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Editorial

The mission of the *IJISPM - International Journal of Information Systems and Project Management* is the dissemination of new scientific knowledge on information systems management and project management, encouraging further progress in theory and practice.

It is our great pleasure to bring you the third number of the tenth volume of IJISPM. In this issue, readers will find important contributions on digital transformation and blockchain.

The first article, "From selling machinery to hybrid offerings – organizational impact of digital servitization on manufacturing firms", is authored by Christoph Brosig, Susanne Strahringer and Markus Westner. According to the authors, the transition toward services has been imperative for manufacturing firms for years. The change from a product-oriented to a more service-dominant business model affects the organizational structure of firms. However, literature provides limited insights into how manufacturing firms organize themselves in this transition. Even though digital technologies are critical for the transition, it is unclear how to orchestrate digital and traditional Information Technology (IT) resources in manufacturing firms accordingly. The authors analyze the case of a typical manufacturing firm that has adjusted its structure to reorganize for solution offerings based on product, service, and digital components. Results describe a hybrid organizational structure that splits front- and back-end units. The back-end units are split along solution components. Digital IT resources are internalized and governed decentrally, with traditional IT resources being outsourced and steered centrally. The findings contribute to digital servitization research by clarifying the overarching as well as the digital and traditional IT-related organization for manufacturing firms.

The title of the second article is "Characteristics of Blockchain and Smart Services, for Smart Governments: A systematic review of the literature", which is authored by Ahmed Alfatih D. Mohamed, Yazan M. Alkhateeb, Puneet Agarwal, Ahmed R. Abdelwahab, Osamah Alrababah, and Taghreed Abu Salim. The interest in blockchain technology has grown rapidly. This is simply because of the security and decentralization that it provides. Nevertheless, most government services around the world run on inefficient systems loaded with heavy bureaucracy. They lead to non-transparent systems and a loss of public confidence in government services. This article presents a systematic review of the literature on this topic, aiming to highlight the characteristics of blockchain technology that demonstrate its uniqueness, together with the characteristics of the smart government services that are required for efficient service delivery. It was found that the dominant characteristics of blockchain technology that are expected to provide the highest value for customers are decentralization and the capacity to be shared and public, whereas the most desired characteristics for the efficient service delivery of smart government services are speed, trust, and participation. The article examine how the use of blockchain technology in government services is impacting their delivery to customers. The findings help governments to develop a blockchain strategy.

The third article, authored by Ágnes Sándor and Ákos Gubán, is entitled "A multi-dimensional model to the digital maturity life-cycle for SMEs". As companies try to maintain and strengthen their competitive advantage, they should be aware of the level of their digital maturity. This article presents a methodology that helps to determine the position of a small and medium-sized enterprise in the digital maturity life-cycle. This is performed on the basis of maturity and digital maturity models and company growth theories. A number of studies and models have been prepared to determine digital maturity on the basis of various sectoral criteria, but these are all one-dimensional. This article proposes a multi-dimensional model for determining the digital maturity life-cycle of small and medium-sized enterprises that takes into account companies' digital maturity, the IT intensity of various sectors, and their organizational characteristics. The model defines five maturity levels together with their relevant characteristics, classified into three levels in terms of data- information. It can help small and medium-sized enterprises adopt more accurate decisions regarding areas in need of development.

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“Executives' role in digital transformation” is the fourth article and is authored by José Fernando López-Muñoz and Alejandro Escribá-Esteve. It is a conceptual article that revisits and updates the concept of top management support (TMS), which has been the long-established rationale for explaining the role of top managers in digitalization activities. In the authors’ view, the concept of TMS is grounded in technological determinism, accounts for attitudinal and behavioral aspects that appear to be little more than exhortation, and accepts the occasional responsibility of top managers in technology management. The authors consider both the crucial role that top managers may play in the digitalization process and the fact that digital technologies have become pervasive in today’s organizations. Then, they develop a model by which top managers and digital technologies are cooperatively involved in digitalization. For that, the authors have looked through the theoretical lens of imbrication and attention perspectives to reconstruct the role of top managers in the digital transformation process. Each imbrication layer can be viewed as a process where top managers form beliefs to act on digital opportunities for strategic action. Specifically, the model provides insights into how executives’ characteristics and social processes impact the likelihood of forming either beliefs about radical or incremental opportunities requiring strategic action. Additionally, the article offers several hypotheses that enrich the knowledge of the relationship between top managers and the digitalization process.

We would like to take this opportunity to express our gratitude to the distinguished members of the Editorial Board, for their commitment and for sharing their knowledge and experience in supporting the IJISPM.

Finally, we would like to express our gratitude to all the authors who submitted their work, for their insightful visions and valuable contributions.

We hope that you, the readers, find the International Journal of Information Systems and Project Management an interesting and valuable source of information for your continued work.

João Varajão is currently a professor of information systems and project management at the *University of Minho*. He is also a researcher at the *ALGORITMI Research Center* at the *University of Minho*. Born and raised in Portugal, he attended the *University of Minho*, earning his Undergraduate (1995), Masters (1997), and Doctorate (2003) degrees in Technologies and Information Systems. In 2012, he received his Habilitation degree from the *University of Trás-os-Montes e Alto Douro*. His current main research interests are related to Information Systems and Information Systems Project Management success. Before joining academia, he worked as an IT/IS consultant, project manager, information systems analyst and software developer, for private companies and public institutions. He has supervised more than 100 Masters and Doctoral dissertations in the Information Systems field. He has published over 300 works, including refereed publications, authored books, edited books, as well as book chapters and communications at international conferences. He serves as editor-in-chief, associate editor and member of the editorial board for international journals and has served on numerous committees of international conferences and workshops. He is the co-founder of CENTERIS – Conference on ENTERprise Information Systems and ProjMAN – International Conference on Project MANagement.

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From selling machinery to hybrid offerings – organizational impact of digital servitization on manufacturing firms

Christoph Brosig
TU Dresden
Helmholtzstr. 10, Dresden 01069, Germany
christoph.brosig1@mailbox.tu-dresden.de

Susanne Strahringer
TU Dresden
Helmholtzstr. 10, Dresden 01069, Germany
susanne.strahringer@tu-dresden.de

Markus Westner
OTH Regensburg
Galgenbergstr. 32, Regensburg 93053, Germany
markus.westner@oth-regensburg.de

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From selling machinery to hybrid offerings – organizational impact of digital servitization on manufacturing firms

Christoph Brosig
TU Dresden
Helmholtzstr. 10, Dresden 01069, Germany
christoph.brosig1@mailbox.tu-dresden.de

Susanne Strahringer
TU Dresden
Helmholtzstr. 10, Dresden 01069, Germany
susanne.strahringer@tu-dresden.de

Markus Westner
OTH Regensburg
Galgenbergstr. 32, Regensburg 93053, Germany
markus.westner@oth-regensburg.de

Abstract:
The transition towards services has been imperative for manufacturing firms for years. The change from a product-oriented to a more service-dominant business model affects the organizational structure of firms. However, literature provides limited insights into how manufacturing firms organize themselves in this transition. Even though digital technologies are critical for the transition, it is unclear how to orchestrate digital and traditional Information Technology (IT) resources in manufacturing firms accordingly. We analyze the case of a typical manufacturing firm that has adjusted its structure to reorganize for solution offerings based on product, service, and digital components. Our results describe a hybrid organizational structure that splits front- and back-end units. The back-end units are split along solution components. Digital IT resources are internalized and governed decentrally, with traditional IT resources being outsourced and steered centrally. Our findings contribute to digital servitization research by clarifying the overarching as well as the digital and traditional IT-related organization for manufacturing firms.

Keywords:
digital servitization; manufacturing firm; organizational structure; digital technologies; service-dominant logic.

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1. Introduction

Kaeser Compressors is a prominent example of a firm that shifted its business model from selling air compressors to selling compressed air as a service [1, 2]. Such a transition from a product-oriented to a more service-dominant business model is recognized as a strategic imperative for many manufacturing firms [3-6]. Scholars refer to this strategic transition as servitization [7].

Nowadays, digital technologies further facilitate servitization. Manufacturing firms employ digital technologies to link data of distributed products back to their value chain to implement new or to enhance existing services, e. g., via remote monitoring [4]. Scholars acknowledge the importance of digital technologies for servitization by introducing the term digital servitization [8]. Manufacturing firms that employ digital technologies can profit from multiple affordances to realize business objectives, e. g., achieving operational excellence in providing services, creating new offerings, or moving to new value propositions [4-6].

Typically, manufacturing firms start with their business model focused on products and additional product-oriented services [9, 10]. Digital technologies help manufacturing firms escape their products' potential commoditization trap by shifting the focus to higher-value products and services [10-12]. Thus, digital servitization of manufacturing firms' business models is often associated with a shift in the companies' strategies [13, 14].

Manufacturing firms need to reflect these strategic changes in their organizational structure [15-18]. Due to the increased focus on services, firms have to adapt their activities, processes, and capabilities [18, 19]. In the case of Kaeser, the firm established a new organizational unit to specialize in its additional service tasks and activities [1]. Generally, the reorganization for digital servitization needs to embrace two aspects, it should (1) enable a service transition starting from a product-oriented structure and (2) foster a firm's benefit from the use of digital technologies [5, 20]. However, literature is still sparse on how firms should adjust their organizational structure to encounter digital servitization [18, 21-24].

Regarding the first aspect, there are discussions about how to reorganize, looking at the offering and its components, and how to handle an organization's customer contact [16, 25]. In terms of structuring an organization around the offering, scholars discuss the separation of intra-organizational units according to product and service spheres [25, 26]. Another stream of research is about structuring an organization in customer-facing front-end units and back-end units [16, 27]. Still, literature lacks guidance on which organizational structures manufacturing firms should adopt [17, 24].

The second aspect in organizing for digital servitization refers to digital technologies and their arrangement within manufacturing firms. Through digital servitization, manufacturing firms adopt digital technologies and consequently adjust their value creation, value delivery, and value capturing [28, 29]. Hence, the adoption of digital technologies requires manufacturing firms to reflect the accompanying dynamics in their organizations, e.g., to enable novel ways of how to collaborate or to facilitate novel roles to manage digital technologies [28, 30]. Even though digital technologies and associated expert roles are critical in digital servitization, few contributions have been made about organizing digital and traditional IT resources, particularly for manufacturing firms [22, 23, 30].

This lack of research about organizational structures is predominantly an issue for manufacturing firms that undergo digital servitization of their business model. In this strategic transition, firms need to balance their previously product-oriented business model while establishing an additional focus on services [12, 31]. Practice confirms that the biggest share of manufacturing firms is undergoing this transition. Only a small share has completed its transition from a goods-dominant "product sales" business model to a service-dominant "as-a-service" business model [32]. Therefore, our paper aims at clarifying the organizational structures of manufacturing firms undergoing digital servitization of their business model by answering two research questions. We first focus on the overarching and then on the IT-related organizational structure:

RQ1: How does the overarching organizational structure of manufacturing firms change when undergoing digital servitization?

RQ2: How do digital and traditional IT organizations of manufacturing firms change when undergoing digital servitization?

To answer these research questions, we consolidate current concepts about organizing for digital servitization in section 2, starting from an overarching firm-level perspective before focusing on digital and traditional IT aspects. We introduce our research methodology based on an in-depth case study (section 3). Section 4 summarizes the case firm's starting point before describing how it organizes for its digital servitization on an overarching level. The section also shows how the case company organizes digital and traditional IT (human) resources. In section 5, we discuss our insights considering existing research. Eventually, we summarize our contribution to digital servitization literature and derive limitations and future research avenues.

This paper contributes to digital servitization and IT research by (a) consolidating previously separate organizational perspectives into a tentative concept for a hybrid organizational structure for manufacturing firms, (b) describing a hybrid organizational structure based on the case of a common manufacturing firm, and (c) showing how to organize digital and traditional IT resources based on the same case. Although our findings are mostly descriptive in nature, they may be used for inductive analogy, that is case-to-case generalization [33]. Across the following sections, we focus primarily on digital and traditional IT resources in terms of human IT resources.

2. Conceptual background

2.1 Digital servitization

Over the past decades, product-oriented manufacturing firms have been looking for opportunities to stand out from competition [7, 34]. Servitization, as a transition towards services, offers the potential to differentiate [35]. Scholars find three reasons that motivate manufacturing firms to initiate a service transition: to improve their competitive positioning, to address evolving customer demands, or to optimize their economic situation [34, 36, 37].

Recently, manufacturing firms have started to employ digital technologies for the servitization of their business models [38-40]. Research understands digital servitization as a firm's transition to adopt new service offerings enabled by digital technologies [4], such as the connection to products, remote monitoring in real-time, or the analysis of machine data for future improvements [4, 5, 24].

Digital servitization research has mainly focused on four topics, including the concept of digital servitization, its effects on stakeholders, digital technologies used in the transition, and the role of digital technologies for the transition [4, 22].

2.2 Digital servitization business models and strategies

The concept of digital servitization outlines a strategic transition of manufacturing firms [13, 14]. Research finds that manufacturing firms add services to their offerings and adjust their value propositions towards customers [5, 22]. This strategic transition affects the overarching business model of manufacturing firms [6, 41].

Scholars differentiate digital servitization business models based on three dimensions: the focus of the offering (product sales vs. results provision), the degree of customization (standard vs. custom), and the level of digitalization [22]. The focus of the offering considers whether the value of an offering primarily stems from the associated product (product-oriented), from ensuring the usability of a product based on associated services (use-oriented), or from ensuring results based on employing products and services (result-oriented) [42]. The degree of customization considers whether an offering is standardized, based on modular components, or a custom solution [22]. The third dimension is the level of digitalization that captures the role of digital technologies for the offering [22]. Digital technologies enable four levels: remote monitoring, remote optimization, remote control, or autonomy of a digitalized or smart product [43, 44].

Scholars find five business model archetypes in this previously mentioned three-dimensional space for digital servitization business models [22]. These five archetypes show the bandwidth of servitization strategies: There are "*Product-oriented Service Providers*" as manufacturing firms that sell products with product-oriented services, like repair, overhaul, or spare parts services [6]. "*Industrializers*" are another type of manufacturing firms that stand out by offering products and associated services on a modular basis. The modularity helps them to increase their efficiency [22]. A case example for this archetype is the provider of propulsion systems that assembles modular maritime motors with a defined set of standard services [31]. "*Customized Integrated Solution Providers*" are manufacturing firms that offer custom solutions of products and services in an integrated way [22]. An example is a producer of hydropower generation turbines that delivers a custom solution based on actual turbines with integrated maintenance services based on remote controlling [31]. "*Outcome Providers*" are manufacturing firms that deliver results by employing products and services [22]. Kaeser Compressors is an example of an "*Outcome Provider"* that monitors its installed base of compressor stations at its customers to ensure that customers can obtain compressed air [2, 43]. Eventually, there are "*Platform Providers*" that link multiple suppliers to achieve results for customers [22]. Yet, there is little empirical evidence for this business model archetype [22].

Manufacturing firms that commit to a digital servitization strategy undergo a strategic transition of their business model. Scholars outline a typical transition from being product-oriented by focusing on product sales to offering an increased share of services to becoming use-oriented or result-oriented [9, 31].

All digital servitization strategies have in common that manufacturing firms need to ensure that their organizations are capable of providing additional services or results as a service [45]. Research finds that an appropriate organizational structure is critical for servitization [27, 46], respectively digital servitization [23, 47]. In their seminal paper, Porter and Heppelmann [45] emphasize the importance of an effective and efficient organizational structure to facilitate digital servitization – coming back to the established notion of "structure follows strategy" [48].

2.3 Organizational structures along digital servitization

In digital servitization, firms face the trade-off of separating business units by tasks of different nature while re-integrating them due to their digital servitization strategy [45]. Servitization research outlines multiple archetypical organizational structures depending on the focus of the business models' offering. Figure 1 shows an overview of overarching organizational structures along a continuum focusing on the offering of business models, from products-oriented to result-oriented [3].

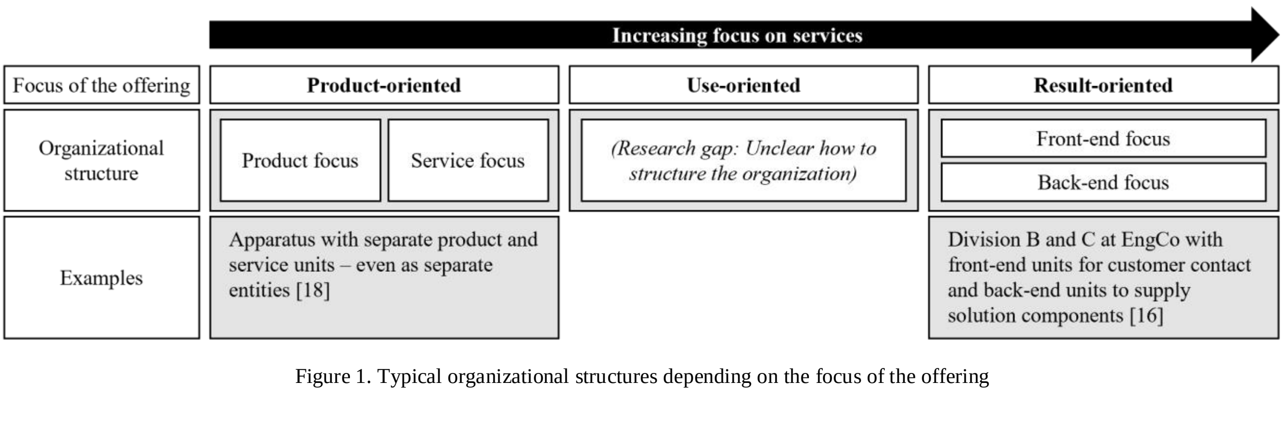

Figure 1. Typical organizational structures depending on the focus of the offering

Along with digital servitization, product-oriented firms add services to their product offerings. Scholars suggest that these firms separate product business units from service business units [26, 36, 49]. There are two motivations for this split. First, the separation of service activities contributes to becoming efficient at creating, selling, and delivering services [36]. Second, the separation fosters a product-centric and a service-centric mindset within each business unit [27, 49]. Apparatus, for example, a provider of electrical equipment for industrial machinery, operates separate product and service units. In this case, the service unit is a separate unit as a separate entity with its own profit and loss responsibility. This separation is intended to strengthen the positioning of Apparatus' services in comparison to products [18].

Another perspective suggests that firms should separate front-end and back-end units when moving their business model to an increased focus on services [9, 16, 18, 27, 47]. A business with a result-oriented business model might offer an outcome as a service with products as tools for service provision [42]. In this example, front-end units are customer-facing units to deliver the outcome [47]. Back-end units supply front-end units with the relevant components [18, 47]. This organizational structure helps manufacturing firms to focus on customer contact in the front-end units while back-end units improve efficiency and operations [27]. The result-oriented business models of division B and division C of EngCo build on a split of the organization in front- and back-end structures [16]. Customer-facing interactions are taken over by a front-end unit, whereas the back-end provides solution components [16].

The mirroring hypothesis offers a theoretical explanation of why firms establish such archetypical organizational structures: As a firm introduces additional services to its offerings, it needs to set up new processes and requires additional expertise for these services. Additionally, the firm needs to rewire its intra-organizational ties to ensure effective and efficient collaboration among existing and new processes and expertise [50]. The mirroring hypothesis posits that the organizational ties need to mirror a firm's offering and vice versa [50]. In terms of digital servitization business models, product-oriented manufacturing firms sell products and offer separate product-related aftersales services. These firms mirror their offerings by separating product and service units. Service-dominant manufacturing firms provide results to their customers by employing different supplies. A separation of customer-facing front-end and supplying back-end units helps firms to mirror their offerings.

In practice, most manufacturing firms identify themselves as in the transition from a product-oriented to a result-oriented business model [32]. Their offerings focus on the products' use as a hybrid between product sales and results as a service, so as use-oriented. Following the mirroring hypothesis, these firms should adjust their organizational structure with an alternative to a product/service split and a front-end/back-end split.

2.4 Organizational structures for digital and traditional IT modes

The second element of digital servitization is digitalization [4]. Scholars posit that firms only benefit from digitalization once they can actually exploit digital technologies [51]. IT organizations face the challenge of supporting several profiles: efficiently delivering IT solutions, like internal information systems, striving for stability [52, 53], but also enabling business units to explore new IT use cases and integrate digital technologies into their processes and products aiming for innovation [45, 53, 54]. Literature refers to this challenge as IT ambidexterity [55]. Scholars suggest adjusting the organization accordingly to resolve this inherent tension [51, 56, 57].

Literature proposes addressing IT ambidexterity by differentiating several modes of the IT function to operate [52]. These IT operating modes are sometimes conceptualized as bimodal IT [53]. One mode enables business units to adopt new IT assets and digital technologies for "systems of engagement" (p. 1421) close to customers in an explorative way, while the other mode takes over traditional IT delivery for "systems of record" (p. 1421) for internal processes in an exploitative way [53]. In addition, some scholars point to product IT as another mode of the IT function [45, 58].

Scholars argue that over the last years, product IT and digital systems of engagement have started to integrate [59]. Digital systems of engagement, like customer apps or online platforms, control product IT components, like interconnected machinery [58]. The convergence of both types of IT leads to a single, explorative IT mode that supports systems of engagement and product IT [59, 60]. In summary, we need to consider two modes of the IT function and, in line with previous contributions, refer to them as digital IT and traditional IT mode [53].

Conceptually, there are two options for how a firm can handle its digital IT and traditional IT mode, either in an integrated or separated way [61-63]. The integrated way refers to setting up a single unit with two internal modes [64-66]. The separated way is to establish two organizational units [61, 67, 68].

Both the digital IT and the traditional IT modes constitute an IT organization as a "(…) collectivity of human resources that perform IT-related tasks" [69, p. 57-2]. Scholars differentiate IT organizations based on resource allocation and IT governance [69-73]. Bimodal IT literature suggests adding the aspect of sourcing to determine the type of an IT organization [61, 67, 74].

IT resource allocation describes how IT resources are distributed across an organization [69]. The allocation includes all types of IT human resources, e. g., for ICT infrastructure operations, programming, or integration of digital technologies [75]. Literature differentiates centralized and decentralized IT resource allocation [69, 70, 75]. Scholars acknowledge that there is a continuum that connects both extremes with hybrid IT resource allocations [75]. While the centralized allocation of IT resources refers to allocating all IT resources in a single IT unit, the decentralized allocation refers to distributing IT resources across various business units. In this paper, we capture these types as three options for IT resource allocation.

IT governance is another factor that determines IT organizations. Scholars frame IT governance as the decision authority and task responsibility for information systems and product development on a strategic and operational level [73, 76-78]. They differentiate the degree of centralization of IT governance [69, 79]. Weill [80] derives IT governance archetypes, e. g., IT monarchy as a form of centralized IT governance, federal IT governance as partially centralized and partially decentralized IT governance, to feudal IT governance as a form of decentralized IT governance [80]. We summarize these options for IT governance as centralized, hybrid, or decentralized.

