4.5		Median	3.5–4.5	4.5–5.0
	p-value	0.005	0.038		*p*-value	0.001	0.073

good agreement at each iteration since ICCs are larger than 0.75 (Koo and Li, 2016) based on a two-way mixed model, mean rating ($k = 2$) and absolute agreement.

The deployment phase includes two evaluation types (Peffers *et al.*, 2012; Hevner *et al.*, 2004): (1) Prototyping that proves the suitability of the developed artifact is achieved through a pilot study. (2) Case study representing a real-world situation is achieved through model application in a company.

3.5 Findings from the maturity model deployment phase

Two case companies employ the developed prototype maturity model to improve the model's utility and effectiveness. Case company-1 operates in the manufacturing industry (producing metal pipes) in Turkey, has an annual revenue of $60M+ and employs 75 blue-collar and 25 white-collar employees. The digital vision of company-1 is to adopt an ERP system with 12 modules for 40 users. Case company-2 also operates in the manufacturing industry (producing warehouse shelf and rack) in Turkey, has an annual revenue of $10M+ and employs 170 blue-collar and 30 white-collar employees. The digital vision of company-2 is to adopt an ERP system with 16 modules for 80 users. Each company was visited three times, and in the first visit, the model dimensions and definitions, measurement instrument questions and structure were reviewed with the manager responsible for executing digital transformation projects within the scope of quality criteria. It is concluded that case study applications can be carried out with the proposed maturity model and the measurement instrument. Then, for each capability item in the maturity model, expert and knowledgeable employees who can evaluate the company's position most accurately on that capability item are determined. In the second and third visits, within two weeks, two maturity assessments were carried out with the selected employees to conduct the case application, and the current maturity level of the company was revealed. Thus, two maturity levels measured at the same company for each capability item are tested for consistency of the results and the measurement instrument. Therefore, Pearson's correlation coefficient is utilized to check the test-retest reliability ($r_1 = 0.854$ and $r_2 = 0.88$ where $p < 0.000$), and the results show high correlations ($0.70 \geq r \leq 0.90$) (Mukaka, 2012), proving the stability of the measurement instrument.

Since both companies operate in different business lines, case company-1 performs better than case company-2 in each dimension, as presented in Figure 6–8. For convenience, the assessment of the case company-1 is discussed. Therefore, digital vision, roadmap and investment strategy for internal digitalization projects are determined. Top management supports and actively engages in intra-organizational activities and consultancy services are obtained to realize the internal digitalization projects. Furthermore, consultancy services are obtained for readiness and planning external digitalization projects. Besides, the company abides by the regulations (tax, incentives, labor rights, etc.) enacted by the local authorities and the government and internally takes legal measures to protect the data and information sovereignty. In the organization and corporate culture dimension, the company adopts innovative culture as measured in "Level-3 Engaged" in Figure 6–8 but needs to spread it through the supply chain to produce more value to reach "Level-4 SC Integration". Mid-level managers are aware that digital transformation is a necessity for the business, but they

Iterations		Maturity model evaluation intraclass correlation	Measurement instrument evaluation intraclass correlation
1	Average	0.848	0.868
2	measures	0.872	0.852
3		0.816	0.869

Table 7. ICC Results (based on two-way mixed model, mean rating ($k = 2$) and absolute agreement)