Bimodal IT literature suggests differentiating IT organizations' sourcing mode [61, 67, 74]. This factor relates to the discussion about the strategic relevance of specific IT resources and capabilities [81]. Literature differentiates IT insourcing, as building up IT resources and capabilities internally, from IT outsourcing [62, 74].

In summary, literature offers four dimensions to categorize IT organizations that take over the digital IT and traditional IT mode: (1) the type of bimodality, (2) IT resource allocation, (3) IT governance, and (4) the sourcing mode. We propose differentiating the digital and traditional IT mode regarding the three latter factors, as shown in figure 2.

(1)	**Type of bimodality**		Integrated		Separated
(2)	**IT resource allocation**	**Digital IT mode**	Centralized	Hybrid	Decentralized
		Traditional IT mode	Centralized	Hybrid	Decentralized
(3)	**IT governance**	**Digital IT mode**	Centralized	Hybrid	Decentralized
		Traditional IT mode	Centralized	Hybrid	Decentralized
(4)	**Sourcing mode**	**Digital IT mode**	Insourced		Outsourced
		Traditional IT mode	Insourced		Outsourced

Figure 2. Conceptualization of options to shape the organization of digital and traditional IT resources

3. Research methodology

We conducted an in-depth case study to explore manufacturers' overarching as well as digital and IT organizations [82]. Due to the immaturity of research in the field of organizational structures for digital servitization, we decided to analyze a single, in-depth case that provides rich context and detailed insights [82, 83]. Along with the case study, we follow the four guiding principles by Yin [83] concerning external validity, construct validity, internal validity, and reliability of the research process.

We purposely selected the case firm to ensure external validity of the case study. We chose the case firm due to its commonness as a manufacturing firm [84] and the revelations of its situation [82]. First, the case firm constitutes a common case for tool manufacturing firms in the German-speaking area [85]. The case firm complies with an average manufacturing firm regarding revenue, the number of employees, and the relevance of its service revenues. Second, the case firm offers revelatory insights as it has recently reorganized to arrange for its new digital servitization strategy. The firm's adjusted strategy focuses on offering solutions over the whole lifecycle based on product, service, and digital components. The firm's organization also reflects this strategic transition.

During the in-depth case study, we collected data from multiple sources, which allowed for data triangulation to ensure construct validity [83, 86]. We collected archival documents, conducted semi-structured interviews, and codified our observations from work shadowing at the case firm. Table 1 shows our data assets. Our data collection started in July 2020, focusing on archival documents. Between August and September 2020, the case firm allowed one researcher to accompany employees at the firm's headquarters to conduct the interviews in person and capture insights from work shadowing. We concluded the data collection in March 2021.

As archival documents, we used publicly and non-publicly available documents. In addition to documents available as brochures or on its website, we had the opportunity to screen internal documents of the case firm, e. g. organizational charts across the firm, internal portfolio reviews of the offering and its components. For the interviews, we conducted semi-structured interviews [87]. Each interview consisted of four structural sections with pre-defined questions while leaving space for improvisation depending on the interview situation: (1) we started with an overarching view of the business model, (2) we moved to a business unit-specific perspective about its organizational role in the business model, (3) we focused on digital and IT resources of the business unit, and (4) summarized the insights by linking the overarching organizational structure and the digital and IT organization. As agreed with the interview participants, all interviews were recorded and transcribed afterward. To ensure confidentiality, it was required to anonymize the interviews in the transcription process. For work shadowing, the researcher could attend strategic meetings and take part in operational tasks. For this purpose, the researcher could accompany the interview participants. When meeting further stakeholders, the researcher was introduced by the interview participants as a neutral observer with a scientific interest in getting to know the firm's organization [83]. Throughout the day, the researcher codified the observations from work shadowing in field notes. After each day, he summarized the core topics in a daily protocol and recapped them with the interview participants. The researcher used these daily check-outs to solicit the participants' views to identify further relevant information [86]. As a result, the researcher decided to schedule further meetings and operational tasks to be attended and searched for specific archival documents. Eventually, the researcher aggregated all documents, interview transcripts, and field notes and linked them in a research diary [83, 86].

After data collection, we established a three-step coding approach to derive insights [88]. The first and second authors of this paper collaborated to review, discuss, and revise each step. The first author started with open coding of documents, interview transcripts, and protocols. We discussed the resulting codes between the first and second author to ensure that there is no investigator bias [83]. Next, we aggregated the initial codes into axial codes. In the last step, we abstracted these axial codes. We used the software tool MAXQDA for our coding. The overall coding resulted in 46 codes based on over 500 coded phrases. In appendix A, we provide a pruned overview of our coding structure.

Overall, we ensured a reliable procedure for our research [86] by planning our approach before entering data collection and analysis. During data collection, we created a research diary and codified our data assets. For the data analysis, we adhered to the three-step coding as a tandem of researchers.

Table 1. Overview of case data assets

Type	ID	Name	Content (Length)
Document	D1	Annual report 2015	Shareholder report – outline of an upcoming new strategy
Document	D2	Annual report 2016	Shareholder report – implementation of the new strategy
Document	D3	Annual report 2017	Shareholder report – acquisition of a respective target firm
Document	D4	Annual report 2019	Shareholder report – last annual report before impact of COVID19
Document	D5	Annual report 2020	Shareholder report – last annual report for strategy implementation
Document	D6	Vision and strategy	Overview of the current vision and strategy with tactical goals
Document	D7	Firm-wide OrgChart	Internal organizational charts covering the case firm up to N-2 level
Document	D8	Portfolio Presentation	Internal presentation of product portfolio for sales pitches
Document	D9	Sales document: automation	Internal sales document about an automation software
Document	D10	Decision document AR Pilot	Internal discussion document about an Augmented Reality (AR) app as a pilot
Document	D11	Remote Service Flyer	Sales brochure describing the functionality of the technical setup
Document	D12	Use Case Remote Service	Sales reference describing use case of remote service functionality
Document	D13	IT Outsourcing	Press release on IT outsourcing contracts of the case firm
Document	D14	Service portfolio flyer	Internal service portfolio overview as a brochure
Interview	I1	Service Manager	Interview with responsible Service Manager (50min)
Interview	I2	Head of New Business Sales	Interview with Head of New Business Sales (55min)
Interview	I3	Head of Sales	Interview with Regional Head of Sales (50min)
Interview	I4	Head of Product	Interview with Head of Product (50min)
Interview	I5	Executive New Business	Interview with an executive of the New Business Unit (45min)
Observation	O1	Discussion: evolution of organization over the past years	Internal discussion about the firm and its evolution after the commitment to its new strategic target, future potential of digitalization for machinery among three leaders of the service unit
Observation	O2	Discussion: AR glasses for maintenance	Internal discussion of the potential of digital technologies like Augmented Reality as a service application
Observation	O3	Discussion: reduced production due to COVID19	Internal discussion centered around the production and the impact of COVID19 on the production load
Observation	O4	Creation of an eLearning	Creation of an eLearning for customer services to exchange air filters
Observation	O5	Creation of service catalogue	Creation of a service catalog for the salesforce
Observation	O6	Observation of service technician	Work shadowing of a service technician solving customer issues as 2nd level support via remote maintenance

4. Results

4.1 Case overview

Our unit of analysis is the organization of a manufacturing firm from Switzerland. The case firm operates globally, with ~75% of revenues from Europe and Asia. The primary customer segments include aerospace, automotive, electronic production, Information and Communications Technology (ICT) providers, and medical technology. Over the last decades, the case firm has created an innovative product portfolio based on organic and inorganic acquisitions of new technologies. The firm employs over 3,000 employees at a revenue of EUR >1bn in 2019 (D4). These numbers and structural characteristics qualify the case firm as a common case among its branch of manufacturing firms in the German-speaking area [85].

In the past years, the market dynamic in the tool manufacturing market shifted: With the growing presence of Asian competitors, prices changed rapidly (D1). In parallel, the demand for connectivity and "Industrie 4.0"-compatibility increased (D2). In this competitive environment, the case firm was positioned as a product innovation leader and renowned for its "Swiss quality," referring to its products' high precision and endurance (D1, O1). Services were perceived as an addition to the product in the sales process (I1).

In 2015, the case firm analyzed the competitive situation and decided to reshape its strategy to seize new business opportunities over the whole lifecycle of its products (D1). The new strategy set out the ambition until 2020 to move to higher-value products and services in the spirit of an innovation leader while maintaining an efficient organization (D6). This strategic shift induced the case firm's transition from a product-oriented to a more service-oriented business model.

Before its strategy implementation, the case firm's portfolio consisted of several product lines based on specific manufacturing technologies (D1). Individual sales colleagues approached customers to sell the products with services as an addition (I3). Customers integrated the machines into their production processes, and product-associated service units helped in case of maintenance needs (I1).

Since 2016, the firm has been implementing its new strategy that emphasizes the two core elements of digital servitization: shifting its value proposition towards higher-value products and services and employing digital technologies to enable these services (D2). In 2020, the last year of the strategy implementation, the COVID19-pandemic significantly impacted sales for specific customer groups (D5). Despite this impact, the manufacturing firm has already achieved several strategic ambitions since undergoing its digital servitization.

The case firm has adopted new manufacturing technologies to extend its product portfolio (D1), core systems of existing products have been upgraded to next-generation industrial computers (I1), and new digital solution components have become part of the internal portfolio by acquiring a previous digital solution supplier (D3). The firm has created new service offerings enabled by new digital solution components, e. g., remote servicing and control of machines or enhanced digital training services (D11, D14, I2). Additional digital components complement the growing service portfolio, e. g., app-based production control dashboards (D11, I2, I5). In terms of its sales approach, the case firm has shifted to a unified sales approach to cover overarching customer needs in terms of its products (I3).

A regional Head of Sales summarizes the strategic changes and indicates the cultural shift that the firm and its employees are undergoing as well: "*It is a challenge for us (...). The business that we did over the past years was selling machinery. Today, we need to sell complex solutions*" (I3).

Another achievement of the strategy implementation is the case firm's overarching reorganization and the establishment of a structure of its digital and traditional IT. In the following sections, we first describe the overarching organization in terms of business units before focusing on the digital and traditional IT organizations.

4.2 Overarching organization for digital servitization

This section focuses on the overarching reorganization of the manufacturing firm that supports the firm's strategic ambition to offer higher-value products and services, as shown in figure 3. We illustrate the former organization in 2015 before focusing on the state after the reorganization in 2020.

Before its reorganization, the case firm was organized in product divisions that operated their own functional business units like engineering, production, sales, and servicing (O1, I3). Each product division made its own decisions (I3). Each product division was centered around products following a typical value chain approach: The engineering departments built and evolved the product, the production units manufactured the machines, and dedicated sales units sold the products to the customers (I3). In the after-sales phase, product-associated service departments organized spare parts, repair services, or training sessions (I1). Digital technologies were sourced as digital solution components from third-party suppliers (I5). Corporate support units took over corporate activities, like HR or finance, and monitored traditional IT services outsourced to a third-party provider (D13).

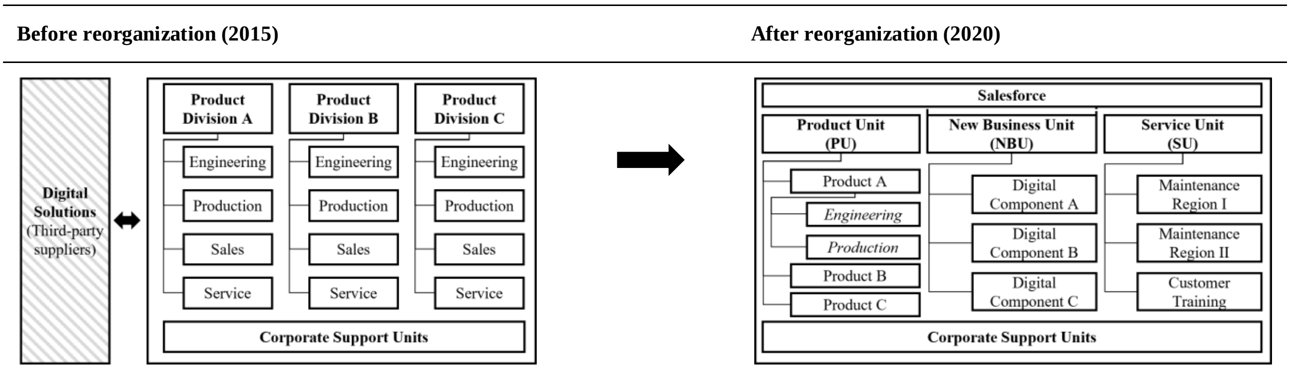

Figure 3. Comparison of the organization before and after the reorganization

In its digital servitization, the case firm transitioned from a product-oriented manufacturing firm to a provider of higher-value products and services. Another part of the case firm's strategy was to address the strategic changes of the adjusted offering through a reorganization (D6). Throughout the case study, we found that the case firm followed three guiding principles along with its reorganization.

The first guiding principle is the split of the organization into front-end and back-end units. In contrast to its previous organization, the case firm now operates a unified salesforce. The unified salesforce orchestrates all customer interactions from the first touchpoint over sales to servicing (O1). A regional Head of Sales emphasizes the importance of a unified front-end layer to sell products and services as solutions: *"We need to act with a unified salesforce (...). This helps us to address detailed questions (...) Today, we need to sell complex solutions." (I3).* The complex solutions are combinations of product and service components enhanced and connected by digital solution components (I1). The salesforce's operating model is to combine these components as a solution and sell them with a mark-up. Therefore, it sources the components from internal back-end units and external companies (I3). The back-end units provide catalogs of available components to the salesforce (D8, O5). In addition, the back-end units support the salesforce with technical know-how for the sales process. The Head of Product confirms that his back-end unit delivers *"(...) training, demonstration software tools, sales brochures, and material" (I4)* to the salesforce. The salesforce also takes over aftersales activities (I3). In the event of complicated technical questions, the front-end unit involves experts from the respective back-end unit (I1, I4).

The second guiding principle is a revised divisional split for back-end units. There are two types of back-end units at the case firm. One type supplies the salesforce with solution components, and the other type refers to corporate support units for administrative tasks. The supplying back-end units focus on solution components, like machinery, services, or digital components. Each supplying unit is responsible for developing, producing, and delivering its components reimbursed by cross charges. The case firm operates three supplying units, the product unit (PU), the service unit (SU), and the new business unit (NBU) (D7). This setup reflects the importance of all components for the firm's solutions. *"Since this year we have a separate service unit. Our management realized that it is worth pushing this topic" (I1).* An NBU executive characterizes the positioning as an internal supplying unit: *"[The NBU] sells [its digital offerings] as an internal supplier to the [salesforce]" (I5).* While the PU and SU only act as internal supplying units, the NBU additionally sells its components to third-party customers. This decision aims at scaling the NBU as it was recently acquired from an Internet of Things (IoT) provider and still has a relatively small footprint in the firm in terms of revenues (I2, D3). The external revenues help to scale the NBU (I5). The second type of back-end unit refers to corporate support units that take over HR administration, financial accounting, and IT infrastructure in a centralized way (D7).

The third guiding principle refers to the autonomy of intra-organizational units. Each unit of the manufacturing firm is responsible for its profit and loss statement. Only the corporate support units are financed by a top-down budget allocation (O1). In practice, salesforce, PU, SU, and NBU collaborate on an internal customer/supplier relationship. Internal customers reimburse internal suppliers based on cross charges. This relationship decouples intra-organizational units. The salesforce sources solution components from the supplying back-end units and compiles a solution based on these components. Each unit along the value chain charges its own margin (I3).

Two aspects of intra-organizational autonomy become prevalent: First, autonomy causes additional administrative work across units. A regional Head of Sales introduces the example of licensing software access for remote machine access to a customer. The salesforce must first subscribe to the respective NBU license before re-selling it to the customer. *"You [as salesforce] need to unsubscribe if your customer no longer needs it" (I3).* A SU representative positions the administrative work between units as a critical step to support the internal shift to value every part of a solution offering: *"Today, it is critical to scale the service aspect to differentiate from competition. (…) We use customer trainings for differentiation. (…) Customer trainings are not cheap. They need to be organized to address customer needs and expectations" (I1).* Second, autonomy requires each unit to build a competitive and sustainable business model itself. The Head of Sales explains their business model: *"The [NBU] charges EUR 500 for the app. (…) I need to add my margin and sell it to the customer for EUR 800. (…) [As salesforce] I offer bundles, including maintenance, remote services, digital offerings" (I3).* An NBU executive describes how autonomy helps the NBU in acting in an entrepreneurial way: *"Every stakeholder [like PU or external customers] wants his requirements with [the] highest priority. This would be unmanageable. We decide based on the highest business value [for us]" (I5).*

4.3 Organization of digital and traditional IT resources for digital servitization

Similar to the changes of the overarching organization, the case firm realigned its IT resources throughout the reorganization. Before the case firm's reorganization, its IT resources monitored a third-party provider to deliver traditional (corporate) IT services. Predecessors of digital solution components were sourced from external providers (D3, I5). As part of the reorganization, the case firm structured its organization of traditional and digital IT resources. Therefore, we look at the case firm's organization of IT resources after the reorganization in the following section. We focus on the case firm's type of bimodality, IT resource allocation, IT governance, and sourcing mode and summarize them in figure 4.

(1)	**Type of bimodality**		Integrated		Separated
(2)	**IT resource allocation**	**Digital IT mode**	Centralized	Hybrid	Decentralized
		Traditional IT mode	Centralized	Hybrid	Decentralized
(3)	**IT governance**	**Digital IT mode**	Centralized	Hybrid	Decentralized
		Traditional IT mode	Centralized	Hybrid	Decentralized
(4)	**Sourcing mode**	**Digital IT mode**	Insourced		Outsourced
		Traditional IT mode	Insourced		Outsourced

Figure 4. Digital and traditional IT of the case firm

The case firm separates digital and traditional IT resources. In its daily language, our interview partners consistently refer to the *"IT colleagues"* as traditional IT resources that supply IT infrastructure and IT applications as part of the corporate support units (I2, I5). In contrast, digital IT resources are part of the PU, SU, or NBU. The Head of New Business Sales demonstratively includes digital IT resources when talking about his team: "*In our [new business] team, we currently develop a dashboard"* (I2). Similarly, the Head of Product points out that software development is a department with close collaboration with the product engineering in his PU. *"(...) We have a separate department for the software, but we are at least together in the same building"* (I4). In summary, the digital and traditional IT modes are separated. Therefore, each of the other aspects of the IT organization needs to be separately examined per mode.

Concerning the IT resource allocation, the PU, SU, and NBU act decentralized as they have different digital IT resource needs. The PU requires digital IT resources with hardware-related skills to extract machine data. The Head of Product (I4) illustrates that the digital IT resources of the PU are *"(...) part of the assembly and production team" (I4)* and develop the data interface of the machine (D9). The NBU employs another type of digital IT resources. These digital IT resources use machine data to create new business opportunities, e. g., an IoT application for remote machine access (D11, D12, I2, I5). *"We use the data [provided by the interface]. In the next step [the IoT application] processes the data (...) and makes them available via a dashboard (...)" (I5).* Similarly, the SU requires another type of digital IT resources for digital services based on machine data. The ramp-up of its own Augmented Reality (AR) developers to extend existing training services with AR eLearning modules is an example of how the SU employs its digital IT resources (D10, I1, O2, O4). *"We [as service unit] ramp up one or two [AR] developers. We know that this topic is becoming more and more important. (...) We are less dependent and do not have to worry about a loss of data or ideas" (I1).* The salesforce does not employ its own digital IT resources. The unit involves digital IT resources from the supplying back-end units as needed by the salesforce (I3). This punctual salesforce support is important as customers' buying centers increase their digital literacy, e. g., to understand cybersecurity risks associated with machines and their digital services (I3). In conclusion, the case firm allocates digital IT resources in a decentralized way across the PU, SU, and NBU to address their specific demands.

In contrast to the digital IT mode, the traditional IT mode is centralized in a corporate support unit and manages business applications, e. g., the CRM or the ERP (I2), provides the ICT infrastructure, or manages the IT helpdesk (I3).

Another characteristic of the IT organization is its IT governance. A Head of Product describes the business units' digital IT as separate islands (I4). The separate islands align based on a minimum standard. The Head of New Business Sales refers to this minimum standard as a common language (I2). *"What we did, was to choose [a standard communication protocol] and [a standard machinery data mapping norm] as joint standard. (...) We speak the same language based on the similar data structure" (I2).* Another executive confirms the importance of this minimum standard for the intra-organizational collaboration between units with different components, like the PU with machinery and the SU with services. *"Often, this [interplay between units with long and short innovation cycles] did not work. (...) Now, based on this standardization, we can collaborate (...) much more efficiently"* (I5). The interviewed service manager confirms this and argues that the decentralized IT governance supports the business units' flexibility (I1). In conclusion, the case firm operates a hybrid IT governance structure for its digital IT mode: A minimum set of decisions remains centralized based on the decision of all involved business units, e. g., regarding machinery communication protocols and data mappings. The remainder of the decisions of the digital IT resources is decentralized to their specific business units.

For the traditional IT mode, the corporate support unit aligns centrally on IT service levels based on the other business units' requirements and decides for the appropriate technology stack and its operations. The decisions are bundled in IT service level agreements (D7, D13).

The fourth characteristic of the digital and traditional IT modes points to the sourcing of IT resources. In its strategy, the case firm commits to addressing digitalization as a driver of the competitive environment while maintaining an efficient organization.

The PU views digital IT resources as critical to its products as mechanical engineers. Therefore, the PU insources digital IT resources on a long-term basis (I4). *"Developing new products is not a single task only for a mechanic (...)*

We want to have all the knowledge and the know-how inhouse. We want to tie up our developers and software expertise (...)" (I4). A second observation shows the NBU's sourcing strategy for digital IT resources. The whole unit has been acquired from a leading IoT provider (I2, I5, D3) to insource IoT capabilities (I5). This insourcing shows a shift of the sourcing policy as the IoT provider has previously been among the third-party suppliers for digital components (I5). The sourcing of own AR experts for new service offerings confirms this sourcing policy (D10, O2). Even though the AR application development is still in a pilot phase, the case firm views the associated AR application developers as strategic digital IT resources for its future service delivery. *"With own developers (...) that focus consequently on AR applications, we can differentiate our customer training offering"* (I1).

The corporate support unit follows a sourcing policy to create an efficient organization (D2). It cooperates with an IT outsourcing partner to run and operate its IT infrastructure and manage business applications (I1, I2, D13). While the case firm owns the ICT assets (I2), it outsources IT services based on long-term contracts (D13).

5. Discussion

This section discusses our four key findings regarding a manufacturing firm's overarching and digital and IT organization while undergoing digital servitization. Table 2 shows an overview of our findings and indicates industry-oriented implications.

Our case study's starting point was that the case firm transitioned from a product-oriented business model to a more service-dominant business model to strengthen its role over the whole product lifecycle. This strategic transition affects the firm's organizational structure. The case firm started from an organizational structure centered around products to an organizational structure that accommodates its new offerings based on products, services, and digital components. From the digital and IT perspective, the firm established a decentralized and internalized digital IT supporting the offerings' structure while maintaining a centralized and outsourced traditional IT for efficiency reasons.

Table 2. Overview of the four key learnings

	Case-specific findings	Industry-oriented implications
#1	The case firm adopts a hybrid organizational structure.	Realign front-end as a unified salesforce to ensure a consistent customer experience
		Split back-end along components to mirror the architecture of the offering
#2	The case firm decouples its intra-organizational business units.	Align the business units as an internal value network contributing to an overarching solution
		Decentralize decision-making to enable entrepreneurial thinking of the business units
#3	The case firm decentralizes and internalizes its digital IT resources along with the business units.	Decentralize digital IT resources by mirroring the structure of the offering to strengthen intra-organizational autonomy
		Emphasize the alignment of the decentralized digital IT resources based on minimum standards
		Internalize strategically relevant digital IT resources
#4	The case firm centralizes and outsources its traditional IT resources.	Increase efficiency and standardization for traditional IT services

Our first finding refers to the case firm's new hybrid organizational structure that consists of a unified salesforce as a front-end unit and back-end units split along the product, service, and digital components. The hybrid organizational structure combines a product/service split, such as a front-end/back-end split, as indicated in the middle column ("use-oriented") in figure 5. Before its strategic transition, the case firm's digital servitization business model archetype was similar to a "*Product-oriented Service Provider"* with a primary focus on products [6, 22]. Services were considered as an add-on to products. The new strategy aims at combining the characteristics of two archetypical business models: (1) an "*Industrializer*" that strives for efficient delivery of combinations of products and services, and (2) a "*Customer*

Integrated Solution Provider” that pursues an integrated offering to address the customers’ needs over the lifecycle [22]. The case firm mirrors these strategic changes in its hybrid organizational structure. The consolidation of sales resources as a unified salesforce increases consistency at the customer interface. Other researchers have captured the idea of a unified salesforce as a customer success unit [27, 45, 47]. Literature indicates that such a unified salesforce may be helpful to link multiple system components as solutions to generate customer value [28, 89]. Similarly, scholars confirm our observations that the salesforce approaches customers with a team of interdisciplinary experts to offer solutions consisting of different components [47]. This unified team provides a seamless customer experience versus multiple, component-specific salesforce teams. In the back-end, the units’ structure mirrors the offerings’ components. This structure creates equal attention for the importance of product, service, and digital components [25]. Operationally, the back-end split supports a division of labor with an optimization per component-specific business model [16, 18, 47]. Even though the back-end split increases focus and efficiency per unit, it also increases the coordination effort among these units. Servitization literature labels this phenomenon as the paradox of performing. Manufacturing firms strive for operational excellence and efficiency while creating customized hybrid offerings [90].

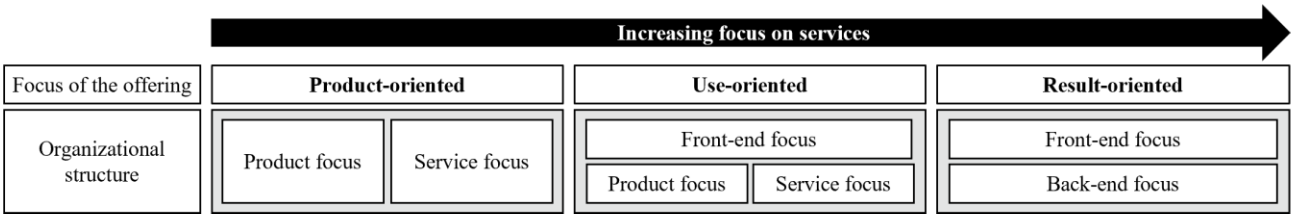

Figure 5. Hybrid organizational structure mirroring the hybrid structure of the offering

Our second finding refers to the decoupling of business units. The case firm decouples its intra-organizational units as a network of value-creating instances. This finding resonates with literature regarding two aspects: acting as a value network and striving for decentralized decision-making in digital servitization. In our case, the business units (except the corporate support units) operate autonomously and focus on their component-specific business models in the back-end and the overarching offering in the front-end. Each unit carries its own profit and loss responsibility. This intra-organizational structure is similar to the idea of value networks or partnerships in digital servitization research [91, 92]. Value networks consist of multiple actors contributing specific components to a complex, overarching offering [22, 93]. Typically, these multiple actors are numerous different firms [91, 93]. Our case shows a value network within a firm building on internal partnerships. Each of the case firm’s units with profit and loss responsibility makes its own decisions for its own business model, e.g., the NBU markets its components beyond the “internal” value network to third-party companies to strengthen its business unit. This aspect of decoupling the business units is consistent with the idea of decentralized decision-making of business models undergoing digital servitization [45, 94]. The decentralized decision-making regime facilitates actors to be entrepreneurial and seize business opportunities autonomously [91]. Still, these actors need to align on their links to prevent conflicts of interests and ensure strategic fit [22, 25].

Even though decoupling stimulates entrepreneurial thinking, we question whether this extreme level within a firm is preferable for digital servitization. Decoupling supports the creation of intra-organizational “islands” instead of modular value networks [18]. The stronger the units are decoupled, the more each “island” optimizes its own component-specific business model. Some scholars even report executives’ concerns about partial mutual cannibalization [92]. Hence, this extreme approach could be an inferior option in the long term. It fosters optimization for local maxima, e. g., profit per business unit, instead of a global maximum, e. g., firm-wide profit.

Both observations about the overarching hybrid organizational structure with a high level of intra-organizational decoupling indicate that this might generally be a favorable option for manufacturing firms undergoing digital servitization. It remains questionable whether extreme levels of intra-organizational decoupling support this transition.

Our third finding refers to the decentralized internalization of digital IT resources. The case firm allocates digital IT resources per business unit as internal resources. This finding aligns with literature in supporting the autonomy of the business units, creating an effective digital IT governance, and strengthening the strategic transition to digital servitization. At the overarching firm level, PU, SU, and NBU act as autonomous actors that create separate components for the offering. Each business unit has a specific demand for digital IT resources. The decentralization of digital IT resources strengthens the business units' autonomy [73]. This IT resource allocation is in line with servitization research that suggests combining digital expertise with traditional firm functions as interdisciplinary firm functions [45]. Recent digital servitization literature even contends that manufacturing firms undergoing digital servitization should develop their own digital capabilities like software companies [28]. The internalization of such resources promotes the creation of novel offerings by unlocking previously unexplored potential [92]. The decentralized digital IT governance at the case firm works by decoupling while committing to a common set of minimum standards based on communication protocols and data mappings to align their decentralized digital IT resources. This IT governance could be an example of "the most visionary destination" [62, p. 116] to govern decentralized digital IT resources in an organization. Furthermore, the case firm internalizes its digital IT resources across its back-end units. This aspect of the digital IT organization confirms the increased importance of digital IT resources for the strategic transition of the case firm towards digital servitization [13, 81, 95]. Our in-depth case study showed that the case firm has a high level of digitalization in the back-end, but also in the front-end, e. g., with the development of app-based digital customer interfaces. Literature suggests allocating IT resources in correspondence with an offering's architecture [59]. Therefore, we found it counterintuitive that the case firm's salesforce does not have its own digital IT resources. Instead, we found that the NBU, a back-end unit, develops several digital customer interfaces. In the future, it might be an opportunity to reallocate the development of digital customer interfaces to the salesforce that interacts with customers to reduce the risk of intra-organizational friction [59].

Our fourth finding addresses the outsourcing and centralization of the traditional IT organization. Our case firm centralizes the allocation of traditional IT resources and corresponding decision rights in a small unit that orchestrates an outsourced provider. This sourcing decision follows the firm's strategic direction to build an efficient organization by outsourcing non-core competencies, e. g., ICT infrastructure operations or internal IT helpdesk [96]. For this purpose, the centralization contributes to an efficient organization by standardizing the ICT infrastructure [18, 97]. In addition, the long-term nature of the observed outsourcing relationship confers with existing digital servitization research that identifies such ICT infrastructural aspects as indispensable for a firm's viability [92].

To the best of our knowledge, this case of a manufacturing firm's IT organization with a digital and a traditional IT mode presents one of the first codified in-depth case examples in the context of digital servitization from an organizational perspective. It shows that the decentralized internalization of digital IT resources facilitates the transition towards a more service-dominant business model enabled by digital technologies. The outsourcing of traditional IT services resonates with previous contributions about IT infrastructure provision as non-differentiating activity [98].

6. Conclusions

Our research has several contributions. First, we address the call to clarify how to approach digital servitization from an organizational perspective to answer RQ1 [21, 22]. We summarize the current perspectives of organizing for digital servitization for a product-oriented or a result-oriented and thus service-dominant business model. We aggregate two theoretical perspectives on firms' organizational structures as a hybrid organizational structure. We describe the hybrid organizational structure based on the case of a common manufacturing firm. The hybrid organizational structure helps to understand how manufacturing firms can manage multiple autonomous business units for solution components in their back-end complemented with a unified sales approach [17].

Second, we clarify how a manufacturing firm sets up its digital and traditional IT modes to support its digital servitization [4, 9, 23] to address RQ2. The decentralized digital IT resources support autonomous business units and ensure that they can utilize digital technologies according to their demand. A minimum consensus serves to align the digital IT resources across business units. This digital IT mode is suitable for manufacturing firms that orchestrate multiple teams of digital IT resources as part of a hybrid organizational structure [18, 23].

For practitioners, we outline the hybrid organizational structure as a reference structure for manufacturing firms that plan to transition from a product-oriented business model to a more service-dominant business model. Our contributions support manufacturing firms that move to a business model with an offering based on product, service, and digital components. We describe intra-organizational decoupling as an option to establish a solution based on such components. Further, our findings offer a perspective of how manufacturing firms can shape and align their IT organization based on a digital and a traditional IT mode for digital servitization.

Our findings are not free from limitations. First, our results build on a single, in-depth case study. We selected this case purposively as a common case from the tool manufacturing industry and chose to describe the case firm’s organizational structure. By describing the context of the case firm as well as the situation before and after the reorganization, we claim that readers can – based on their experience – use the case for understanding new settings as well, i.e., at least so-called “naturalistic generalization” (inductive analogy) is supported [33, 99]. Still, our findings cannot be generalized to other industries or different firm sizes without caution. Second, even though our data is grounded on multiple perspectives, we could not gather an explicit interview from the case firm’s support unit. Due to the ongoing COVID-19-pandemic, the case firm’s workforce was ramped down so that the remaining employees needed to cover higher than usual workloads. As an alternative, we agreed with the case firm to explore the role of the support unit from interviews with experts of the firm’s remaining parts and observations from work shadowing of these experts.

Future research can extend our findings on how firms can approach digital servitization. We propose three avenues for future research.

First, researchers could analyze other manufacturing firms that balance product and service focus and update our suggestion of a hybrid organizational structure as they transition to a more service-dominant business model. It would be interesting whether different types of manufacturing firms exploit different sub-types of hybrid organizational structures.

Second, the case firm shows a high degree of intra-organizational decoupling. This decoupling creates internal friction. While we explicitly observe coupling mechanisms of the digital IT resources across the decoupled business units, it remains unclear how this is concretely managed on the overarching level. Future research should clarify appropriate coupling mechanisms to overcome local optimization of solution components leading to global optimization of hybrid solutions.

Third, we found that our case firm has increased demand in digital IT resources, e. g., for AR or IoT development. In an extreme case, the firm acquired an IoT provider to offset its gap in expertise. It remains unclear how this might work for firms with fewer capital resources. Future research could clarify IT sourcing strategies of manufacturing firms that initiate digital servitization.

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Appendix A. Overview of the coding structure

For clarity reasons, we pruned our 46 codes to 28 codes displayed in figure 6. Hence, we provide an overview of our coding structure up to the 3rd coding level for the codes "context" and "offerings", and due to the relevance of the "organization" up to the 4th coding level for this branch.

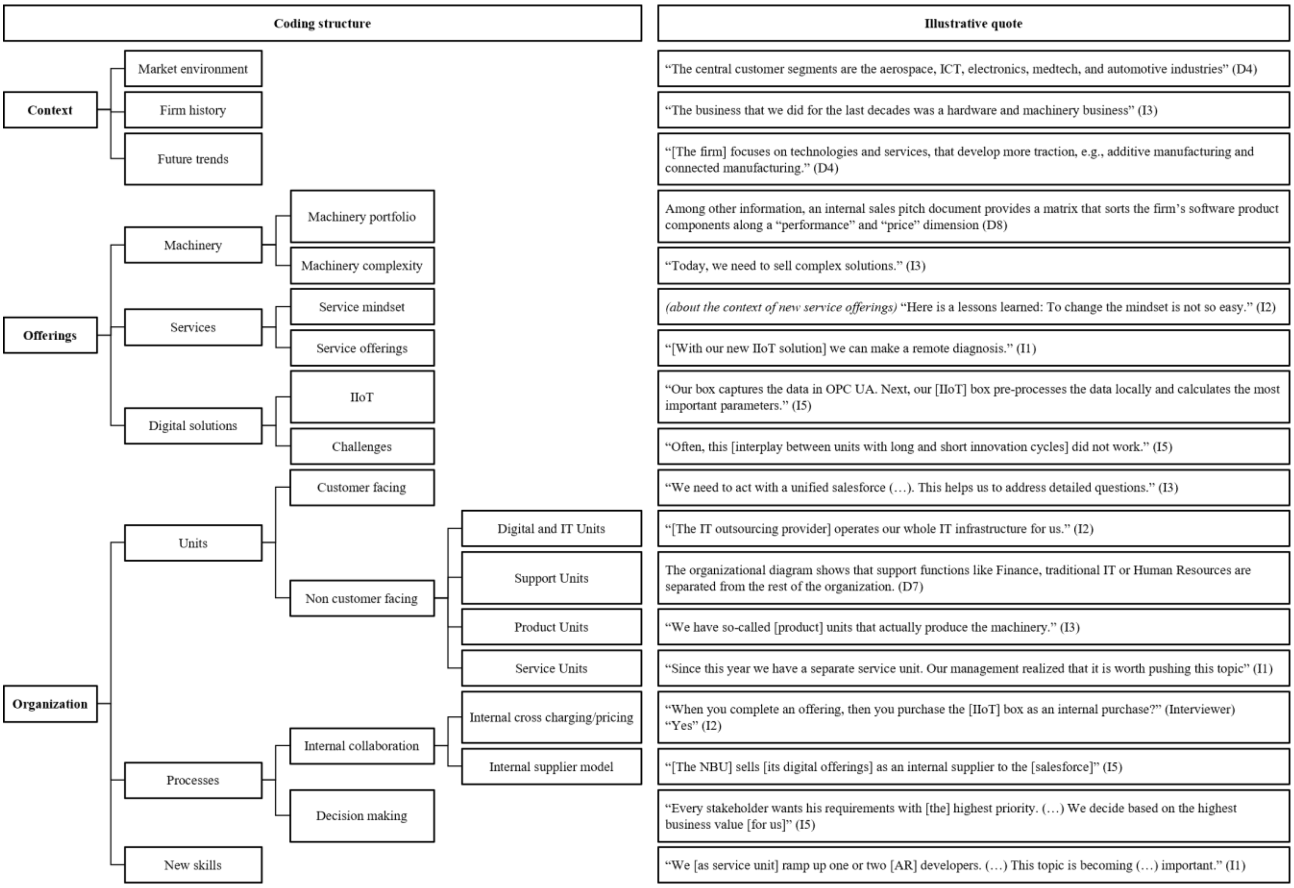

Figure 6, Pruned overview of the coding structure with illustrative quotes

Biographical notes

Christoph Brosig
PhD candidate at the Faculty of Business and Economics TU Dresden, Germany. He graduated from the Technical University of Munich with a master's degree in Management and Technology. His research interests focus on servitized business models and IT-enabled service innovation success. His doctoral thesis is about organizational changes of servitized business models. More information available at https://orcid.org/0000-0001-7809-0796

Susanne Strahringer
Professor of Business Information Systems, especially IS in Manufacturing and Commerce at TU Dresden, Germany. Before joining TU Dresden, she held positions at the University of Augsburg and the European Business School. She graduated from the Darmstadt University of Technology where she also obtained her PhD and completed her habilitation thesis. She has published in Information & Management, Journal of Information Technology Theory and Application, Information Systems Management, and Journal of Information Systems and e-Business Management among others. Her research interests focus on IS management, ERP systems, and enterprise modelling. More information available at https://orcid.org/0000-0002-9465-9679.

Markus Westner
Professor of IT Management at OTH Regensburg, Germany. He is author of several journal articles and conference papers. His teaching and research focuses on IT strategy and IT sourcing. He acts as Associate Editor for Information & Management and various other IS journals. Before he started his academic career, he worked as a management consultant in a project manager position for one of the world's leading management consultancies. More information available at https://orcid.org/0000-0002-6623-880X

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Characteristics of Blockchain and Smart Services, for Smart Governments: A systematic review of the literature

Ahmed Alfatih D. Mohamed
University of Wollongong Dubai
Dubai, UAE
am419@uowmail.edu.au, ahmed.elfatih06@gmail.com

Yazan M. Alkhateeb
University of Wollongong Dubai
Dubai, UAE
yazalkhateeb@gmail.com

Puneet Agarwal
University of Wollongong Dubai
Dubai, UAE
puneetagarwal022@gmail.com

Ahmed R. Abdelwahab
University of Wollongong Dubai
Dubai, UAE
ah_r2006@yahoo.com

Osamah Alrababah
University of Wollongong Dubai
Dubai, UAE
rababah86@gmail.com

Taghreed Abu Salim
Abu Dhabi University
Abu Dhabi, UAE
taghreed.abu-salim@adu.ac.ae

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Ahmed Alfatih D. Mohamed
University of Wollongong Dubai
Dubai, UAE
am419@uowmail.edu.au, ahmed.elfatih06@gmail.com

Ahmed R. Abdelwahab
University of Wollongong Dubai
Dubai, UAE
ah_r2006@yahoo.com

Yazan M. Alkhateeb
University of Wollongong Dubai
Dubai, UAE
yazalkhateeb@gmail.com

Osamah Alrababah
University of Wollongong Dubai
Dubai, UAE
rababah86@gmail.com

Puneet Agarwal
University of Wollongong Dubai
Dubai, UAE
puneetagarwal022@gmail.com

Taghreed Abu Salim
Abu Dhabi University
Abu Dhabi, UAE
taghreed.abu-salim@adu.ac.ae

Abstract:
The interest in blockchain technology has grown rapidly, day by day. This is simply because of the security and decentralization that it provides. Nevertheless, most government services around the world run on inefficient systems loaded with heavy bureaucracy. They lead to non-transparent systems and a loss of public confidence in government services. The present systematic review of the literature on this topic aims to highlight the characteristics of blockchain technology that demonstrate its uniqueness, together with the characteristics of the smart government services that are required for efficient service delivery. It was found that the dominant characteristics of blockchain technology that are expected to provide the highest value for customers are decentralization and the capacity to be shared and public, whereas the most desired characteristics for the efficient service delivery of smart government services are speed, trust and participation. The paper went on to examine how the use of blockchain technology in government services is impacting on their delivery to customers by using examples from all around the world and to conduct a SWOT analysis of the use of blockchain in the government sector. Its findings are expected to help governments to develop a blockchain strategy that helps smart government services to adopt blockchain successfully.

Keywords:
blockchain; e-government; smart-government; government Service; smart service; e-service.

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1. Introduction

Nowadays we are witnessing the boom of various emerging technologies that are not only affecting our lives but also dramatically change the way that many things are being done. Scholars such as Oliveira et al. [1] and Akram et al. [2] have suggested that the effect of these new technologies is to disrupt the ways in which businesses are running their processes and delivering services. Since an unknown entity calling itself Nakamoto first introduced it in a mysterious white paper that ultimately led to the creation of cryptocurrency [3], blockchain has gained global attention. It solved a known problem in cryptography that emerged in the 1980s and 1990s: how to verify time stamps and prevent double-spending [4]. Ølnes et al. [5] stressed that blockchain technology was still immature and should be analysed and experimented with to avoid wasting resources on failure. Similarly, a paper presented by Potts [6] confirmed that we are still at an early stage of applying blockchain in the public sector. When we reach the next stage where all the sectors complement each other, the innovations in the government sector will be noticed [6].

Governments worldwide provide the major infrastructure services in their domains, as seen in their transportation systems, roads, ports, airports, etc. Government public services are also in touch with all citizens, providing them as customers with various services, such as licensure, regulatory frameworks and finance. With this commitment, governments seek to streamline their processes and services by adopting smart systems and to transform their bureaucratic procedures by digital formatting. Researchers have highlighted the promise for smart government services that is inherent in blockchain technology of securing and using the inexpensive management of huge databases [7]–[9]. Blockchain and smart government services both rely heavily on technology, making them the best fit for each other. Many scholars have mentioned the benefits yielded by applying these two technologies together, building upon the features of each one. In fact, many governments such as Estonia, Spain, the UAE, the UK, the USA, Korea and Singapore have already started to implement blockchain technology in their smart services [10], [11]. The decentralizing nature of blockchain can facilitate the interaction between government institutions, citizens and economic agents, improving the processes of information registration and exchange. Blockchain can considerably reduce government administrative tasks, allowing all the information storage and exchange to take place through blockchain protocols and leaving only a supervisory role for the government [5], [11]. Alketbi et al. [12] have divided the potential uses of blockchain technology in smart government services into three main applications, namely, monetary uses (such as e-payments), contracts (such as smart contracts and stocks) and social applications (such as education and health). Allessie et al. [11] from a similar perspective have identified five main uses for blockchain in the government sector: citizen ID management, tax reports, development management, e-voting and regulatory.

With the above in mind, this study aimed to answer the following research questions:

- Q1: What is blockchain technology and what are its most important characteristics?
- Q2: What are smart government services and their most important characteristics?
- Q3: What are the implications of blockchain for smart governments?

The contribution of this paper can be summarized in three points. First, the current study provides what is, to the best of our knowledge, the first literature review to highlight the most prominent characteristics of blockchain technology in the literature that have the greatest impact on smart service delivery, specifically in the government sector. It also provides an insight in the literature into the most prominent features of smart government services required for efficient service delivery. Second, it provides an overview of the implications of blockchain technology for smart government services by citing cases from all over the world. Third, it draws on these implications and provides a SWOT analysis for the use of blockchain technology in smart government services which provides further insights into the role of blockchain technology in smart government services.

The rest of this article is structured as follows. In Section 2, we present the methodology used to conduct this systematic review. Section 3 provides an overview of the treatment in the reviewed literature of blockchain and smart government services and their characteristics and implications. In section 4, we analyse the data using statistical graphs and SWOT analysis. Finally, section 5 gives our concluding remarks as well as the limitations and implications of our paper and recommendations for future research.

2. Methodology

The systematic literature review was carried out using the framework of Vom Brocke et al. [13]. This framework was deemed most appropriate for our study because it was formulated on the basis of information systems (IS) literature. It consists of five stages – the definition of the review scope, conceptualization of the topic, literature search, analysis of the literature and formulation of the research agenda – connected in a circular manner. The first four steps are discussed in the methodology section, while the fifth step is discussed in section 5.