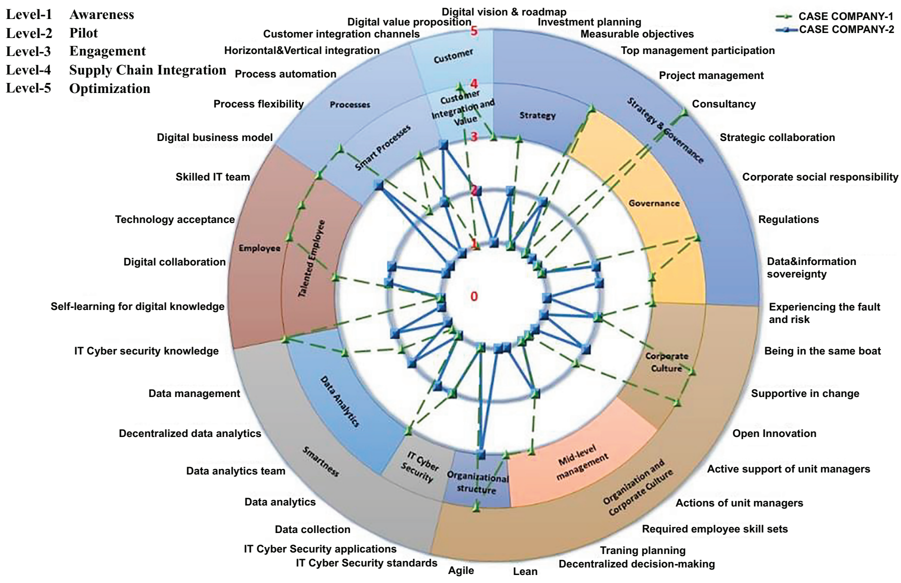

Figure 6.
The findings from maturity assessment in case companies (Capability items)

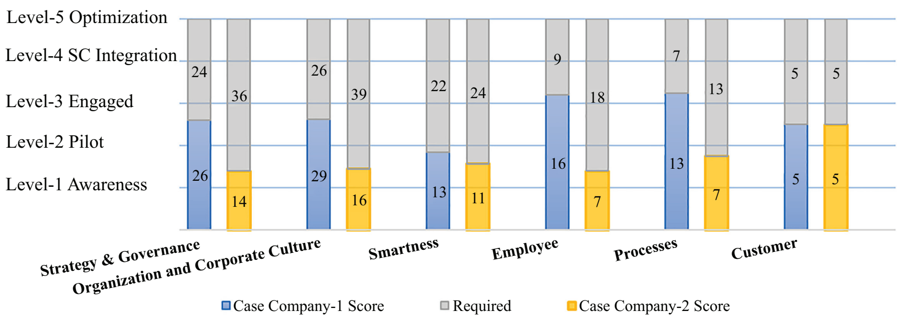

Figure 7.
The findings from maturity assessment in case companies (Sub-dimensions)

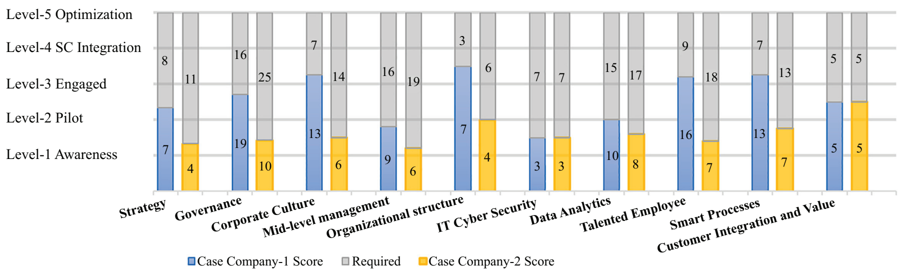

Figure 8.
The findings from maturity assessment in case companies (Dimensions)

cannot fully embrace the digital vision and cannot actively engage in digitalization efforts. As for the organizational structure, the company continuously improves and increases productivity, eliminates waste in processes and establishes a flexible and responsive organizational structure to the fast-changing market dynamics. The employees of case company-1 and its supply chain stakeholders have sufficient IT cyber-security and believe that the company benefits from digital technologies that are user-friendly and easy to use. Besides, the employees internally collaborate and the company has a skilled IT team. However, the employees are still at the awareness level to have a self-training plan, self-develop digital literacy and follow recent technological innovations.

In the customer dimension, the company is aware of connecting with the customer through omnichannel digital applications. Moreover, the company, with the supply chain stakeholders, has the ability to propose added value and create a digital revenue stream by adding complementary digital products and services to existing ones. The company establishes internal and external digital business models that sustain the flexibility of operations and processes, enabling companies to respond to the fast-changing market environment. Besides, the company digitally integrates the business functions, processes and operations within the company. However, automation of the processes is in the pilot application levels. The company has an awareness of cyber-security standards and adopted pilot cyber-security applications. Furthermore, the company collects real-time data but lacks data analytics. On the other hand, the company has a database strategy and system for internal operations.