2.1. Defining the scope

The taxonomy presented by Cooper [14] was used to define the scope of our literature review. This taxonomy consists of six characteristics representing different categories, namely, focus, goal, organization, perspective, audience, and coverage. Table 1 below shows the categories that characterize our literature review.

Table 1: Taxonomy of our literature review adopted from cooper [14].

Characteristic	Chosen category
Focus	Covering all types of paper, including theoretical and applied
Goal	Identifying the central issue and synthesizing past literature
Organization	Organizing the literature in chronological order, and the conceptual order into themes
Perspective	Considering a neutral perspective for the authors
Audience	Targeting specialized scholars
Coverage	Covering a representative sample of studies

2.2. Conceptualization of topics

To formulate our search keywords, we started by using our main keywords “Blockchain” and “Smart Services” in the Scopus database, since it is considered one of the best-known databases. We searched for records using these two terms in the title, abstract, or keywords and conducted a concept map to find related search terms. We found some additional keywords, such as “e-service” and “smart government”, used in these records that were applicable to our study.

2.3. Literature search

Next, we conducted a refined search of the database including all the keywords that we obtained. The main keywords used in this research were “Blockchain”, “Smart Service”, “e-Service”, “e-Government” and “Smart Government”. As Werner suggested [15], these keywords were used in different combinations to go through other digital databases. The databases used in this study are IEEE explore, SpringerLink, ScienceDirect and Google Scholar. A total of 510 titles were collected, each containing one or more of the researched keywords. Additionally, some records were obtained from backward and forward searching. All the records were collected and processed using the Mendeley citation manager.

2.3.1. Inclusion and exclusion criteria

To ensure that the best available papers to fit the purpose of our study were collected, we engaged in three stages of exclusion, as follows:

1. Title and abstract: the title and abstract for each paper were read carefully to decide the relevance of the paper to our research objectives and that it includes more than one characteristic of blockchain or smart government service. At this stage, all the duplicated records resulting from the use of different databases were deleted. In addition, records not written in the English language were excluded.
2. Type of publication: we included only records from journal papers, conference papers and books. All other types of records such as white papers, letters and patents were excluded. Moreover, records dealing with the engineering aspect of blockchain and smart services such as computer-based modelling or cryptocurrencies were excluded and only papers dealing with the social aspect were included (since the focus of the paper is on the social aspect).
3. Time: the time-frame for blockchain publications was chosen to be between 2016 and 2022 because 2016 was the year that witnessed the development of decentralized applications through blockchain using smart contracts in the public services [16], [17]. However, e-Government history emerged in the late 1990s [18], and it, therefore, seemed logical to review the literature on smart services associated with this period and to confine the search for smart services to the 21st century, i.e., 2001 to 2022. Additionally, according to Xiao and Watson [19], more recent literature can be more relevant to the current situation and thus provide more useful insights.

At the end of these three stages, seventy-seven papers were chosen to be the sources of our research. The classification of papers used in this research according to the year of publication and type of paper is presented in Figure 1 below, which shows that more than 70% of the publications were recorded between the years 2015 and 2022. This reflects the breakthrough achieved in blockchain technology for public services during this period.

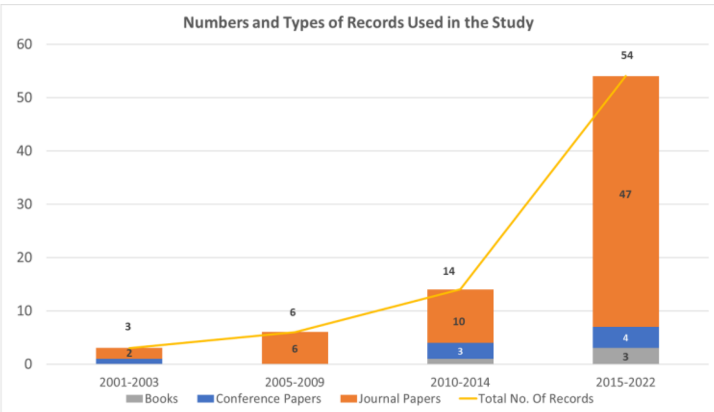


Figure 1: Classification of records according to the type and year of publication.

2.4. Analysis of the literature

At this stage, data were extracted through the use of deductive coding to divide the papers under the heading of themes as recommended by Xiao and Watson [19]. Three themes stood out: one presents the blockchain characteristics, one concerns the characteristics of smart services, and one focused on the impact of blockchain on smart government services. The first two themes were placed in tables, as shown in Tables 3 and 4. The third theme was used to tie the previous two themes together. To analyse the data effectively, concept mapping was used as recommended by Vom Brocke et al. [13] and the three chosen themes were treated as units of analysis. It is worth mentioning here that the features and characteristics of blockchain and smart government services addressed in this study do not constitute an exhaustive list; rather the study presents the most frequent features and characteristics mentioned in the literature. Figure 2 below shows the steps taken in conducting our systematic review of the literature.

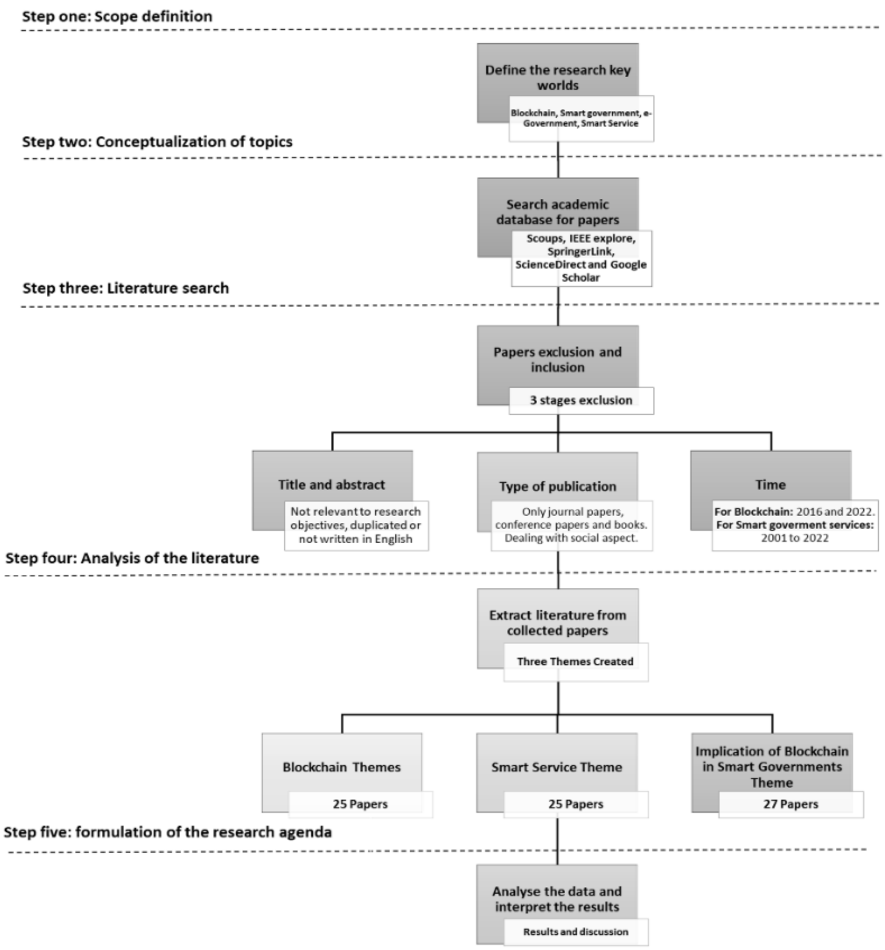


Figure 2: Block flow diagram for research methodology adopted from Vom Brocke et al. [13].

3. Literature review

3.1. Blockchain technology

Blockchain is a technological concept consisting of a distributed digital ledger in a decentralized network. The name originated from its nature, where individual records (called squares), are connected in a single rundown, called a chain [20]–[24]. It verifies the integrity of the data through a cryptographic mechanism [20], [22], [24]. Blockchain forms a structured distributed system which makes sure that every exchange is legitimate before being added to the chain. This guarantees that no invalid squares are included. It also guarantees that the chain is never broken and that each square is recorded all the time [20].

In blockchain technology, every exchange added to the chain is approved by many computers on the network, called its nodes. These nodes hold a copy of the ledger throughout the network. They are governed by frameworks designed to screen certain explicit types of blockchain exchange [20]. These frameworks are classified into three main types, namely, public blockchain, private blockchain and hybrid blockchain [23], [25]. Since its inception, blockchain has evolved in distinct phases year by year in major ways. Researchers have divided these phases into four main generations, going from blockchain 1.0 up to blockchain 4.0. Table 2 below shows the major changes that blockchain experienced in each phase [16], [17].

Table 2: Blockchain technology evolution [16], [17].

Blockchain Generation	Year	Main Characteristics	Associated Sector
Blockchain 1.0	2009	Introduction of cryptocurrencies such as Bitcoin	Digital payments and the financial sector
Blockchain 2.0	2010	Development of smart contracts and blockchain tokens such as Hyperledger and Ethereum	Financial sector
Blockchain 3.0	2015	Development of decentralized applications through smart contracts	Healthcare, IoT, smart cities, financial sector, businesses and supply chain
Blockchain 4.0	2018	Integration with 4.0 Industry applications and real-time public ledger services	4.0 Industry applications in all sectors and artificial intelligence (AI)

3.2. Blockchain features and characteristics

Many characteristics of blockchain technology can positively impact on business processes. These characteristics make blockchain a possible solution to many problems and challenges in current systems. Table 3 below shows the most frequently mentioned characteristics in the literature that we reviewed.

3.2.1. Decentralization

The Peer-to-Peer (P2P) methodologies that blockchain employs play a significant role in protecting its users by improving the decentralized applications installed in many devices. Since it is P2P, it is not constrained by any single unifying element [22]. Therefore, digital currency is simply one of the potential uses of this innovation. In general, blockchain exhibits three aspects of innovation: cryptography, distributed conventions and information stockpiling. When we join these aspects together, they progressively decentralize its applications, which is the essence of blockchain's innovation [24].

3.2.2. Trust

Blockchain technology is interesting, simply because it casts doubt on the way in which human interactions have hitherto been directed, every one of which depends on trust. By eradicating the need for intermediaries, blockchain technology promotes trust [24]. Through blockchain technology, all processes take their course without the need of a third-party facilitator and each exchange is straightforward and reported to all [26].

3.2.3. Shared and public

Blockchain is like a world in which data are installed in computerized code and stored in straightforward and shared databases, protected from any change. Anyone can publish a transaction and join the system by following a set of rules guided by the information that the controlling party provides. Each modification will have an advanced and unique record that can be traced [21], blockchain's power to reproduce the record ensures that it does not get lost. The more places a thing occupies, the less dependable it becomes, and the possibility of it being permanently lost increases. This is one of blockchain technology's weaknesses [27].

3.2.4. Immutability

Crosby and Nachiappan [20] stated that the significance of blockchain is in the security and the protection that it provides, permitting clients to give decentralized evidence of records that cannot be changed by any outsider. The unchanging nature of blockchain and its immutability are what give blockchain its uniqueness, making it a perfect solution for transactions in digital currencies. This is because of its capacity to announce a reality universally and with no focal point of power, unaffected by any other individual effort to change its truth [23]. Additionally, data are conveyed in a non-participatory way, precluding faulty security positions [28]. However, this should not imply that blockchain is beyond a change in any circumstances. According to Atzei et al. [29], the history of blockchain can be altered by the controlling parties.

3.2.5. Redundancy

Blockchain repeats the record in order to preserve it from loss. For example, storing an element in N spots requires as much as N times stockpiling as well as system transfer speed to impart the information to every one of the spots. The additional redundancy is unlikely to benefit the capacity, the cost or the speed of the system transfer [27]. From another point of view, adaptability is an issue facing blockchain; for example, when the quantity of transfers increases, the blockchain becomes bigger and it ends by being slow and costly to store [22].

Table 3: Blockchain technology characteristics in the reviewed literature.

No.	Year	Article Title	Published In	Reference	Decentra-lization	Trust	Shared and Public	Immu-tability	Redun-dancy
1	2016	Blockchain Technology: Beyond Bitcoin.	Applied Innovation	[20]	✔	✔	✔		
2	2016	Blockchain Technology: Principles and Applications	Research Handbook on Digital Transformations	[23]	✔	✔	✔	✔	
3	2016	Where is Current Research on Blockchain Technology? A Systematic Review	PLOS One	[26]	✔	✔	✔		✔

No.	Year	Article Title	Published In	Reference	Decentra-lization	Trust	Shared and Public	Immu-tability	Redun-dancy
4	2016	Beyond Bitcoin, Enabling Smart Government Using Blockchain Technology	ICEG	[7]	✓	✓	✓		
5	2016	Blockchain For the Internet of Things: A Systematic Literature Review	IEEE	[22]	✓	✓	✓		✓
6	2017	Blockchain Hype or Hope?	USENIX Mag.	[27]	✓	✓	✓	✓	✓
7	2017	The Truth About Blockchain	Harvard Business Review	[21]	✓		✓		✓
8	2017	Future Living Framework: Is Blockchain the Next Enabling Network?	Technological Forecasting and Social Change	[28]	✓		✓	✓	
9	2018	Blockchain 101: What Is blockchain And How Does This Revolutionary Technology Work?	Transforming Climate Finance and Green Investment with blockchains	[24]	✓		✓	✓	✓
10	2018	What Problems Will You Solve with blockchain?	MIT Sloan Management Review	[30]	✓	✓		✓	✓
11	2019	Blockchain Characteristics and Consensus in Modern Business Processes	JIII	[31]	✓		✓	✓	
12	2019	Technical Aspects of blockchain and IoT	Advances in Computers	[32]	✓	✓		✓	
13	2019	Blockchain Technology: Implications for Operations and Supply Chain Management	SCM	[33]	✓	✓	✓	✓	
14	2019	A Review on blockchain Technology and blockchain Projects Fostering Open Science	Frontiers in blockchain	[34]	✓		✓	✓	
15	2020	Solutions To Scalability of blockchain: A Survey	IEEE Access	[35]	✓	✓			✓
16	2020	Blockchain-Based Electronic Healthcare Record System for Healthcare	JISA	[36]	✓	✓		✓	
17	2020	Blockchain For Industry 4.0: A Comprehensive Review	IEEE Access	[17]	✓			✓	✓
18	2020	Blockchain Applications in the Agri-Food Domain: The First Wave	Frontiers in blockchain	[37]	✓		✓	✓	✓
19	2021	Blockchain Implications in The Management of Patient Complaints in Healthcare	Journal of Information Security	[38]	✓	✓	✓	✓	✓
20	2021	The Revolution of blockchain: State-of-the-Art and Research Challenges	Archives of Computational Methods in Engineering	[39]	✓	✓		✓	
21	2021	What Do We Really Need? A Systematic Literature Review of the Requirements for blockchain-based E-government Services	Lecture Notes in Information Systems and Organisation	[40]	✓		✓	✓	✓
22	2021	Blockchain-based Distributed Platform for Accountable Medical Data Sharing	International Conference on Utility and Cloud Computing Companion	[41]	✓	✓			✓

No.	Year	Article Title	Published In	Reference	Decentra-lization	Trust	Shared and Public	Immu-tability	Redun-dancy
23	2021	The role of blockchain technology in telehealth and telemedicine	International Journal of Medical Informatics	[42]	✔		✔	✔	
24	2022	Blockchain as a driving force for federalism: A theory of cross-organizational task-technology fit	International Journal of Information Management	[43]	✔	✔	✔		
25	2022	Blockchain governance in the public sector: A conceptual framework for public management	Government Information Quarterly	[44]	✔		✔	✔	

3.3. Blockchain and smart contracts

One of the major highlights in the blockchain 2.0 phase was the development of smart contracts which is considered the main enabler for blockchain in smart governments [16], [17]. A smart contract is a program that keeps running on blockchain. The blockchain performs services by means of these smart contracts eliminating the need for a third-party facilitator. It has rules for exchange and transfer, which cannot be changed during the execution, nor can any of the stakeholders meddle with it without the others' knowledge. To avoid conflict and guarantee trust, the contract may cite what others need to affirm in the exchange before the agreement is executed [5]. Furthermore, it has its right of execution authorized by the agreement convention. An agreement can encode any set of guidelines in its programming language. Smart contracts permit a wide range of uses; they can count budgetary instruments, e.g., money-related subordinates, and self-upholding or self-sufficient administration applications such as decentralized betting [45]. Therefore, smart contracts hold the key to implementing blockchain in smart governments, because they resolve any trust-related issues and provide an easy solution for any conflict that may arise.

3.4. Smart government services

With the arrival of industrial revolution 4.0, which brought some technologies such as blockchain, artificial intelligence, automation and the Internet of Things (IoT), amongst many others, we are witnessing a complete change in the way services can be delivered. It is difficult to imagine what the face of service delivery in the next five years will be, as organizations create and implement the latest trends in rapid technological marvels. As a result, governments are also taking active measures to ensure the use of these technologies in delivering public services and meeting their customers' needs effectively by means of what is called smart service.

3.4.1. Smart services and smart governments

A research paper by Marquardt [46, P. 794] has defined smart service as used in the Smart Urban Services project: "services tailored to specific customer used cases, with the help of data and intelligent processing". These smart services rely on smart data which are effectively extracted from big data. They also use the concept of machine learning and information to analyse and process these smart data [47]. New terminology has come up that gives the name 'smart government' to the phenomenon of a government's use of these smart services. Smart government means the execution of many business forms; it encourages data innovations which empower data to stream consistently crosswise over government offices and projects to end by naturally giving extremely efficient resident administration [48]. Governments adopt these technologies in developing policies and measures for sustainable development models, rapid economic growth and a better quality of living for their citizens.

Smart services are considered the main driver for smart governments. They are being used to improve public services and administration functions by making use of big data, intelligent processing and digital technologies to serve the public and provide people with a high level of customization. According to Marquardt [46], a smart service required some conditions to be fulfilled in advance, namely:

- The service should be customer-centred and solution-oriented,
- The service should be electronically integrated with the product that performs the service,
- Big data and secured data such as IoT should be collected and analysed by a computer.

Further requirements were added by Gil-Garcia et al. [49], in the context of smart government service; they considered the integration of technologies, information and innovation, coupled with an advanced thinking mindset in the government to be necessary for implementing smart services in a smart government. The implementation of smart services offers ample opportunities to the government sector and its digital transformation, such as greater efficiency, cost reduction, improved customer satisfaction and faster decision making [46].

3.4.2. Smart services' applications

For a smart city to be constructed, Su et al. [50] identified three levels in a system that were required, namely, public infrastructure, a platform for the public use of services and the availability of application systems. They proposed that by providing this layered system, a platform could be created for inclusive planning, emergency responses and administrative services, thus creating a single-stop service system. A research paper by Bătăgan [51] suggested many applications whereby governments could use these smart services, for example, systems for processing documents, administrative services and electronic information services for citizens. These applications together with changes in the model of governance have led to a smart-growth phenomenon, which is a combination of several changes in the way that public administration is conducted, resulting in several initiatives. These are servitization (developing the capacity to provide service, unlike traditional products), informatization (becoming a knowledge-based society), innovation (focusing on innovations and entrepreneurship) and digitalization (using technological advances) [52].

3.5. Smart government services characteristics and features

Citizens of any nation can enjoy the various features which come naturally with citizenship, such as access to public services and the rights sanctioned by those in power in the land. In this sense, the smart government model of governance gives citizens a very important role in the administration of services [53], [54]. Smart government systems have become more relevant today because they provide a more cost-effective and efficient system of governance than previous models did, improve the trust of citizens in the government and thus increase the participation of citizens in their governance [55].

Smart government services have several key characteristics, such as trust, civil partnership, accessibility, reliability and speed of delivery [53], [56], [57]. A study by Alawadhi and Morris [56] using the unified theory of acceptance and use of technology (UTAT) model has identified reliability, trust, speed of delivery and peer influence as the service-facilitating factors responsible for the adoption of smart services. The most frequently mentioned characteristics in the reviewed literature are listed in Table 4 below.

3.5.1. Participation

Participation of the citizens in smart government services can be considered a type of co-production (with the government) of services. Service co-production refers to the deep involvement and participation of the citizens in service delivery and decision-making. It involves the use of ICT (Information and Communications Technology) and is often labelled e-participation [58]–[60]. Co-production is particularly important because it provides opportunities for cost reduction and improved efficiency for these smart services [60], [61]. Another concept of co-production and participation in smart services is citizen-sourcing, where the government collects information from citizens about the services provided. The service quality can be improved by governments sharing ideas and feedback with the public or by the public requesting services and reporting problems with the system [61].

3.5.2. Trust

The aspect of trust is considered too wide and complex a concept to be confined to one definition or a certain set of elements [62]. However, the trust factor in using new technologies has been discussed widely throughout the literature, especially when dealing with the intention to adopt or actual adoption [63]–[68]. Having confidence in both the government and the technology used by the services forms a fundamental part of citizens' engagement and their adoption of these services [63]. According to Zucker [69], trust in the economic environment is one of three kinds: institutional, characteristic and processional, the last being considered the most important, since it is based on previous experience and interaction.

3.5.3. Reliability

Smart services use technology to execute their processes. If it enables them to provide the service efficiently and responsively when needed, it can be called reliable [70]. Reliability is considered a direct determinant of service quality because it largely affects the customer's perception of its quality [71], [72]. It is defined as the amount of variability in the service attributes [73], [74]. According to Zeithaml [75], reliability is the most important factor in the adoption of smart services. Reliability can represent the availability, durability, or consistency of a service quality over time; it also represents the ability of the service to perform what is promised every time [71], [74].

3.5.4. Speed

Nowadays, the speed of service delivery has become an important aspect of our daily lives; this is because of the technological advances in speed that the world is witnessing [76]. The speed of service delivery refers to the rate at which the service is delivered or processed [77]. In a study by Shamdasani [78] on self-service internet technologies, he found that the speed of service delivery significantly influences customers' perceptions of quality. Government services often deal with enormous numbers of transactions per day, making the requirement of fast and efficient transactions crucial.

3.5.5. Transparency

Transparency and trust are often mentioned together in the literature as desired features for government services. Open data and the co-production of the service offer examples of transparency in smart services. Customers need to know what is being done with their private information when they trustingly share it with the government in order to use its services [61]. Moreover, transparency plays an important role in opposing corruption, especially through the use of ICT [79].

Table 4: Smart services characteristics for smart governments in the reviewed literature.

No.	Year	Article Title	Published In	Reference	Partici-pation	Trust	Relia-bility	Speed	Transpa-rency
1	2001	Developing Fully Functional e-Government: A Four-Stage Model	Government Information Quarterly	[54]	✔	✔			
2	2002	Encouraging Citizen Adoption of E-Government by Building Trust	Electronic Markets	[64]	✔	✔	✔	✔	✔
3	2003	Diffusion of Innovation & Citizen Adoption of E-Government	International Conference on Electronic Commerce	[57]	✔	✔	✔	✔	✔
4	2005	Four Strategies for The Age of Smart Services	Harvard Business Review	[80]	✔				
5	2006	Determinants of User Acceptance of the e-Government Services: The Case of Online Tax Filing and Payment System	Government Information Quarterly	[66]	✔	✔	✔	✔	✔
6	2007	Perceived Usefulness, Personal Experiences, Risk Perception And Trust as Determinants of Adoption of E-Government Services in The Netherlands	Computers In Human Behaviour	[65]	✔	✔	✔	✔	
7	2008	History And Development of Transport Telematics	Archives of Transport System Telematics	[81]			✔	✔	✔
8	2008	Antecedents and consequences of service quality in consumer evaluation of self-service internet technologies	Service Industries Journal	[78]		✔	✔	✔	
9	2010	Governance Infrastructures In 2020	Public Administration Review	[82]		✔	✔	✔	✔
10	2011	Smart City and The Applications	IEEE	[50]	✔	✔	✔	✔	
11	2011	Smart Cities and Sustainability Models	Informatica Economică	[51]		✔	✔	✔	✔
12	2011	Conceptualizing Smart City with Dimensions of Technology, People and Institutions	International Conference on Digital Government Research	[83]				✔	✔
13	2012	Enabling Technologies for Smart City Services and Applications	IEEE	[84]	✔				
14	2013	Smart Cities in The New Service Economy: Building Platforms for Smart Services	AI & Society	[52]	✔	✔	✔		
15	2013	Using Citygml to Deploy Smart-City Services for Urban Ecosystems	ISPRS Archives	[85]	✔	✔	✔		✔
16	2014	The Use of The UTAUT Model in The Adoption of e-Government Services in Kuwait	41st Hawaii ICSS	[56]	✔	✔		✔	
17	2014	Smart Government, Citizen Participation and Open Data	Information Polity	[86]	✔	✔	✔	✔	✔
18	2014	Developing And Validating a Citizen-Centric Typology for Smart City Services	Government Information Quarterly	[53]	✔	✔	✔	✔	
19	2014	Transforming e-Government to smart government: A	Intelligent Computing,	[48]		✔	✔	✔	✔

No.	Year	Article Title	Published In	Reference	Partici-pation	Trust	Relia-bility	Speed	Transpa-rency
		South Australian perspective	Communication and Devices						
20	2015	Smart Tourism: Foundations And Developments	Electronic Markets	[87]	✔		✔	✔	
21	2018	Exploring User Participation Practice in Public E-Service Development – Why, How and In Whose Interest?	The Electronic Journal of e-Government	[55]	✔	✔	✔	✔	✔
22	2019	The Role of Smart Government Characteristics for Enhancing UAE's Public Service Quality	International Journal on Emerging Technologies	[88]	✔			✔	
23	2020	Success Factors Influencing Citizens' Adoption of IoT Service Orchestration	IEEE Access	[89]	✔	✔	✔	✔	✔
24	2021	What Do We Really Need? A Systematic Literature Review of the Requirements for blockchain-based E-government Services	Information Systems and Organisation	[40]	✔	✔	✔		✔
25	2022	E-Service Experience as the Antecedent of E-Trust & E-Loyalty: An Integration of Behavioral and Technology Perspectives	International Journal of Mechanical Engineering	[90]	✔	✔		✔	✔

3.6. Blockchain in government services

New revolutions in governmental systems are among the major topics of discussion all over the world [91]. The applications of data science technologies such as Artificial Intelligence (AI), the Internet of Things (IoT), Big Data, Predictive Analysis and blockchain show the way to extract the new generation of smart governments [91]. Establishing smart cities by combining Building Information Modelling (BIM), IoT and blockchain are the major bequests of the new technologies in our own day. BIM will provide the required information about the available facilities and infrastructure, IoT will combine these facilities intelligently through fixed devices and blockchain distributed ledger technology will ensure information security while blockchain smart contracts operate the system [91].

Big data auditing is a requirement to ensure that smart government activities are running smoothly. Blockchain data auditing (BDA) could be established to avoid any risk of the presence of third-party auditing (TPA), protect the privacy and avoid subsequent cyber-attacks [92]. Many governments around the world have already engaged in innovative technological initiatives across their platforms. For instance, in New York City, Predictive Data Analysis is used to determine which buildings may be fire hazards so as to take all the appropriate safety measures. In Seoul, cell phones and geospatial data are used to operate night bus services with only 30 available vehicles in a city with a population of 10 million. Barcelona, the European capital of innovation, has around 100 smart city projects [91].

Blockchain distributed ledger and smart contracts are considered the major elements to combine with other types of technology such as big data and IoT in the provision of trust and the keeping of records. It is also considered the nucleus of a decentralized, low-cost and more efficient way of restructuring public services. A research paper by Jun [93] asked why blockchain technology had been installed by different countries and found that in applying this technology in public services the main principle of blockchain technology lay in its social effect, because the consensus mechanism forms the core of blockchain. Many researchers, such as Năsulea [94], consider blockchain to be a disruptive technology. This is particularly apposite when we look at its potential to change the concept of the delivery of services.

At the same time, however, it implies a negative perspective because the old systems and models are not yet designed for this type of technology and this encourages resistance to its introduction.

3.6.1. Blockchain and smart government services globally

Governments are launching blockchain technologies in projects that could transform compliance with regulatory systems and identity management and could maintain government records. Moreover, they are initiating these transformations in election processes and other democratic voting models [91]. Singapore's Signpass is an example of the investment in these transformations. Signpass allows access to many governmental services, like electronic health records. Another example is the Georgian government with Bitfury, the Bitcoin company which established a system for registering land titles using blockchain. Blockchain's inherent cryptography which requires permission to access may prevent corruption and reduce the amount paid in customs duties by combating fake export invoices. The process may prevent fraud worth around 10 billion dollars [95].

Another interesting finding is that the Chinese government saw that the characteristics of blockchain, such as distributed ledger and smart contracts, meet the functional requirements of photovoltaic (PV) in many respects, notably automated accounting and the settlement of funds. The integration of blockchain technology with distributed photovoltaic energy (PV) breaks the current centralized pattern and mode of business, which implies that the amount of profit will change accordingly. The blockchain distributed concept and smart contract cover the three bottlenecks of future distributed PV when there are many stakeholders with many disparate standards and when the participants do not trust one another. Hence, blockchain technology reduces transaction costs and also makes transactions more efficient [96].

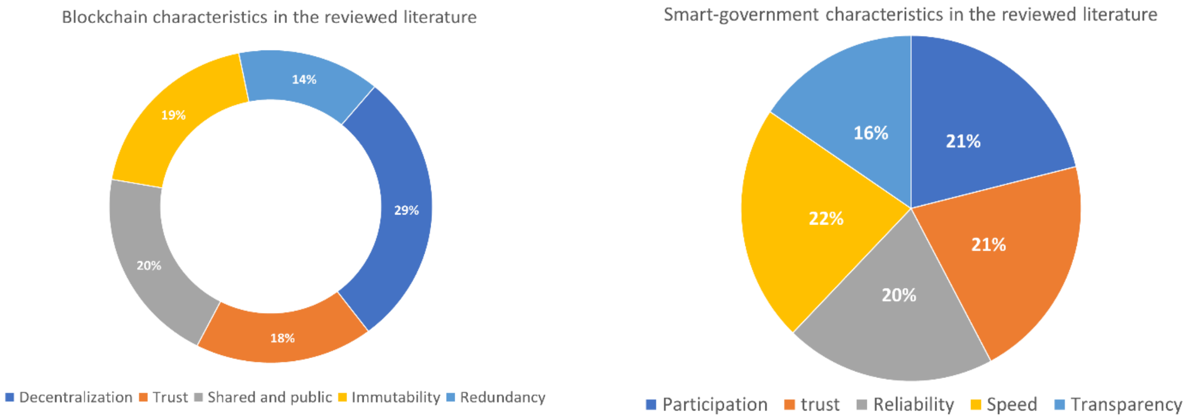
Saudi Arabia's SADAD digital payment system and Smart Dubai are other Gov-tech initiatives that use blockchain technology. Dubai has established the Global Blockchain Council to provide affordable, simple, easy and efficient services for its citizens and residents by analysing recent and future blockchain applications. Dubai launched seven blockchain trails covering business registration, title transfer, diamond trade, health records, digital wills, tourism engagement and shipping [91]. On another level, Estonia has already started using blockchain technology in several government sector services such as voting, taxes, medical records, identity checks and banking [97]. It initiated the e-Residency program to create a transactional digital identity for anyone in the world [98]. The leaders of Estonia, interestingly, mentioned that if the country was ever invaded by any other country, all government operations could still be operated remotely through Estonia's online blockchain smart government system [97].

According to Kshetri and Voas [95], many properties are illegally owned without any contracts in many developing countries, such as India, Ghana and Honduras. This makes the prospect of blockchain technology very welcome in developing countries, for it has the power to combat corruption, protect property rights and help disadvantaged groups like refugees or displaced persons.

4. Analysis and discussion

Among the characteristics of blockchain as a technology are decentralization, trust, being shared and being public, immutability and redundancy. The literature reviewed in the present study revealed that researchers most commonly identified the characteristics of decentralization (29%) followed by being shared and being public (20%) as shown in Figure 3 (a). These findings agree with other researchers' findings; for instance, Seebacher and Schüritz [99] found in their research on blockchain technology in the service domain that the most important characteristics were decentralization and being shared and being public. Alkhateeb [38], for his part, found that the most important characteristics of blockchain technology that best suited the healthcare sector services were its transparency, decentralized character, immutability and anonymity.

The blockchain characteristics shown in Table 3 are the most often mentioned as being expected to provide the highest value to citizens when a government implements them. However, certain other characteristics are considered equally important but are not for the most part addressed in the literature. Among them are its democratization (being publicly available) [17], reliability (allowing transactions without human or machine errors) [24], tokenization (transforming "real world" resources such as cash and stocks to blockchains) [17], and being chronological and time-stamped (trial of transactions), etc. [100].



(a) (b)

Figure 3: (a) blockchain characteristics, (b) Smart-government services characteristics in the reviewed literature.

With regard to characteristics of smart government services, writers give the highest importance to speed (22% of writers did this) followed by trust and participation (21% of writers did this), as shown in Figure 3 (b). These results reflect the findings of the majority of researchers; for instance, Carter and Belanger [63], surveying 140 students in the USA, concluded that trust and accessibility were the two most important reasons for citizens to adopt the use of smart services offered by governments. Another (quantitative) study of the smart service features that persuaded citizens to adopt them was conducted by Lean et al. [67], who concluded that trust, perceived usefulness, perceived relative advantage and perceived image had the highest impact on adoption. Moreover, others such as Hung et al. [66] and Nowacki [81] found in their research that perceived usefulness, ease of use, perceived risks, trustworthiness and compatibility were the reasons why people accepted smart services.

Apart from the smart government services characteristics mentioned above and shown in Table 4, there are some characteristics that smart government services ought to include for the sake of efficiency which are addressed in the literature but less frequently. For instance, one of the main challenges that blockchain technology faces is interoperability which is the integration with existing data management systems for smart services [46]. For smart government services to be integrated successfully with blockchain, smart services systems should feature interoperability [44]. In addition, smart services have other desired characteristics that are not highlighted in this study because they are not widely mentioned in the literature such as effectiveness (ensuring the effective delivery of quality services) [89], compatibility (being compatible with citizens' lifestyles) [57] and innovation (in the modes of service) [88], etc.

The use of blockchain technology in government services is promising and could be an important element in the quest by various governments to become a smart city. However, this technology is still nascent and various security and technical issues must be addressed before it can be implemented on a large scale and become fully accepted by the public. The lack of standards, scalability, change management and cybersecurity are the major issues with blockchain technology and further research is required to resolve them [91]. Most of the discussions about blockchain technology in the literature focus on the possibilities and issues of the technology itself but ignore issues except those at the extremes, such as those to do with implementation, trade-offs, limitations and governance [5].

Taking the e-Residency project in Estonia as an example, we believe that it should be undertaken with stricter regulations such as limiting first registration to those located in Estonia at the time. For instance, it would not be possible to encourage the UK or any other country to go ahead now with an e-Identity project on the grounds that it had succeeded in Estonia, because Estonia and the UK differ so widely in their culture and the size of their population; managing to collect 1.3 million identities electronically is not at all the same as managing to collect around 70 million. Proactively, researchers such as Sullivan and Burger [98] discussed the risks of initiating smart residency in Estonia. They mentioned that the authentication process for e-Residency does not meet the international standards set by AML/CTF (Anti-Money Laundering and Counter-Terrorism Financing Act). For instance, no face-to-face interview is required in Estonia before e-Residency is certified and this opens the door to money laundering; this is why its banks now demand face-to-face interviews to open new accounts [98].

Scholars such as Peters and Panayi [101] reflected in their research on several issues – authorization, data certainty, data protection and data validity – that need to be explored when blockchain financial applications are being made. Moreover, other academics such as Ølnes [7] and Carson et al. [10] argued that the attention on blockchain technology has focused merely on financial capabilities and strengths and overlooked its underlying abilities and opportunities as a technology that can be applied from several perspectives such as those of a smart government. Similarly, a paper by Crosby et al. [20] argued that the financial and non-financial aspects of blockchain show different capabilities and predicted significant adoption of it in the coming years. However, it will be taken up slowly due to the risks and threats which are associated with it. To reap the benefits of implementing blockchain technology, many changes in the design of processes, responsibilities and governance will have to be made [5]. Allessie et al. [11] argued this point by linking it to governance since the decentralized nature of blockchain technology is expected to create uncertainties over the stability of the network. It removes central control from the government and therefore makes it obligatory to re-engineer government processes in response [5], [11].

As with any new technology, smart government services face many challenges and obstacles owing to the nature of these services and their high dependency on technology. Marquardt [46] finds that among these challenges are the lack of standardization, lack of skilled workers, high investment requirements, security and data ownership as well as deficiencies in data analysis and technology. Looking at these challenges from a closer perspective, we see many other challenges that may not be related to the technology itself but rather relate to the mindset of the people involved. For instance, Harsh and Nikhil [48] highlighted the challenges facing governments that appear during the transformation of government services into smart services, identifying the cultural challenge and fear of failure as two of the greatest. In the same context, Marquardt [46] identified other challenges affecting the implementation of blockchain, such as the absence of change management approaches and lack of vision. Interestingly, all authors agree that the unavailability of models and frameworks to help assess the transformation, in terms of implementation [48] and in terms of measuring the social and economic impact of open data [46], represent a big proportion of these challenges.

To generalize these aspects more widely, SWOT analysis of the strengths, weaknesses, opportunities, and threats, in the reviewed literature was performed (see Figure 4) to assess the implementation of blockchain in smart governments. The core strength of this technology is the security and privacy that it offers. Yet the vulnerability of this technology lies in the fact that it is a newly born technology and has not yet been fully explored, posing some threats to its implementations. Even so, we cannot ignore the vast array of opportunities that it provides to governments mainly in reducing costs and providing services of better quality.

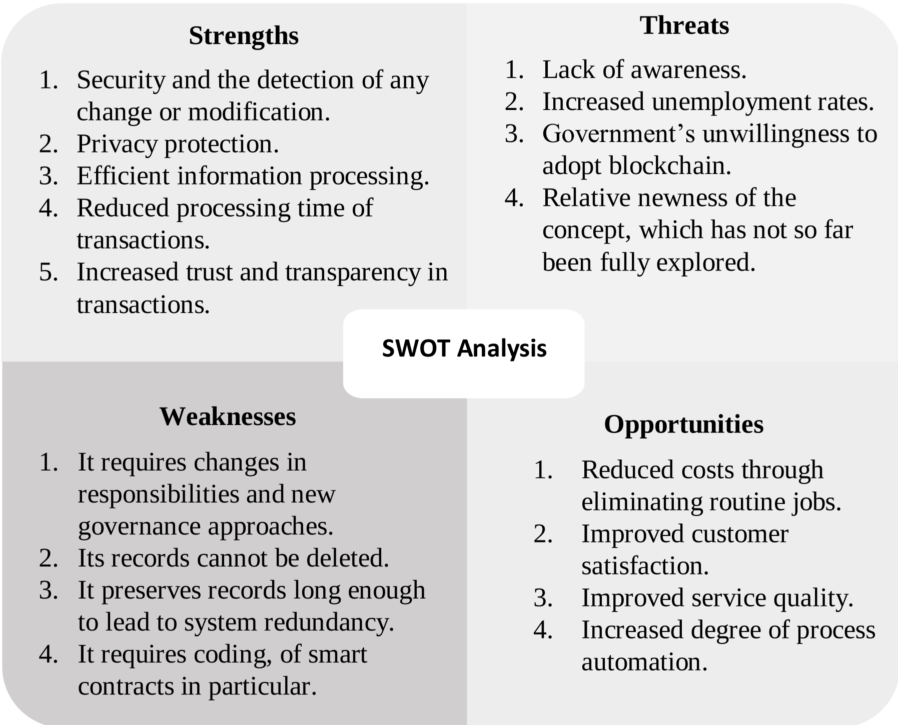


Figure 4: SWOT analysis for blockchain implementation.

5. Conclusion, implications and future research

Blockchain as a technology has enormous capabilities in different fields and as such, has aroused immense interest due to the chance to adopt it in other areas beyond the financial. Its capacity can be used in the field of information security, to exchange data and information efficiently. However, at this stage, the adoption of this technology is advancing at a slow pace.

Within the literature, the characteristic of blockchain technology found most common was decentralization, whereas for smart government services the most common characteristic was found to be speed. This literature review concludes that even though there are still some weaknesses in blockchain technology arising from the fact that it is still in its initial stages, adopting blockchain technology in government services is now showing great potential and creating many opportunities especially by reducing overall cost, speed up services and improving both quality and customer satisfaction. It is expected that innovative technologies such as blockchain will have a significant impact on everyday life in the coming decade.

5.1. Implications

From a research point of view, this study helps in identifying the most important characteristics of blockchain and smart government services that can be used to create the highest value for stakeholders. Moreover, it highlights the challenges to blockchain adoption in smart government and the opportunities it brings to this sector. From a practical point of view, this study will aid governments that are seeking to adopt this technology to better understand the requirements for successfully implementing it in the government sector in terms of its characteristics. This will be particularly useful to ensure the compatibility of these smart services with blockchain technology before its adoption.

5.2. Limitations, challenges and recommendations for future research

The main limitation of this study is the very limited literature on the challenges of adopting blockchain technology specifically in government services. Hence, more extensive studies should be made on this topic to facilitate the adoption of blockchain in government services. More robust research should focus on measuring the readiness of governments to adopt blockchain technology and defining the barriers to a successful adoption. Moreover, there should be more intensive research on the implications of blockchain in smart government and smart services. Value co-creation through blockchain is another subject that can be explored, to discover how blockchain creates value for citizens through smart services.

Among the major challenges facing the implementation of blockchain in smart government services are trust, reliability and citizen partnership; therefore, it is recommended not to drive the integration of technologies with the sole purpose of increasing efficiency. Citizens should also by this means be allowed to be part of decision-making in matters related to their data. Therefore, this area can be further explored to find how to improve trust in the services offered by the governments and the impact of governments on these services.

The present research surveyed the research papers published in the English language in the periods 2016-2022 and 2001-2022 specifically on blockchain technology and smart government services respectively; as a result, we may have missed some high-quality publications published in articles in other languages or outside the specified timeframe mentioned above. Additionally, although the selection and reading process of the literature was conducted carefully, it may be subject to some bias in its selection and information extraction process. Moreover, it did not include all the available literature on blockchain and smart government services that have ever been written. Therefore, future research may benefit from the use of such analytic techniques as the “Citation Graph” and the “Density Map” which enable researchers to process and review a great number of articles and studies.

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Biographical notes

Ahmed Alfatih D. Mohamed
Ahmed Alfatih obtained his master's degree in Quality Management from the University of Wollongong (UOW). He worked as a research assistant for many projects related to Blockchain, Digitalization, IoT, Quality Management, and Waste Management. He is also a chemical engineer with more than a decade of experience in the industrial sector. Currently, Ahmed is working as a Head of Quality Control in a UAE-based company where he led many major projects of digital transformation, quality improvements, and sustainability.

Yazan M. Alkhateeb
Yazan M. Alkhateeb currently holds the position of regulatory and compliance officer in a 252 beds general hospital, he has more than 10 years of experience in healthcare. Yazan holds a bachelor’s degree in Nursing and then pursued his master's degree in Quality Management and graduated with distinction from the University of Wollongong (UOW). He is passionate about technology and digital transformation. He explored Blockchain and Natural Language Processing (NLP) in the management of patient complaints in his thesis.

Puneet Agarwal
Puneet Agarwal is an electrical and electronic engineer. He holds a master’s degree in Quality Management from the University of Wollongong (UOW). Puneet is an initiative-driven and experienced young professional with over 6 years of experience in research and analysis, innovation, entrepreneurship, project management, and quality management where he developed various projects such as a smart wheelchair, and drone ambulance. He worked in aerospace, energy, consulting, and the oil and gas industry. He currently works as a Quality Specialist at Emirates Safety Laboratory. His current research interests include the use of technology in public services, lean six sigma in improving services, and business strategy.

Ahmed R. Abdelwahab
Ahmed R. Abdelwahab holds a master’s degree in Quality Management from the University of Wollongong (UOW) and a Bachelor’s degree in pharmaceutical from Beni-Suef University. He is a Certified Trade and Logistics Professional (CTLP), and currently works as Warehouse Operations Specialist in Bayer Middle East FZE. His current research interests include Supply Chain Automation, Digitalization, Artificial Intelligence, and Quality Management.

Osamah Alrababah
Osamah Alrababah is currently working as a senior clinical audiologist at Healthpoint hospital in Abu Dhabi-UAE, with around 13 years of experience in the diagnosis and rehabilitation of hearing and balance problems. Previously, Osamah was the Head of the Audiology Department in Sharjah City for Humanitarian Services in UAE. He holds a master’s degree in Quality Management from the University of Wollongong, Dubai (UOWD). He has vast practical experience in change management, strategy implementation, and quality improvement. His current research interests include technology adoption and implementation, especially in the healthcare sector.

Taghreed Abu Salim
Taghreed Abu Salim obtained her Ph.D. from the United Kingdom's Cranfield University, specializing in Customer Involvement in Service Design. She also holds an MSc from the University of Algiers in Business Management and a BA from the United Arab Emirates University. Dr. Taghreed has worked at managerial levels in business consultancy, training, and higher education sectors. She has extensive international experience, having worked in the UAE, UK, and Algeria. Dr. Taghreed has a long experience in the service design and service delivery process with a strong focus on e- services and now on smart services. During her Ph.D., she was involved in developing a service design process for a new business model (Product service system/PSS) in collaboration with Rolls-Royce and other large companies in the UK and Europe. In the last two years, she successfully managed to raise two grants from the industry to assess the quality-of-service provision and understand more about the impact of UAE culture on service design and delivery. Also, she is working with her student to develop a tool that will assess the quality of social media in the higher education sector.