4. Discussions

This study aims to propose a maturity model development framework based on design science theory and utilizes this framework to develop a descriptive digital transformation maturity model. Therefore, the contribution of this study to the literature is twofold. The first contribution is to explore and then extend the design science literature for proposing a novel maturity model development framework. The theoretical roots of design science for information technology are based on the work of March and Smith (1995), and Hevner *et al.* (2004) theorize guidelines to explore the fundamentals of design science research. Afterward, Peffers *et al.* (2007) propose a methodology for conducting design science research in information systems in six steps, each defining the conceptual principles of the design science research. The studies of Hevner *et al.* (2004) and Peffers *et al.* (2007) complement each other to conceptualize the design science and comprehend the procedures for conducting research. Thus, the literature is improved for a concrete structure for maturity model development by De Bruin *et al.* (2005), emphasizing the main phases of generic model development. De Bruin *et al.* (2005) present a framework in six phases and identify the model characteristics of each phase that help researchers to plan the model development procedure of what to carry out. Becker *et al.* (2009) also focus on a maturity model development procedure by generalizing and consolidating the approaches in existing models, and they extend and embody the guidelines of Hevner *et al.* (2004). The proposed procedure for developing a maturity model includes a process flowchart that clearly explains what to carry out at each process.

Furthermore, Mettler (2011) and Van Steenbergen *et al.* (2010) also conceptualize the maturity model development framework and identify the procedures in phases. However, the effort in the existing design science research is limited only to the conceptualization and identification of the model development procedure and briefly what steps it includes. It is observed that design science research alone falls short of developing a maturity model since design science literature provides a guide for researchers as a theoretical framework for developing design artifacts. However, developing a maturity model also requires a practical framework that not only conceptualizes and emphasizes what steps to follow but also what these steps include and how to realize these steps. Therefore, this practical framework should include a robust methodology empirically tested by qualitative and quantitative means, clearly communicated and well-documented. The development of a maturity model is seen as a comprehensive and holistic process that includes various phases, as in Figure 1. Therefore, this study proposes a three-phased maturity model development framework based on the design science procedures and closes the gap by providing activities, methodologies, validation methods and expected outcomes of each phase. Besides, build-and-evaluate iterations that are the baseline of the guidelines by Hevner *et al.* (2004) that are emphasized and utilized at each activity which is evaluated, iterated and tested for a valid outcome. The iteration approach for the build-and-evaluate principle is an evolutionary process to design a saturated maturity model. The requirement of a novel maturity model development framework that extends the design science studies and explores the methods and methodologies is also confirmed when existing maturity models are analyzed as presented in Table 2. Peer-reviewed studies which claim to follow design science conceptualize and document the design procedure. However, there exist certain gaps in utilizing theoretical support from literature, multi-methodological approaches and sustaining the documentation quality and validation processes of methods.

The second contribution of this study is to develop a descriptive digital transformation maturity model by utilizing the proposed framework and demonstrate the applicability of this framework. The developed maturity model differs from the literature in three ways coherent to the development framework that includes three phases. Since digital transformation is a broad topic and developing a maturity model requires a holistic approach, this study carries out a planning phase to identify the problem and scope definition and maturity model characteristics with a systematic and comparative literature search. Asdecker and Felch (2018) comparatively analyze the existing models in terms of application focus, number of dimensions and levels, overall documentation quality, Pirola *et al.* (2020) in terms of application focus, number of dimensions and levels and model dimensions, Colli *et al.* (2019) in terms of maturity assessment approach and assessment outcome, Wagire *et al.* (2021) in terms of number of dimensions and levels and model dimensions. The comparison criteria in these studies reveal the basic characteristics of the models but not for clear guidance for the design phase. Therefore, the first phase explores the research principles, literature analysis methods, model development methods and documentation quality of each constituent part in the existing models. Besides, an extensive item collection process that circumscribes the digital transformation domain is carried out. It is observed from the literature that such a systematic and comparative literature analysis is a gap. The second part that differs from the literature is the design phase since we introduce build-and-evaluation iteration that is lacking in existing models. The design phase should include iterative multi-methodological approaches. However, existing maturity models apply one part of the guideline, the multi-methodology.

The design product (maturity model) evolves and saturates through iterative evaluations, including model dimensions and capability items, maturity levels and measurement instrument. The evolution of the model dimensions, maturity levels and measurement instrument is saturated through in-depth iterative discussion sessions. In each session, experts are asked to evaluate the proposed maturity model with respect to defined quality criteria which covers comprehensibility, comprehensiveness, relevance, consistency, detailedness, ease-of-use and applicability. According to the evaluations, quantitative methods are used to determine further review sessions. The most important feature that distinguishes this perspective from methods such as interview (i.e. Colli *et al.*, 2019; Pirola *et al.*, 2020; Santos and Martinho, 2020; Wagire *et al.*, 2021), focus group studies (i.e. Bibby and Dehe, 2018; Lichtblau *et al.*, 2015; Schuh *et al.*, 2017) or Delphi studies (i.e. Bibby and Dehe, 2018) used by existing maturity models is that it follows an iterative process and include quantitative methods into the design process. Furthermore, a case study is a common method to carry out the final validation of the design product. Therefore, prototype testing as a pilot study is conducted to obtain feedback from the case company for the improvement of the model, and afterward, a case study is conducted to prove the real-life applicability of the developed model.

5. Conclusion

A novel maturity model development framework that is theoretically supported by design science and includes three phases with iterative multi-methodological approaches is proposed in this study. Each phase guides researchers and practitioners to conceptualize the maturity model and the related domain and contribute to the holism of the maturity model concept. In the first phase, the components that make up the digital transformation domain and the basic characteristics of the current maturity models are analyzed and synthesized exhaustively with a concept-centric perspective by applying a rigorous methodology. With the comparative evaluation of the existing studies, the gaps in the literature are clarified and the dimensions, sub-dimensions and capability items that make up the digital transformation maturity model are determined. In the second phase, the proposed maturity model concept is iteratively evolved by industrial experts through discussion sessions and quantitatively evaluated for saturation. In the third phase, the proposed maturity model is deployed for prototype testing for practical evaluations, and finally, two case studies are conducted to demonstrate and validate the applicability of the maturity model. With this 3-phase maturity model development framework based on design science theory, an exhaustive, reliable and valid maturity model and a measurement instrument are developed and tested with empirical methods and case study applications.

This study guides researchers to develop a maturity model regardless of the domain by proposing a maturity model development framework based on design science as a theoretical implication. The activities and outcomes of each phase are proved the efficiency and usefulness of the proposed framework. Moreover, the developed descriptive digital transformation maturity model that aims to prove the applicability of the proposed framework can be utilized to measure the company's current state throughout the digitalization journey for practical purposes. Even though it is designed for descriptive purposes that only present the current state, it can be used to benchmark the company over time or between competitors. Besides, a descriptive maturity model is a starting point for developing a prescriptive maturity model which provides improvement measures through maturation Pöppelbuß and Röglinger (2011).

The proposed maturity model development framework is limited to the application of this study and is required to be validated in various domains. Besides, the applicability of the developed digital transformation maturity model is required to be tested in more companies (including various sectors and company sizes) for generalizability. Since the developed maturity model is for descriptive purpose and does not identify the importance weights of the model dimensions, sub-dimensions and capability items, it lacks providing guidelines for improvement throughout the digital transformation journey. This study does not present a maturity index of a company; instead, it presents the current status with radar and pie-chart combination. As another future research recommendation, a maturity index calculation method is beneficial to quantify the measurement results.

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Supplementary material

Table S1. Measurement instrument

	Capability items	Measurement instrument
Strategy and governance	*S1.1*-Digital vision and Roadmap	A digital vision statement and roadmap is prepared, which includes concepts such as how digital transformation projects and processes will be carried out, how the future organizational structure will be, how the value created for the customer will be defined, how the organization transformation will be communicated with the internal and external stakeholders
	S1.2-Investment planning	The project investment plan is prepared, and the investment budget is prioritized to include internal and external digitalization projects
	S1.3-Measurable objectives	Comprehensible and measurable goals are determined in line with the vision statement and communicated with internal and external stakeholders
	S1.4-Top management participation	The top management actively participates and supports all processes, such as implementing the digital transformation strategy and vision document, eliminating the bottlenecks encountered in the projects, motivating and encouraging the employees and persuading them to believe in change
	S1.5-Project Management	The assignment of the Chief Digital Officer (CDO) and the project team with technical and managerial abilities, the creation of project plans that include parameters such as time, cost, scope and the administrative coordination of internal and external stakeholders are achieved within the project management perspective
	S1.6-Consultancy	While carrying out digital transformation projects, consultancy services are obtained in various processes, and benefits are provided
	S1.7-Strategic collaboration	In order to transfer know-how and increase project success, Strategic collaboration is carried out with companies that have successfully realized digital transformation or are digital leaders in a specific project to sustain know-how transfer and increase digitalization success
	S1.8-Corporate social responsibility	The company responsibly trains the future workforce within the social responsibility framework and supports regional and national projects
	S1.9-Regulations	Since digitalization is a new concept, the laws (tax, incentives, labor rights, etc.) brought by the governments are followed, and timely compliance is achieved
	S1.10-Data and Information Sovereignty	Employees and external stakeholders act responsibly and comply with the rules in protecting data and information sovereignty. The company has provided legal measures

(*continued*)

Table S1.