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A multi-dimensional model to the digital maturity life-cycle for SMEs

Ágnes Sándor
Budapest Business School, Faculty of Finance and Accountancy
Buzogány u. 10-12., Budapest, 1149
Hungary
sandor.agnes@uni-bge.hu

Ákos Gubán
Budapest Business School, Faculty of Finance and Accountancy
Buzogány u. 10-12., Budapest, 1149
Hungary
guban.akos@uni-bge.hu

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Ágnes Sándor
Budapest Business School, Faculty of Finance and Accountancy
Buzogány u. 10-12., Budapest, 1149
Hungary
sandor.agnes@uni-bge.hu

Ákos Gubán
Budapest Business School, Faculty of Finance and Accountancy
Buzogány u. 10-12., Budapest, 1149
Hungary
guban.akos@uni-bge.hu

Abstract:
As companies try to maintain and strengthen their competitive advantage, they should be aware of the level of their digital maturity. The study aims to present a methodology that helps to determine the position of a small and medium-sized enterprise in the digital maturity life-cycle. This is performed on the basis of maturity and digital maturity models, and company growth theories. A number of studies and models have been prepared to determine digital maturity on the basis of various sectoral criteria, but these are all one-dimensional. The study therefore proposes a multi-dimensional model for determining the digital maturity life-cycle of small and medium-sized enterprises that takes into account companies' digital maturity, the IT intensity of various sectors and their organizational characteristics. The model defines five maturity levels together with their relevant characteristics, classified into three levels in terms of data-information. It can help small and medium-sized enterprises adopt more accurate decisions regarding areas in need of development.

Keywords:
digitalization; digital transformation; digital maturity; SME; life-cycle model; life-cycle functions.

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1. Introduction

The global pandemic has accelerated digital transformation, affecting both internal and external corporate processes, potentially reflected in corporate performance. According to the analysis of Dell Technologies [1], companies use several digital technologies in response to the digital emergency. Their digitalization level should be assessed for strengthening their current competitive position and to advance further development [2].

As all changes, digital transformation is not free of problems. Companies face a number of transformation related difficulties, as they need to rethink their day-to-day operations, which requires a shift in attitudes. Additionally, organizational culture and firm management are key to digital transformation [3], [4]. It follows that an all-encompassing corporate attitude is needed for successful transformation. Beyond high costs, one of the biggest difficulties is the extraction of information from data, and its use for decision-making. In this new and rapidly changing environment, intellectual capital is gaining appreciation, companies gain a competitive advantage if they are capable of transforming data-information, and ultimately of making decisions more efficiently and faster.

The Digital Maturity Models (DMMs) help to assess the digitalization of companies by determining their current position on the basis of different factors and identifying areas of development, providing guidance for reaching the target status. They also contribute to the transformation of organizations and the improvement of their competencies by launching process of change. Most digital maturity models, such as those of [5],[6],[7],[8],[9],[10],[11],[12], apply a linear approach and are one-dimensional. In digital transformation, however, the digitalization evolution paths are not linear [13]. Companies, namely, undergo changes at various phases of the life-cycle. Among other things, their competitive strategies, market position and organizational structure change. During their life-cycle, however, they do not necessarily pass each phase – phases may skip in some cases. In relation to digital transformation it is also important to consider the sector in which the company operates, as companies in the financial sector have a greater need for digitalization than those in the construction industry.

Our study therefore aims to define a digital maturity life-cycle model that helps developing companies in determining their current position in digitalization. This is a true-value, multi-dimensional model that takes into account parameters of the corporate growth and maturity models, and the digital intensity of various sectors. This model helps small and medium-sized enterprises (SMEs) to take appropriate decisions for facilitating their development, as a higher digital maturity level increases their competitive advantage. It also contributes to efforts of SMEs to become more conscious and systematic at company level.

The research focuses on SMEs instead of large companies, as the latter tend to have a stronger digital maturity as their organization is better structured and their business processes are accurately described. In contrast, even SMEs' main processes are unclear in many cases, their organizational structure is less modeled and clear, and they do not have control over their digital situation [14], so we want to provide them with a model on which software simulation can be easily built. The model allows the company to monitor its operations with exact calculations and determine where it is in the digital maturity lifecycle, making decision-making faster and more accurate, and it can more effectively identify areas where intervention is needed to operate more efficiently.

The model, therefore, provides a medium-term assessment of SMEs' digital position. This medium-term phase can be a quarter, a half-year, or a year. During this time, the model can be considered static, but the phases change/may change dynamically, and in this regard, the model is indeed dynamic over a longer period.

The study briefly discusses the importance of life-cycle models, the characteristics of maturity models, and then assesses the different digital maturity models in terms of the types of models developed so far, on the one hand, and the number and substance of maturity levels, on the other. We then examine the digital intensity of different sectors, which has an impact on digital maturity. In the part on methodology, we present the developed digital maturity life-cycle model with definition of the five maturity levels with precise metrics. Finally, we present options for the further development of the model.

2. Background

2.1 Life-cycle models

In literature a number of theories explore the life-cycle of companies, which attempt to identify their life-cycles [15], [16] [17].

The corporate life-cycle may be divided into different phases, which are built on each other and characteristics of the individual phases are relatively uniform. The life-cycle is determined by age, sales growth, dividend yield and capital expenditures. Additionally, the characteristics of organizations change in different life-cycle phases. Life-cycle models generally cover the period from the establishment of the business until its termination. In the breakdown of phases, similarly to product life-cycle curves, only in a significantly more complex form, and often the growth of a company is expressed by changes in its size [18].

The growth theory of companies developed by Penrose [15], was used by Greiner [17] to develop one of the most often cited models – the evolution/revolution model of corporate growth [19], [20].

The general growth models include the above mentioned and further developed Greiner [17] model, and the models of Scott [21], and Lippitt and Schmidt [22]. These models can be typically applied irrespective of company size and apply a multifaceted approach, with diverse areas of application [23].

According to Greiner [17], many companies struggle with problems rooted in past strategic management decisions and are not caused by current events or dynamic market trends. The termination of evolutionary problems in different phases of organizational growth provides the theoretical basis for his model (Fig. 1).

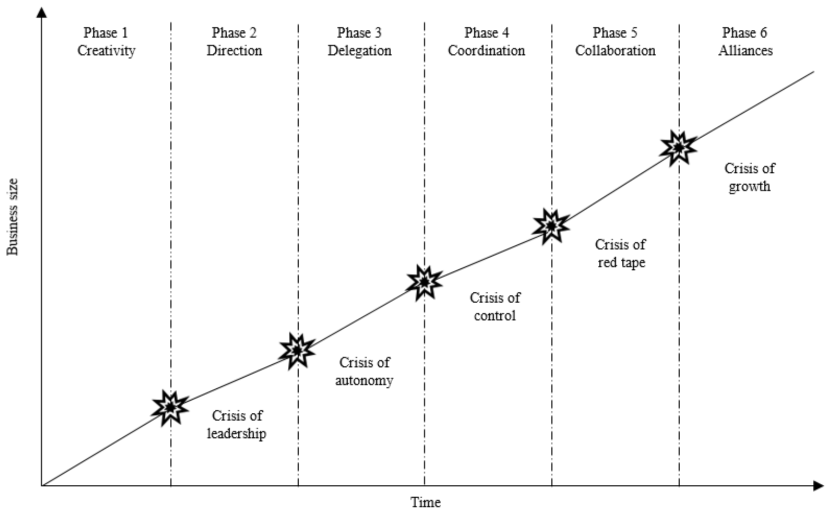

Fig. 1. Greiner model (adapted from Greiner [17])

Each growth phase consists of a relatively stable period of growth (evolutionary phase), which is followed by a “crisis”, when major organizational changes are needed to continue the company’s growth (revolutionary phase). In this phase the company struggles with management and control problems, among other things. It is important to note that each phase is the result of the previous phase and cause of the next phase. Greiner [17] originally proposed this model with the five phases of growth in 1972, and added the sixth phase in the updated version of his original study published in 1998.

Companies in faster growing industries generally experience all five phases at a faster pace, while those in slower growing sectors will experience only two or three phases in the span of many years [17].

His model importantly draws attention to problems arising in the individual phases, yet fails to address the declining path of the company. The model therefore fails to map the entire life-cycle of the company. As noted by Levie and Lichtenstein [24], during their life-cycle, companies do not necessarily pass through each phase – they may skip certain phases.

We will aim at bifurcation in relation to the digital maturity levels, i.e. follow an SME (which is a complex, dynamic system) from a stable condition through an unstable condition (a level up in our case) to another stable condition, where the new stable condition is created by bifurcation with two options available for the system (moving forward or backward) to regain the stable condition. It is never possible to determine in advance the condition the system will actually end up in [25].

2.2 Maturity models

Similarly to the growth models, maturity models help to assess and evaluate the current status of the company, and provide guidance as to the areas in need of development to achieve transformation and a higher level of maturity [10], [26]. They also support companies in monitoring progress and in deciding when and what to do to make progress. These models are based on the general qualitative model (evaluated on the basis of qualitative characteristics) [27].

Literature refers to a number of maturity models developed for different purposes, most of these are based on the five-level model of Capability Maturity Model Integration (CMMI), which classifies development phases into five levels of maturity. In addition to scientific maturity models, there are also many maturity models developed by advisors and associations [12].

2.2.1 Capability Maturity Model Integration

Originally aimed at analyzing the quality of software development processes, the Capability Maturity Model (CMM) developed at Carnegie Mellon University gained popularity in the 1980s in the assessment of organizational capabilities. Process maturity concepts can be generally also applied to non-software processes. During the past decade this measurement methodology was adopted in a number of scientific disciplines [28].

CMMI is the integrated version of CMM, a process development framework allowing application to both software and system development, introduced in the second half of the 20th century. The CMM and CMMI standards now also use maturity models qualifying the given company or organization, and its projects. Since its initial version, a number of its extensions have been used as a general and effective method for understanding and future improvement of general business performance [29].

CMMIs are represented in two different ways: stepped/phased representation and continuous representation (Table 1).

Table 1. Capability and maturity levels of CMMI (adapted from Linstedt and Olschimke [30])

Levels	CMMI staged representation	CMMI continuous representation
0.		Incomplete
1.	Initial	Performed
2.	Managed	Managed
3.	Defined	Defined
4.	Quantitatively Managed	Quantitatively Managed
5.	Optimizing	Optimizing

Stepped representation focuses on the whole of the organization. It defines roadmaps for each phase. These phases are called maturity levels, which also indicate the maturity of the organization in relation to a process area. Once the organization meets all requirements on the maturity level, it can move to the next level to continue the improvement of its processes. The continuous model varies from the phased model, as it provides less guidance on the order of process areas to be implemented and developed. This type of approach defines capability levels for characterizing the status of organization processes. The combined models combine these models [31], [30].

At the present, the maturity models are no longer related to certain areas of application, but rather refer to different dimensions, such as people, processes and organizational capabilities. Greiner's [17] growth model – noted above – is also a good example of this, where certain growth phases lead to "crises", specific management problems, and these must be resolved for achieving further growth.

2.3 Digital maturity models

A holistic approach is necessary for achieving digital maturity, as the company needs to coordinate factors relevant in terms of the company's operation through use of available technologies within and outside of the organization [32]. Digital capabilities are required for continuous adaptation; these help advance the digital maturity of the company. Maturity, as a qualitative parameter, continuously changes over time, where companies learn to appropriately respond to the digital competitive environment [33].

Thordsen et al. [34] argue that the correlation between maturity and organizational performance can be interpreted as being directly proportional, i.e. a higher maturity level is associated with higher performance. There is also a correlation between management style and maturity, where controlled management is associated with lower maturity than is the case with more free management, which potentially allows a higher maturity level [35]. Consequently, digital maturity is interpreted as the joint result of strategy, culture and management.

The level of the application of technology by SMEs significantly depends on the orientation of the owner/manager. Decision-making in their case is predominantly based on intuition; for example, in the course of digital transformation greater emphasis should be placed on the availability of competent specialists. The adaptation of SMEs to a rapidly changing environment tends to be slower and iterative in contrast to a precise series of clear steps and decisions [36], [12].

It is necessary to apply digital maturity models to be able to determine a company's digital maturity, which enable identification of areas with deficiencies, in need of development, on the one hand, and key areas the company needs to focus on, on the other [37]. Thus, the chief purpose of digital maturity models is to assess the current status of the company achieved in digitalization, where different levels are determined in terms of evolutionary phases. Generally speaking, different organizations apply these models to assess their current capabilities and to achieve further development. It is also important to consider that digitalization evolution paths are not linear [13].

In the course of reviewing the relevant literature, we used the following key words and terms applied in the Web of Science, Emerald, ScienceDirect and Google Scholar databases for analyzing the levels of different digital maturity models:

"Digital Maturity", "Digital Maturity Model", "Digital Maturity Levels", "Digital Maturity Framework"

The searches cover the period between 2015 and 2020. In relation to IT, it is important to ignore studies older than 5-10 years due to the rapid development of technology, and owing to the novelty of the topic, searches produced results for a retrospective period of 5-6 years. After analysis of the titles and abstracts of the articles, we found 31 studies focusing on digital maturity models. Most of the articles were related to Industry 4.0. Following the thorough reading of the articles, 18 studies were chosen with relevance for the research (Table 2).

The relevant models found not only include scientific models, but also models developed by consultancy firms, as digitalization is very much practice-oriented. We therefore manage these together.

Table 2. Digital maturity models

Reference	Year	Type of maturity model	Maturity stages
Ganzarain and Errasti [5]	2016	Industry 4.0	(1) initial (2) managed (3) defined (4) transform (5) detailed business model
Gill and VanBoskirk (Forrester 4.0) [6]	2016	General	(1) sceptics (2) adopters (3) collaborators (4) differentiators
Berghaus and Back [39]	2016	General	(1) promote & support (2) create & build (3) commit to transform (4) user-centered & elaborated processes (5) data-driven enterprise
PwC [40]	2016	Industry 4.0	(1) digital novice (2) vertical integrator (3) horizontal collaborator (4) digital champion
Valdez-de-Leon [7]	2016	Telecommunications Service Providers	(0) not started (1) initiating (2) enabling (3) integrating (4) optimizing (5) pioneering
de Carolis et al. [41]	2017	Manufacturing	(1) initial (2) managed (3) defined (4) integrated & interoperable (5) digital-oriented
Kane et al. [33]	2017	General	(1) early (2) developing (3) maturing
Klötzer and Pflaum [8]	2017	Manufacturing Industry's Supply Chain	(1) digitalization awareness (2) smart networked products (3) the service-oriented enterprise (4) thinking in service systems (5) the data-driven enterprise
SAP [42]	2017	General	(1) non-existent (chaotic) (2) ad hoc (isolated) (3) managed (systematic) (4) defined (strategic) (5) optimized (data-driven)
Lloyds Bank [43]	2017	General	(1) passive (2) getting started (3) established (4) high (5) advanced
Colli et al. [9]	2018	Industry 4.0	(1) none (2) basic (3) transparent (4) aware (5) autonomous (6) integrated
Mittal et al. [26]	2018	Smart Manufacturing	(1) novice (2) beginner (3) learner (4) intermediate (5) expert
Issa et al. [44]	2018	Industry 4.0	(1) no Industry 4.0 or only "ad-hoc" (2) departmental level (3) organizational level (4) inter-organizational level
North et al. [10]	2019	General	-
Schumacher et al. [11]	2019	Manufacturing	-
Gurumurthy et al. (Deloitte) [45]	2020	General	(1) lower (2) medium (3) higher
Albukhitan [46]	2020	Manufacturing	(1) unaware (2) conceptual (3) defined (4) integrated (5) transformed
Kuusisto et al. [12]	2020	General	(1) preliminary (2) defined (3) managed (4) excellent

The number of dimensions was a criterion in assessing the different models, as the term "maturity" is in most cases signified as being one-dimensional in literature examining maturity models. In various models the number of dimensions refers to the various factors/capabilities of digital maturity, such as human resources, strategy, culture.

In our case, dimension carries a classic geometric meaning, i.e. the value of a given function produced by three independent parameters. We therefore illustrate the model in an orthogonal system.

Maturity levels represent the maturity level of a given dimension. Each level must have guidance that clearly defines expectations related to the level and a detailed description of its characteristics [38].

Based on Table 2, there is an average of five model levels, irrespective of the industry.

In the case of four models, the number of levels were based on CMMI principles. These were chosen because the CMMI provides a specific structure for maturity levels, defining the capabilities of a company at individual levels [11], [25], [40], [41]. We will also follow this principle in relation to the model we developed.

Data-driven operation, as the highest maturity level, is present in a total of three models [7], [38], [41]. This criterion is important in relation to our model as well, because we believe that the highest maturity level should be data-driven, as acceptance of being data-driven enables greater objectivity and reveals correlations that are not necessarily straightforward. It follows that being data-driven is important by allowing the drawing of conclusions supported with data and the adoption of substantiated decisions instead of the reliance of company managers and experts purely on experience and intuition. The other advantage of being data driven is the capacity to assess, test and optimize processes in advance through simulations before live application. A data-driven enterprise represents in any event a paradigm shift [8],[47].

Five of the models focus on SMEs [4], [9], [11], [25], [42]. Two of these models are based on the CMMI [12], [26].

The multi-dimensional approach is applied only by Mittal et al. [26], where an intelligent manufacturing maturity model is developed for SMEs by assessing three dimensions. The *x* axis represents organizational dimensions, the *y* axis represents the set of tools and the *z* axis represents the five maturity levels. With these the company is capable of assessing its maturity level and identifying steps necessary for reaching the next maturity level within the organizational dimension. We apply this approach as well.

2.4 IT intensity of sectors

Digitalization affects sectors in different degrees. Digital maturity significantly depends on the company's sector, as not all sectors require high levels of digitalization.

Calvino et al. [47] examined the prevalence and development of technology in different sectors in 36 sectors of 12 countries (Australia, Austria, Denmark, Finland, France, Italy, Japan, Netherlands, Norway, Sweden, United Kingdom, USA) based on data related to the 2001-2015 period. This is the only relevant research on this topic that also pointed out that the level of digital transformation in specific sectors mainly depends on investment in "digital" tools, company relations maintained with customers and suppliers, and changes in human capital.

The following factors played a role in determining digital intensity:

- Rate of ICT tools and investment in software;
- Intensity of ICT tool and service purchases relative to output;
- Rate of robots per employee;
- ICT specialist intensity;
- Level of propensity for online sales.

The individual sectors were classified into four categories based on their relative economic ranking, depending on their digital intensity. These are distinguished as "low", "medium-low", "medium-high" and "high" (Table 3). Sectors are classified according to the ISIC Rev.4 (International Standard Industrial Classification of All Economic Activities). The taxonomy has the benefit of its development with use of currently available sectoral aggregates.

Sectors with a high digital intensity include, inter alia, transport vehicles, financial and insurance activities, and telecommunications. Transport vehicles include, for example, rail, waterway vehicles and aircraft, and military vehicles. In their case, up-to-date digitalization and use of state-of-the-art technologies is essential. In contrast, the least intensive category includes, for example, agriculture, forestry and fisheries, accommodation and catering activities, which do not necessarily need higher levels of digitalization for successful operation.

With our model the intensity period may be determined by classification of the IT intensity of difference sectors.

Table 3. Sectoral taxonomy of digital intensity: global indicator (2013-15) (adapted from Calvino et al. [47])

Sector	Quartile of digital intensity 2013-15	Sector	Quartile of digital intensity 2013-15
Administrative and support service	High	Basic metals and fabricated metal products	Medium-low
Advertising and other business services	High	Chemicals and chemical products	Medium-low
Finance and insurance	High	Coke and refined petroleum products	Medium-low
IT and other information services	High	Education	Medium-low
Legal and accounting activities, etc.	High	Human health activities	Medium-low
Other service activities	High	Pharmaceutical products	Medium-low
Scientific research and development	High	Residential care and social work activities	Medium-low
Telecommunications	High	Rubber and plastics products	Medium-low
Transport equipment	High	Textiles, wearing apparel, leather	Medium-low
Arts, entertainment and recreation	Medium-high	Accommodation and food service activities	Low
Computer, electronic, optical products	Medium-high	Agriculture, forestry, fishing	Low
Electrical equipment	Medium-high	Construction	Low
Furniture; other manufacturing; repairs	Medium-high	Electricity, gas, steam and air cond.	Low
Machinery and equipment n.e.c.	Medium-high	Food products, beverages and tobacco	Low
Public administration and defence	Medium-high	Mining and quarrying	Low
Publishing, audiovisual and broadcasting	Medium-high	Real estate	Low
Wholesale and retail trade, repair	Medium-high	Transportation and storage	Low
Wood and paper products, and printing	Medium-high	Water supply; sewerage, waste	Low

3. Digital maturity life-cycle model

In contrast with existing maturity models generally focusing on a single "layer", we concluded that these are insufficient, that is, they do not provide a sufficiently detailed picture of SMEs. Consequently, we aim at developing a three-variable, true-value model that can determine the given company's position within the life-cycle, i.e. the stage of its digitalization, to enable it to take more accurate decisions during digital transformation.

Thus, the model examines SMEs on the basis of three criteria – digital maturity, organizational maturity, IT intensity – and it is possible to determine the maturity level of the given company with the help of an accurate metric. We define five levels for the life-cycle, which are based on the Greiner growth model and CMMI model.

3.1 Methodology

Different components are needed to determine the digital maturity and companies' digital maturity in their lifecycle. To determine the components, we conducted primary research with a pairwise comparison questionnaire necessary for the Guilford method [48], which is not a statistical questionnaire, but a conclusion based on the opinions of a well-selected group of experts. There is no need for stratified sampling and a minimum sample limit; the only major consideration is finding expert knowledge and the experts. Not all factor groups participate with equal weight in the maturity model. There is no uniform selection criteria system for choosing the weighting procedure. From a mathematical point of view, the most well-established procedure is the Guilford procedure. It is based on the pairwise comparison already mentioned, which can be used to weight the evaluation factors on an ordinal scale [48].

It is divided into three main areas:

- Recording expert opinions,
- Processing expert opinions using individual and then group preference matrices,
- Determination of weights.

1. Weighting of evaluation factors

All possible pairs:

$$\binom{n}{2} = \frac{n(n-1)}{2} \tag{1}$$

Systematic error in the arrangement of pairs and any learning distortion resulting from a regular arrangement should be avoided. Therefore, a random arrangement or a Ross [49] arrangement with even less distortion should be used.

2. The decision-maker indicates which evaluation factor they prefer in each pair. Based on theoretical considerations, indifference is not allowed (same preference). The same preference is not allowed because Thurstone [48] has shown that most people can differentiate between two things in terms of preference.

3. Compilation of the preference table. The evaluation factors are listed in both rows and columns in the preference table. The intersection of each row and column indicates the preference relationship of that pair, with the convention that the sign in the field represents the preference of the factor corresponding to that row over the factor corresponding to that column.

For a given assessment factor, the row sum and the column sum must be a numeric value of n-1.

Since the unconditional transitivity of the preference relation is not specified in a normative manner, it can be assumed that there are inconsistent triads among the decision-maker's preferences. The consistency index of decision-makers should be calculated this way.

4. Calculation of the numerical value of the consistency index for an even-number of result set

$$K = 1 - \frac{24d}{n^3 - 4n} \tag{2}$$

where d is the number of inconsistent triads.

This can be calculated using the following formula:

$$d = \frac{n(n-1)(2n-1)}{12} - \frac{\sum a^2}{2} \tag{3}$$

where a is the sum of the rows in the preference table.

5. Determination of preference rates. Each a value is increased by 0.5, and the number is divided by the number of evaluation factors.

6. Preference ratios are transformed to u values of the standardized normal distribution.

7. As this is an interval scale, it is better to convert it to a scale with a starting point of 0 and an endpoint of 100. This is corrected in our solution because an endpoint of 0 would not play a role in digital maturity, so the scale is corrected at the end.

The preference table is obtained in aggregate form by aggregating the individual preference tables. Based on the aggregated preference table, the degree of agreement of decision-makers can also be calculated.

Square deviation:

$$\Delta = \sum_j (R_j - \bar{R}_j)^2, \tag{4}$$

where

Δ is the square deviation,

R_j is the individual sum of the ranks,

$\bar{R}_j = \frac{k(n+1)}{2}$ is the arithmetic mean of the sum of the ranks,

where

k is the number of decision-makers,

n is the number of evaluation factors.

It can be proved mathematically that Δ takes on the maximum value if the decision-makers have a complete agreement.

The value of Δ_m of the total agreement can be calculated directly from the following equation:

$$\Delta_m = \frac{k^2(n^3-n)}{12}, \tag{5}$$

where

k is the number of decision-makers,

n is the number of evaluation factors,

If necessary, the actual Δ value is compared to the Δ_m value of the total agreement. The resulting ratio (w) is *Kendall's* coefficient of concordance; in short, *Kendall W*.

$$w = \frac{\Delta}{\Delta_m} \tag{6}$$

It can be seen that the value of w [0; 1] is within a closed interval on both sides. In case of complete agreement w=1, in case of complete opposition w=0. Of course, there is another calculation method in which we can form the coefficient of concordance using the elements below the diagonal in the aggregate preference matrix [48].

Based on the method detailed above, we determined the weights of the components required for digital maturity in an earlier paper [50] and organizational maturity, which are essential for creating the digital maturity life-cycle model.

That is why this paper will only present the important results of the earlier research of digital maturity. Digital maturity consists of the strategic, technical, technological, and human resource characteristics of a digital organization.

Table 4 shows the sub-components and main components of digital maturity together with identified weighting factors.

Table 4. Weights of digital maturity sub-components (adapted from Sándor and Gubán [50]

No.	**Component**	**Weight**	**No.**	**Component**	**Weight**
1.	Knowledge application	0.10223	15.	Organizational decision making	0.02816
2.	Innovation capability	0.08032	16.	ERP	0.02813
3.	Web page/webshop	0.07223	17.	Chatbot	0.02772
4.	Adaptability	0.06691	18.	Own server usage	0.02611
5.	VPN connection	0.05282	19.	Corporate culture	0.02446
6.	Contact with customers	0.05059	20.	Social media usage	0.02408

No.	Component	Weight	No.	Component	Weight
7.	Search Engine Optimization	0.04564	21.	Mobile phone consumerization	0.02137
8.	Own domain name	0.04366	22.	Contact with suppliers	0.01897
9.	Mobilapp	0.03958	23.	Internal communication	0.01897
10.	Cloud usage	0.03617	24.	Internet usage	0.01862
11.	BI	0.03458	25.	CRM	0.01809
12.	Agility	0.03408	26.	Telephone communication	0.00925
13.	(IT) strategy	0.03407	27.	Isolated machines	0.00870
14.	Unique email address	0.02969	28.	Business phone	0.00480

Based on the opinion of experts, in relation to sub-components, digital maturity is primarily determined by appropriate expertise and the capacity for development.

Table 5. Weights of the main components of digital maturity (adapted from Sándor and Gubán [50])

Component	Weight
Peopleware	0.28354
Online presence	0.18153
Technical solutions	0.17731
Orgware	0.17523
Software	0.11697
Hardware	0.06543

The weighting factors of the main components (Table 5) also support the above, namely, that the human factor prevails over technology.

Digital maturity metric for the analyzed SME:

$$d = \sum_{i=1}^{28} d_i w_i \tag{7}$$

$d_i (\in [0;1])$: is the value for the given component for the analyzed SME:

w_i: is the weighting factor of the *i* component in the above Table 5.

Below we focus on the other two components. The sector (IT intensity) variable is included on account of dependence on the SME's scope of activity. It is very important to note that activities determine digital expectations. Certain activities do not require an IT environment and solutions at a higher level; higher maturity can be achieved faster and easier in relation to these. In relation to activities built on and sensitive to digitalization and IT, expectations are significantly higher and achievement or maintenance of a higher maturity level is more difficult. Thus, dependence on such variable can also be simply defined, qualitative classification can be easily mapped for the [0;1] period on the basis of Table 3, allowing us to work on a quantitative scale. Moreover, the above quartiles can be further fine-tuned (this study does not detail this). In a short (1-2-year) ΔT period, an SME commonly does not aim to change digital intensity (it may be triggered by changes to the scope of activity, or the regulatory environment, such as connection of cash registers to the tax authority), particularly to increase the digital maturity level. By contrast, expectations are higher for higher levels of the life-cycle in relation to activity based on more intense IT activity.

The third variable is the organizational dimension. This variable was included among function variables, because it is significantly affected by the organization's internal structure, operation and management structure, and also limits the digital internal structure's status and options for development. For this reason, an organizational change in the right direction may improve qualitative changes to the digital structure, thereby raising the organization's maturity level and options for maintaining it at a high level. This component is evaluated similarly to the one related to digital maturity.

We applied the pair-wise comparison method [48] for determining the weighting factors of sub-components. The sub-components are as follows:

- Division of labor: number of elements contained by the core activity;
- Number of decision-making levels: types of decision-making levels at the given company (senior, middle, operational levels);
- Level of regulation: extent to which sub-tasks and functions within the organization are regulated in writing;
- Segmentation: extent to which scopes of activity, and their subordination and interdependence are distinct from each other;
- Leadership vision: future status of the company, means and steps, and milestones necessary to achieve it;
- Employee commitment: extent to which the employee is capable of facilitating achievement of the general corporate target with his/her professional skills and commitment;
- Human resources: measures aimed at hiring and retaining appropriate human factors necessary for achieving corporate goals (wage compensation, physical, emotional, intellectual well-being).

We sent the comparative questionnaire mainly to leading SME experts, and also to teachers and researchers with experience in HR theory and management. The experts include university experts, respected teachers and researchers of tertiary education. IT and management professionals working for SMEs and with different qualities. and having IT insight. They were selected on the basis of their professional respect. We applied a transformed Guilford method for evaluating the questionnaires, where responses showing contradictions – i.e. which did not have an acceptable level of consistency – were filtered.

A total of 53 responses were received from experts (at a ratio of 30-23 between the two groups). Most of these included consistent responses. There were 26 and 32 responses at a 95% and 90% consistency level, respectively. There are no major differences in this regard, as we had available acceptable responses at the 95% level as well. We received a rather low 0.17 value for the calculated agreement indicator, nevertheless we accept the received adjusted weighting factors (adjustment factor k =3). We accordingly calculated the following weighting factors for the sub-parameters (Table 6).

Table 6. Weights of organizational dimension

Sub-component	**Weight**
Division of labor (la)	0.148386
Number of decision-making levels (dl)	0.105105
Level of regulation (lr)	0.114767
Segmentation (sg)	0.095097
Leadership vision (lv)	0.181416
Employee commitment (ec)	0.203392
Human resources (hr)	0.151837

$$o = 0.148386la + 0.105105dl + 0.114767lr + 0.095097sg + 0.181416lv + 0.203392ec + 0.151837hr \quad (8)$$

In terms of methodology, we applied heuristic adjustment for determining the life-cycle function. In the present case, by this we mean that we surveyed the characteristics of the function (*M*) and sought a continuous function corresponding to such characteristics. This also means that the function should also allow parameterization to ensure the best adjustment, on the one hand, and during parameterization the produced function may not lose the characteristics. Based on the foregoing, the function to be produced has three independent non-negative true value variables and one true value.

$$M(d; o; a) = M(D(d); O(o); A(a)) \quad (9)$$

i.e. it is produced as a function of the appropriate component functions and analyzed in one ΔT period. In the analysis it does not change in either the o or the a ΔT period (meaning that it is given in terms of the maturity level).

Furthermore, the function values indicating the "status" of the given SME life-cycle (hereinafter "status function") should have a value between 0 and 1 due to normalized input values and for the sake of simpler comparison and uniformity:

$$M(d; o; a) \in [0; 1] \quad (10)$$

where

$d \in [0; 1]$ is the metric of SME digital maturity,

$o \in [0; 1]$ is the metric of organizational maturity,

$a \in [0; 1]$ is the value of digital expectation related to the company's scope of activity.

The function does not necessarily have to reach either the value of 0 or 1, as companies in an "absolutely perfect" and "inappreciably poor digital state" do not exist. During parameterization, however, we need to ensure that it arbitrarily approximate these two extreme values. As an additional expectation related to the function, its behavior based on *d* (digital maturity) – i.e. with fixed *o, a* values – should strictly increase, and in the initial "phase" the start-up should be convex, as changes to lower digital values should be followed by greater changes to the life-cycle, thus the function should be convex in this case, and should have a concave start-up in case of a higher digital value. It is also obvious that similar observations may be made in relation to the organizational maturity variable (*o*), with fixed *d, a* values. Such rules are not applicable to the third variable, as digital expectations for all scopes of activity are specific, depending on the sector, location of the activity, staffing etc. Furthermore, the SME changes only minimally, i.e. to a negligible extent, in terms of organization and scope of activity with an impact on the digital level.

It is obvious that application of a simple product function does not provide a true picture of the situation, i.e.

$$M(d; o; a) = D(d)O(o)A(a) \quad (11)$$

In case of a function of such structure, namely, it is not possible to ensure the above conditions, that is, appropriate monotony and convexity along the function's axial plane sections. So it is not possible to ensure that for all values of *a*, the function *M* take up the maximum value for high *d* and *o* values.

3.2 Digital maturity life-cycle and life-cycle level functions

According to our interpretation, the definition of digital maturity life-cycle is a scale of up to 10 levels of digital development that shows the place of an SME in the examined environment.

For creation of the two functions, we define a possible function based on criteria defined by the methodology:

At analyzed time $t \in \Delta T$

Accordingly, we define how the status function can be created using the component functions of the independent variables. It is obvious that application of a simple product function does not provide a true picture of the situation.

We chose the logistics function, as its structure corresponds to changes in parameters, that is, in the initial phase – it is difficult to advance upward at the start of the life-cycle and the same holds true for the top phase.

$$M(d;o;a) = \frac{1}{1+e^{\left(\beta_1-k_1\beta_1\frac{d}{1-\frac{a}{2}}\right)}}\frac{1}{1+e^{\left(\beta_2-k_2\beta_2\frac{o}{1-\frac{a}{2}}\right)}} \tag{12}$$

With $\beta_1 \in \mathbb{R}^+$ we can regulate the "gradient" of the d variable curve, while $k_1 \in \mathbb{R}^+$ marks the place of the inflection point; if this value is 2, then the value is *d* = 0.5. The same applies to the $\beta_2 \in \mathbb{R}^+$ and $k_2 \in \mathbb{R}^+$ parameters, except on the basis of the *o* variable.

The defined life cycle function is the result of a multi-step selection process. We did not find any recommendations or solutions for the function in the literature, so we relied on our analyses. Considering its nature, the function gives a characteristic diagram not necessarily symmetric to the center in a strictly monotonic convex to the concave manner with an inflection point for *d* and *o*, i.e., digital maturity and organizational dimension. Furthermore, there are neither perfectly bad nor perfectly good (0 and 1, respectively) values in practice, so the sigmoidal function results in a very good solution for these two dimensions. Experience has shown, but we have also indicated earlier, that two dimensions can be created to be independent of each other, so they are listed as a sequence function in the solution function. In contrast, IT intensity (a) already affects both dimensions. If we examine only this dimension, it is no longer described by a sigmoid function. With a constant value of $d_0; o_0$ our function takes the following form:

$$M(d_0;o_0;a) = \frac{1}{1+e^{\left(\beta_1-k_1\beta_1\frac{d_0}{1-\frac{a}{2}}\right)}}\frac{1}{1+e^{\left(\beta_2-k_2\beta_2\frac{o_0}{1-\frac{a}{2}}\right)}} = \frac{1}{\left(1+e^{\left(\beta_1-\frac{c_1}{2-a}\right)}\right)\left(1+e^{\left(\beta_2-\frac{c_2}{2-a}\right)}\right)} = \frac{1}{\left(1+c_3e^{\frac{2-a}{c_1}}\right)\left(1+c_4e^{\frac{2-a}{c_2}}\right)} =$$
$$\frac{1}{(1+c_3e^{c_5-c_7a})(1+c_4e^{c_6-c_8a})} = \frac{1}{(1+c_3e^{c_5-c_7a})(1+c_4e^{c_6-c_8a})} = \frac{1}{\left(1+\frac{c_9}{\alpha^a}\right)\left(1+\frac{c_{10}}{\gamma^a}\right)} \tag{13}$$

where $\alpha, \gamma > 1$

and: $c_1 = 2k_1\beta_1 d_0;\ c_2 = 2k_2\beta_2 o_0;\ c_3 = e^{\beta_1};\ c_4 = e^{\beta_2};\ c_5 = \frac{2}{c_1};\ c_6 = \frac{2}{c_2};$

$$c_7 = \frac{1}{c_1};\ c_8 = \frac{1}{c_2};\ c_9 = c_3e^{c_5};\ c_{10} = c_4e^{c_6};\ \alpha = e^{c_7};\ \gamma = e^{c_8}.$$

The robustness test can also be performed, first as a function of the changes in the parameters. According to the β parameters:

$$M(d;o;a) = \frac{1}{1+e^{\beta_1\left(1-k_1\frac{d}{1-\frac{a}{2}}\right)}}\frac{1}{1+e^{\beta_2\left(1-k_2\frac{o}{1-\frac{a}{2}}\right)}} = \frac{1}{1+e^{\beta_1}{}^{\left(1-k_1\frac{d}{1-\frac{a}{2}}\right)}}\frac{1}{1+e^{\beta_2}{}^{\left(1-k_2\frac{o}{1-\frac{a}{2}}\right)}} \tag{14}$$

$$M(\beta_1) = \frac{1}{1+\beta_1^{\left(1-k_1\frac{d}{1-\frac{a}{2}}\right)}}c \tag{15}$$

where $0 < c < 1$

Therefore, the β parameters in the sigmoid function change the base of the exponential function.

$$|M(\beta_1+\Delta\beta_1) - M(\beta_1)| = \left|\frac{1}{1+e^{\beta_1+\Delta\beta_1}{}^{\left(1-k_1\frac{d}{1-\frac{a}{2}}\right)}} - \frac{1}{1+e^{\beta_1}{}^{\left(1-k_1\frac{d}{1-\frac{a}{2}}\right)}}\right| c = \left|\frac{1}{1+e^{\mu(\beta_1+\Delta\beta_1)}} - \frac{1}{1+e^{\mu\beta_1}}\right| c =$$
$$\left|\frac{1}{1+\alpha^{(\beta_1+\Delta\beta_1)}} - \frac{1}{1+\alpha^{\beta_1}}\right| c < \left|\frac{1}{1+\alpha^{\beta_1}\alpha^{\Delta\beta_1}} - \frac{1}{1+\alpha^{\beta_1}}\right| \tag{16}$$

where $0 < \beta_1 + \Delta\beta_1$ since $\alpha > 1$ and $\beta_1 > 0$

$$|M(\beta_1+\Delta\beta_1) - M(\beta_1)| < \frac{\alpha^{\beta_1}\left|1-\alpha^{\Delta\beta_1}\right|}{1+\alpha^{\beta_1+\Delta\beta_1}\alpha^{\beta_1}+\alpha^{\beta_1}\alpha^{\Delta\beta_1}+\alpha^{\beta_1}} < \frac{\left|1-\alpha^{\Delta\beta_1}\right|}{\alpha^{\beta_1}\alpha^{\Delta\beta_1}+\alpha^{\Delta\beta_1}+1} < \frac{\left|1-\alpha^{\Delta\beta_1}\right|}{\alpha^{\Delta\beta_1}(\alpha^{\beta_1}+1)}$$
$$< \frac{\alpha^{\beta_1}\left|\alpha^{\Delta\beta_1}-1\right|}{\alpha^{\beta_1}+1}$$

So, the change as a function of β is exponential.

The examination of the parameter k is much more complicated, as it depends very much on the relation of the variables $d; o; a$ to each other; for this reason, we do not examine it in the study.

In the second step by dimensions, that is:

$$\Delta_d M = M(d;o;a) - M(d+\Delta d;o;a)$$
$$\Delta_o M = M(d;o;a) - M(d;o+\Delta o;a)$$
$$\Delta_a M = M(d;o;a) - M(d;o;a+\Delta a)$$

The details of this are not the subject of our study; in any case, it can be stated that for more advanced dimension values for $d > k_1$, $\Delta_d M < \Delta d$, and for $o > k_2$, $\Delta_o M < \Delta o$. In the case of real enterprises, $\Delta_a M \approx \Delta a$ can also be stated.

So it fulfills the expectation of monotony and exponentiality, which can be expected to provide a higher maturity for a higher level of value in a sector with a higher IT demand (of course, the model also allows the function to be linear with proper parameterization).

Based on these, the given M function behaves as expected with the other constant values and takes its values within the desired interval for all three dimensions. Verification of absolute correctness can only be done with empiricism. In contrast, creating empirics required a theoretical model that could be accepted as a starting function (later, this will be replaced by a neural network built based on the collected samples, but this will require a basic model).

Fig. 2. shows the M function with a fixed value for a; $a = 1$ in the first case, $a = 0.1$ in the second case.

Fig. 3. shows the M function with a fixed value for $o = 1$ in the first case, $o = 0.3$ in the second case and , $o = 0.1$ in the third case.

Since we already took into account the limits of the final maturity levels in dependence on the variables of the function M, it will be sufficient to apply a linear scale for their determination. As a result of the above analysis, we define five levels for the life-cycle, which are based on the Greiner growth model and CMMI model. The five levels are easy to use and well categorized. It can be further increased or decreased and changed dynamically.

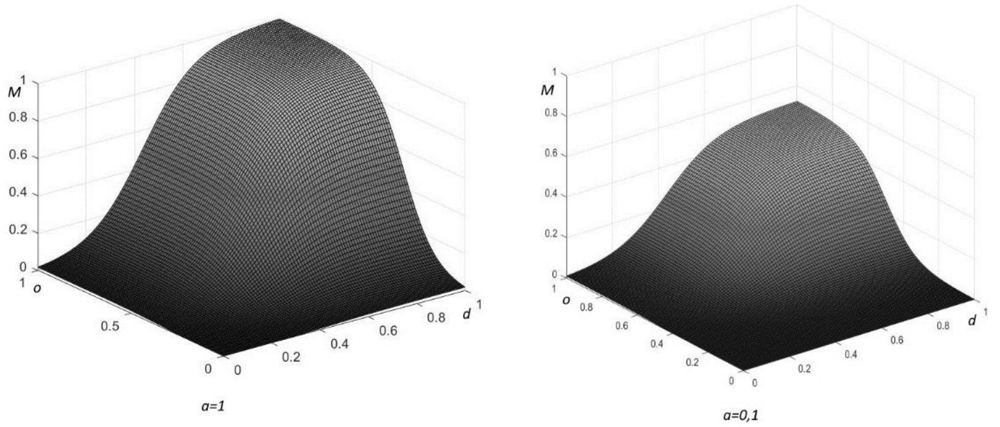

Fig. 2. Function sections with fixed IT intensity values (in sequence: a=1; a=0.1)

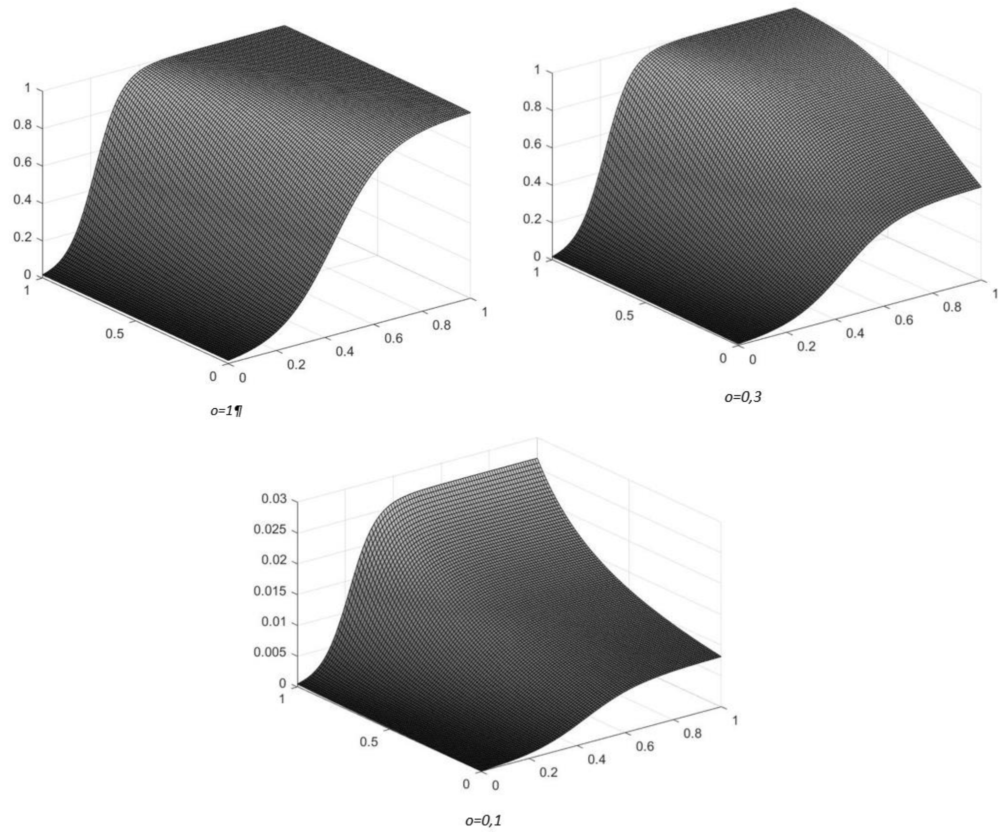

Fig. 3. Function sections with fixed organization values (in sequence: o=1; o=0.3; o=0.1)

In terms of the number of levels, it is important to note that the few levels do not show a sufficiently subtle picture, and the “jumps” are based on big changes that do not inspire SME leaders to make smaller changes. On the other hand, too many levels make the situation unclear, and even a very small change can be seen as a significant achievement by managers. In the case of the model, the number of levels can be changed at any time, ensuring the flexibility of the model.

1. initial: An SME is at this level if it is a start-up or has changed its activity, where the new activity is at a higher level in terms of digitalization, or the business has not yet focused sufficient attention on digital development. In this phase, the primary task is the setting of goals.