	Capability items	Measurement instrument
Organization and corporate culture	*S2.1*-Experiencing the fault and risk	Employees are not afraid of trying new practices, taking measurable risks and making mistakes. Therefore, the organization can tolerate employees making mistakes and encourage innovation
	S2.2-Being in the same boat	The company has a business culture with a transparent and open communication culture, where employees can see themselves as a part of the whole, have a relationship of trust with their managers, work in a team towards a common goal
	S2.3-Supportive in change	Employees trust and adopt digital transformation, their fears and concerns are eliminated, they do not resist change, and on the contrary, they embrace change
	S2.4-Open innovation	Employees do not hesitate to declare, develop and experience innovative ideas internally and externally
	S2.5-Active support of mid-level managers	Mid-level managers embrace the goals set by the digital transformation vision, understand and effectively communicate the change, have a unified goal, actively engage in digitalization efforts
	S2.6-Actions of mid-level managers	Mid-level managers follow best practices, examine the success/fail stories, communicate with employees, develop incentive systems for the motivation of employees, and follow digitalization activities within the unit they manage
	S2.7-Required employee skill	Employee skills required for digitalization projects are determined
	S2.8-Training	Training for digitalization efforts is identified, planned and realized for employees and SC partners
	S2.9-Decentralized decision-making	Decisions on repetitive/programmable functions are carried out autonomously, or decision-making power is delegated to become decentralized
	S2.10-Lean	Continuous improvement activities are carried out, waste in the process is eliminated, non-value added processes are redesigned, employees' creativity is encouraged and lean perspective and lean leadership concepts are adopted in the organization
	S2.11-Agile	An organizational structure is flexible and responsive to the fast-changing market dynamics and purified from hierarchical silos. The employees are appointed to their duties based on their expertise, share a common goal and are empowered

(*continued*)

	Capability items	Measurement instrument
Smartness	*S3.1*-IT Security standards	The company complied with national and international IT security standards
	S3.2-IT Security applications	IT system security is carried out by the company internally and ensured by SC partners to establish trust
	S3.3-Data collection	Real-time data is collected autonomously from employees, equipment, operational processes, products, customers and suppliers using sensors (IoT devices, etc.) and communicated through wireless or wired networks
	S3.4-Data analytics	Collected data is analyzed in real-time utilizing technological tools such as AI, ML, cloud computing, big data processing, etc.
	S3.5-Data analytics team	The company appoints a dedicated data analytics team as a strategic asset
	S3.6-Decentralized data analytics	The data is collected and analyzed using smart sensors or CPS with embedded microprocessors and the generated information autonomously and in a decentralized way controls the manufacturing or business processes
	S3.7-Data management	Data sources are combined in a scalable, autonomous and central database system within a data management plan and strategy
Employee	*S4.1*-IT security knowledge	Employees and supply chain partners have sufficient IT security knowledge (data and communication)
	S4.2-Self-learning for digital knowledge	Employees and supply chain partners have a self-training plan for digital literacy and IT/technology knowledge and follow recent technological innovations
	S4.3-Digital collaboration	Employees cooperate and collaborate, take a participatory approach to innovative processes, share knowledge and work as a team
	S4.4-Technology acceptance	Employees believe that the company benefits from digital technologies and think digital technologies are user-friendly and easy to use
	S4.5-Skilled IT team	IT team has adequate technical and managerial skills
Processes	*S5.1*-Digital business model	Business processes are digitized company-wide and operated in an integrated manner via digital technologies and information systems
	S5.2-Process flexibility	Operations, processes and business functions are flexible enough to respond to the fast-changing market environment
	S5.3-Process automation	Repeatable processes are automated by utilizing digital tools such as AI, ML, etc.
	S5.4-Horizontal and Vertical integration	Business functions, processes and operations are digitally integrated within the company (vertical) and across supply chain stakeholders (horizontal)
Customer	*S6.1*-Customer integration channels	The company integrates and connects with the customer through multi-channel and omnichannel digital applications (social media, web page, mobile applications, etc.)
	S6.2-Digital value proposition	Complementary digital products and services to existing ones are created for the customer

Table S1.

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