2. pathfinder: At the pathfinder maturity level the business is already showing a need for digital development/growth, and the first steps have been taken, but it lacks a developed concept as to the method of change, steps to be taken and the resources to be invested in. Therefore, at this level it is necessary to define detailed implementation solutions and plans for the goals, and to review these to determine whether they correspond to market levels, solutions on the market and of competitors.

3. advanced: A business at an acceptable level of digital maturity and development, but with several variations from the market environment and well-performing competitors. At this level it is necessary to define tasks for criteria, that is, to adapt to the analyzed environment and competitors, enabling achievement of a higher maturity level relative to them.

4. managed: The digital maturity level of the SME is of good quality; it is ahead of some competitors, and the system now internally detects deficiencies and attempts to correct these in the right direction.

5. optimized and providing feedback: At the highest level it is now very important to monitor and analyze changes in the environment, and to develop it through feedback, so as to avoid falling back to a lower maturity level. This not only involves maintaining the level, as development of the environment entails further development. These must be detected and responded to as soon as possible.

The five maturity phases may be classified into three levels in terms of data-information (Fig. 4):

1. Data searches, interpretation of information, queries;
2. Data analysis with statistical methods, statistical prospective analysis;
3. Data-driven BigData technologies, use of business intelligence.

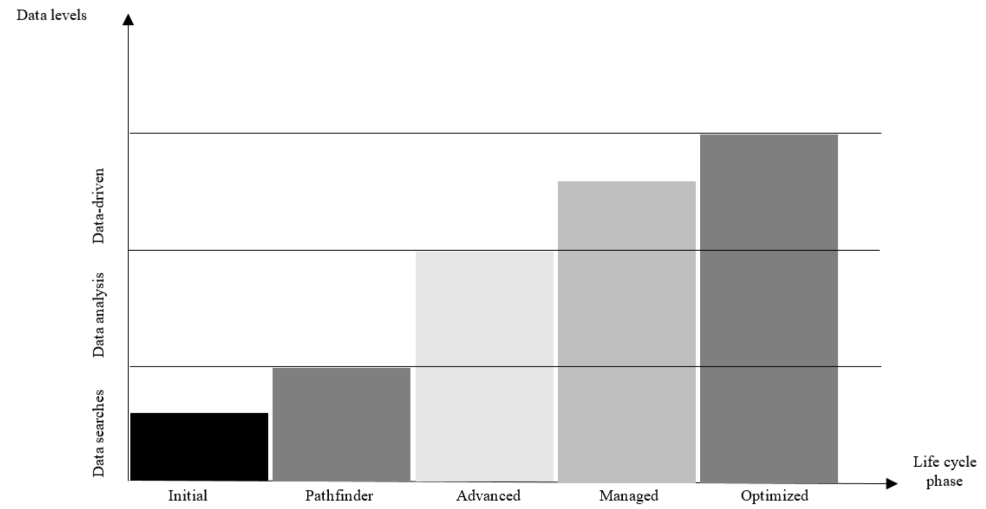

Fig. 4. Classification of maturity levels

We then perform the mapping:

$$L = \begin{cases} initial & if \quad 0 < M \leq 0{,}2 \\ \text{pathfinder} & if \quad 0{,}2 < M \leq 0{,}4 \\ advanced & if \quad 0{,}4 < M \leq 0{,}6 \\ managed & if \quad 0{,}6 < M \leq 0{,}8 \\ optimized & if \quad 0{,}8 < M \leq 1 \end{cases} \tag{17}$$

Accordingly, the sectional layer functions will be as follows in relation to some parameters. In the first case $a = 1$, in the second case $a = 0.5$, in the third case $a = 0.1$. (Fig. 5.)

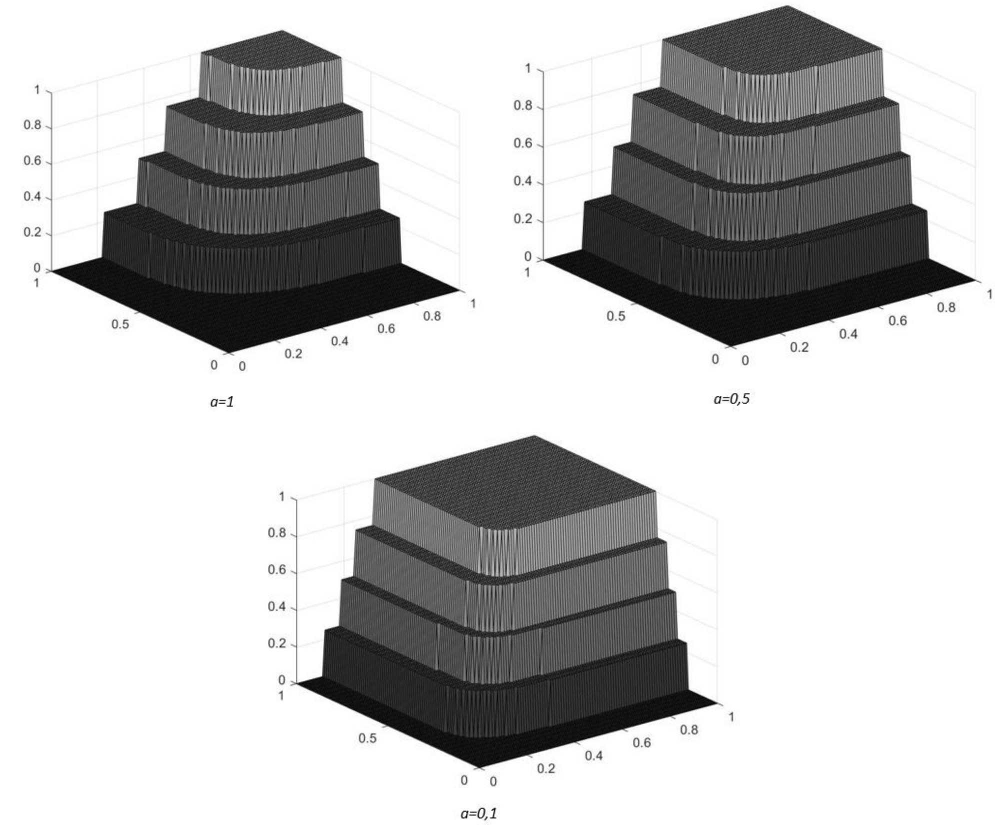

Fig. 5. Maturity levels with fixed IT intensity values (in sequence: a=1; a=0.5; a=0.1)

Or in the first case $o = 0.3$, in the second case $o = 0.7$ (Fig.6.)

The life-cycle levels are fully interoperable with each other. In other words, theoretically any level may be reached from any level. Obviously chances are much higher that the change will result in movement to a neighboring level. If the change is significant, a larger jump cannot be ruled out, either.

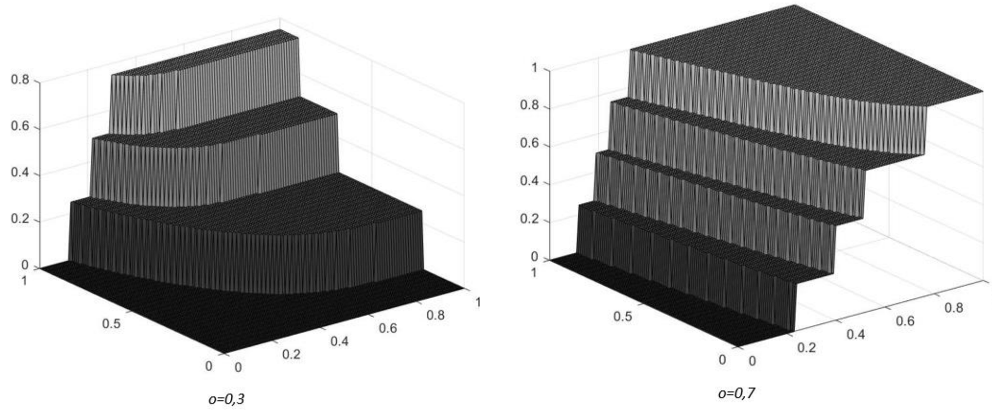

Fig. 6. Maturity levels with fixed organization values (in sequence: o=0.3; o=0.7)

Let’s take intensive smart farming as an example, specifically an investment in livestock farming (such types of development are possible for SMEs and family business as well). In this case, the transition is from livestock farming performed with traditional, manual activities and human-controlled machinery to smart farm solutions based on Industry 4.0 and IoT, which are two extremes of the maturity level. Traditional solutions do not require major digitalized solutions, and are even possible without these. It follows that the (d) value of digital maturity may be close to zero, or is very low. Organizational maturity is not expected to be at a high level, either; available human resources perform many tasks and tasks are coordinated on the basis of own experience and circumstances. IT intensity is very low.

As a result of a major smart farming project, the digitalized IT-driven solution significantly relies on IoT, network communication, consumerization of tools, and utilization of services (GPS, internet, cloud services, BI solutions, AI forecasts and controls). This entails large-scale IT (hardware, software, orgware, peopleware) development, potentially resulting in a very high digital maturity level. These solutions require the structuring of the organization and the designation of management levels, i.e. organizational maturity (a) will also have a high value.

Despite IT intensity changing only to a moderate extent, in the life-cycle model the SME may reach the highest level if it also reaches the upper level of the market and competitors. Obviously, during the project the organization will progress through the entire life-cycle, but will remain at the levels only for a short time, and possibly go back and forth between levels on a cyclical basis. Secondly, another misconception is clearly debunked, that a very significant technical development (hardware and/or software) will not automatically raise the digital maturity life-cycle level. As shown in Table 5, the weighting factor of these two components is 0.1824, which does not represent a major level in the d value, either.

3.3 Further development of the model

The model may be applied in practice, if we can determine how it is possible to move upward from a given life-cycle level or to stay on level, and how a decline can be avoided. We can provide a solution only if a sufficiently large sample of SMEs is collected, that is, we know their digital maturity, organizational maturity levels, and can also determine their position within the digital maturity life-cycle, together with its value. In this case we receive appropriate values $(\beta_1, \beta_2, k_1, k_2)$ for parameters of the M function, on the one hand, and can clarify the function itself, on the other. In knowledge of the known input-output data pairs, the arbitrary M function applied so far can be substituted. With the above we can acquire experience on how we can more successfully step up a level by changing the given input parameter (or by joint fine-tuning of parameters).

4. Conclusion

In the course of digitalization, it is essential for companies to attempt to respond to external environmental factors as soon as possible. Digitalization offers a major opportunity for SMEs as well, enabling, among other things, easier outreach to customers. One of the most frequent problems occurring during digital transformation is companies not knowing how to begin with development. The various digital maturity models support this process.

A number of such models – based on maturity models – have been developed over the years. These models, however, are one-dimensional; they do not assess in due detail the relevant processes of companies, especially in relation to SMEs.

The developed digital maturity life-cycle model examines companies' digital maturity, organizational characteristics and the IT intensity of scopes of activity based on three dimensions. Companies do not necessarily progress linearly between levels; they may skip certain levels to reach the level of highest digital maturity, or the reaching of a given level does not guarantee that they will not fall back to a lower level at a later time. There are five maturity levels distinguished on the basis of the model: initial, repeatable, defined, managed and optimizing. We then classified these levels into three groups based on data-information (data-seeking, data-analytical, data-driven). The data-driven company is at the highest level, which is capable of fully analyzing available data and taking decisions even by means of simulation.

The life-cycle levels are fully interoperable with each other. At the various levels the approach and vision of the owner/manager related to digitalization plays a key role. Obviously the extent to which necessary technical developments are implemented by a company to at least maintain its current position over competitors also depends on the given sector. The model may help company executives to better understand factors requiring conscious management for improving digital maturity.

This model provides a theoretical description for a preprocessing tool, based on which the preparation of a system design no longer takes a long time, and the resulting IT application can also be easily implemented as a tool. Consequently, the application that can be made and is not part of the paper helps easily and quickly determine SMEs' digital maturity and lifecycle position for later use. The model helps start the digital transformation because the model indicates which areas a given company needs to develop for a successful transformation.

As a further aspect of the model's potential development, the position of the company within the digital maturity life-cycle could be determined on the basis of an adequately large sample and we could gain a picture of the digital maturity of SMEs.

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Biographical notes

Ágnes Sándor
Ágnes Sándor is an assistant lecturer at Budapest Business School Department of Business Information Technology. She is currently a PhD student at the Doctoral School of Entrepreneurship and Business of the Budapest Business School. Her research interests focus on digitalization, digital maturity.

Ákos Gubán
Ákos Gubán was born in 1956. He got his master degree in mathematics at Science University of Szeged, Hungary in 1981. He got his PhD in 2004 in information science at the University of Miskolc, Hungary. His major field of research is AI, logistics and sustainability, information systems and sustainability and heuristic modelling. The State Insurance Company between 1989-90 employed him in the private between 1974 and 1990. Since 1990 he is employed by Budapest Business School, Collage of Finance and Accountancy, Department of Business Informatics as a full professor. He was also the head of department. Dr. Ákos Gubán is a member of Hungarian Association of Logistics, Purchasing and Inventory Management. Currently he is a Professor Emeritus.

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Executives' role in digital transformation

José Fernando López-Muñoz
ESIC Business & Marketing School
Avda. Blasco Ibáñez 55, Valencia 46021
Spain
jfernando.lopez@esic.edu

Alejandro Escribá-Esteve
University of Valencia & Ivie
Avda. Tarongers, s/n., Valencia 46022
Spain
alejandro.escriba@uv.es

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José Fernando López-Muñoz
ESIC Business & Marketing School
Avda. Blasco Ibáñez 55, Valencia 46021
Spain
jfernando.lopez@esic.edu

Alejandro Escribá-Esteve
University of Valencia & Ivie
Avda. Tarongers, s/n., Valencia 46022
Spain
alejandro.escriba@uv.es

Abstract:
This conceptual paper revisits and updates the concept of top management support (TMS), which has been the long-established rationale for explaining the role of top managers in digitalization activities. In our view, the concept of TMS is grounded in technological determinism, accounts for attitudinal and behavioral aspects that appear to be little more than exhortation and accepts the occasional responsibility of top managers in technology management. We consider both the crucial role that top managers may play in the digitalization process and the fact that digital technologies have become pervasive in today's organizations. Then, we develop a model by which top managers and digital technologies are cooperatively involved for digitalization. For that, we have looked through the theoretical lens of imbrication and attention perspectives to reconstruct the role of top managers in the digital transformation process. In our view, each imbrication layer can be viewed as a process where top managers form beliefs to act on digital opportunities for strategic action. Specifically, our model provides insights into how executives' characteristics and social processes impact the likelihood of forming either beliefs about radical or incremental opportunities requiring strategic action. Additionally, we offer several hypotheses that enrich our knowledge of the relationship between top managers and the digitalization process.

Keywords:
top management support; digitalization; imbrication; affordances; attention; digital transformation.

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1. Introduction

For contemporary organizations, undergoing a "digital transformation" process becomes mandatory to pursue innovation and remain competitive [1, 2]. This process entails both digitization and digitalization. While digitization refers to the encoding of actions or representations of actions into a digital format (zeros and ones) suitable for computational technologies, digitalization refers to the ways in which organizational life is organized through and around digital technologies. Nowadays, digital technologies directly affect the mechanisms through which businesses create and capture value [3, 4], and these technologies are inextricably intertwined with social relations to weave the fabric of organizations [5]. In this context, researchers emphasized that top management support (TMS) is the most important organizational factor for fully taking advantage of digital technologies [6-8]. In fact, the concept of TMS currently embodies the main basis for analyzing the role of top managers in digitalization activities. Despite this valuable work, research on TMS considers digital transformations as special-case activities in organizations, mainly examined from a project management perspective [e.g., 7, 9, 10, 11]. TMS research findings have been mixed, confusing, and lack cumulative insights. Prescriptions for TMS are vague [11], embodying good practices far removed from the root cause of top managers' influence on project performance [12]. Moreover, the underlying psychological and social processes, by which executives' participation in digitalization activities are converted into strategic choices remain unknown [12]. Scholars suggested opening such black box of TMS [13, 14].

The relationship between participation and digitalization success was traditionally assumed to be necessary and sufficient though moderated by such contingencies as task interdependence or system complexity [see e.g., 15, 16, 17]. By contrast, Markus and Mao [18] argued that such a relationship is neither necessary nor sufficient but merely influential and that the nature of this participation process is emergent. With this view, we reconstruct the role of top managers in the digitalization process by adopting an emergent perspective. We then conceive top managers' participation as a dynamic process, in which any outcome emerges unpredictably from complex and reciprocal interactions between the top management team (TMT) and digital technologies within an organizational setting. We undertake such a reconstruction by drawing on the imbrication perspective [19] and then considering each imbrication layer as a process, in which top managers form beliefs to act on digital opportunities for strategic action [20].

The term "imbrication" literally refers to overlapping but mutually enabling layers to describe the way social and digital practices can become interconnected [21]. Specifically, the imbrication of executives and digital technologies means that they function interdependently and acknowledges that both are necessary for digital transformation to occur. As we will explain, opportunity belief arises from a two-stage process [20]. First, the identification stage elucidates how executives identify digital novelties or changes as potential opportunities. Second, the evaluation stage explains how executives form the belief that these identified technological changes represent an opportunity worthy of exploitation. Furthermore, we hypothesize that TMT characteristics and social processes influence potential opportunities' recognition. Opportunities are classified in terms of being incremental and radical. While incremental opportunities often arise from small changes, radical or discontinuous opportunities often do from big changes in the technological trajectory. Specifically, we suggest that TMT's demographic heterogeneity, behavioral integration, and attentional bottom-up processing are positively related to the likelihood of noticing discontinuous opportunities, although TMT tenure can hold back that possibility. On the other hand, we propose that a low level of social conflict along with a high degree of cognitive conflict within the TMT can facilitate consensus reaching for radical opportunity beliefs. Moreover, we suggest that TMT shared leadership can improve the likelihood of positive evaluation of radical opportunities' implementation.

Next, we provide an in-depth account of previous research in TMS. Subsequently, we suggest adopting an emergent perspective on top managers' participation in digitalization activities. Afterwards, we argue that the imbrication perspective perfectly captures the notion that the TMT and digital technologies are widely viewed as cooperatively involved, thus illuminating an emergent participation view. Finally, we propose that each imbrication layer provides insights into how the TMT attention is allocated to identify potential opportunities and intervening processes which might impact the likelihood of forming beliefs about radical and incremental opportunities requiring strategic action.

2. Top management support: making the case for new theory

Of the many definitions of TMS [see 7], the following two may be representative. First, TMS to digital transformations consist of understanding the importance of digital technologies, sponsoring initiatives of technology personnel, and participating in digital transformation project activities [22]. Second, TMS includes shaping the organizational context to make it more adaptive or facilitating the adapting of the digital technology to organizational characteristics [15]. Past research has shown that TMS is a critical organizational factor for successful information systems (IS) planning [23, 24], successful IS implementation [25, 26], and generally to take full advantage of digital technologies [6, 7, 27, 28]. In particular, with respect to project success, TMS was shown to be the most critical success factor [10, 11]. Although lack of TMS may not necessarily doom a project to failure [29] or may not even be favorable [30].

TMS has been largely decomposed using two constructs: involvement [or beliefs; 13] and participation [31]. Executive participation refers to the top manager's activities or personal interventions in technology-related matters: digital transformation planning, development, and implementation. Executive involvement is concerned with the psychological state of the top manager, reflecting the top manager's perceptions and attitudes concerning digital technologies—that is, the degree to which a top manager views digital technologies as critical to an organization's success [31]. As noted by Dong et al. [7], the attitudinal interpretation of TMS promotes a back-seat driver view in which top managers are seen to take a hands-off approach, just focusing on creating a generally supportive climate. On the other hand, the behavioral interpretation advocates an active participant view [18, 31] in which top managers are encouraged to directly influence the mutual adaptation between the technology and the organization, assuming responsibility for both technical and organizational changes [32]. Dong et al. [7] by looking at TMS through the theoretical lens of metastructuration [33], offer a behavior-based definition of TMS, which includes three types of actions: first, resource provision, e.g., providing funds, technologies, staff, and user training programs; second, change management, e.g., promoting organizational receptivity of the new technology; and third, vision sharing, e.g., communication, actions related to ensuring that lower-level managers develop a mutual understanding of the core objectives and ideals for the new technology.

Recent lines of inquiry on TMS have gone further. For example, the content of top management's supportive behavior has been broken down in a multidimensional construct consisting of a set of inter-related behavioral categories such as resource provision, structural arrangements, communication, expertise, and power, exhibited during a project [7, 9]. Other scholars have proposed a dynamic and situated view, i.e., top managers must be flexible, adjusting their supportive behaviors and intensity to the specific context and particular technologies at different times. TMS fluctuates during the project course ranging from moments of direct involvement to periods of low attention and enthusiasm. TMS is not always passively readily available but could be gained and regained through a project's active mobilization and constant alignment efforts [9, 12, 34]. Moreover, the need for social alignment is argued, i.e., the shared understanding between the chief information officer (CIO) and the TMT about the role of digital technologies in the organization, driven by a broad variety of technology governance mechanisms [35-37]. Furthermore, a shared agreement on the actual value of digital technologies among executives may be decisive for clarifying future goals for these technologies. Consensus is harder to reach when TMT members are heterogeneous. The absence of consensus – discord – suggests technology disengagement [38, 39].

Although this large body of research has yielded some recurrent patterns, findings have been mixed and confusing, and for the most part it has not provided cumulative insights. For example, although TMS represents the context for project success [40] related to single projects or in multiple-project environments [34], prescriptions for TMS have not clearly been developed [11], and particularly, prescriptions for involvement and participation appear to be little more than exhortation, i.e., good practices far removed from the root cause of top managers' influence on project performance [12]. Top managers generally consider projects to be an operational issue, and rarely of their direct interest [41]. Moreover, the psychological and social processes, by which executive participation in digitalization activities are converted into strategic choices, remain largely a mystery. Empirical investigations have so far failed to open the black box of TMS [12, 42]. Calls made in the literature suggest opening such black box of TMS [13, 14]. There is only limited reliable knowledge about the types of behavior that underlie TMS, and little insight has been gained into the reasons why executives' support is sometimes low [9]. Thus, how, and why TMS contributes right across the digitalization process are not well understood [9, 22].

Although TMS has long been theorized to play a critical role in the implementation of digital transformations, empirical studies have not always supported this hypothesis [43]. Prior studies found that TMS is necessary and sometimes a sufficient condition to ensure project performance [10, 11], although not necessarily doom a project to failure [29]. Therefore, the absolute criticality of TMS has been questioned [34]. It seems successful outcomes cannot be achieved without high levels of TMS, whereas weak or poor TMS can be mitigated, for example, in the presence of high level planning and user involvement [11]. Studies found TMS not critical and showed contradictory results while the empirical evidence is either weak or inconclusive –i.e., positive, negative, inverted u-shaped– [7, 11, 17, 29, 34, 43-45]. Therefore, a clear and compelling understanding of the behavioral spectrum that makes up TMS is not yet fully understood. Furthermore, differing perspectives have resulted in inconsistent measures [7, 9, 11, 15, 31, 46, 47]. Then, further research is required to explore how TMS contributes to success.

Such observations and doubts invite a fresh examination of TMS for the digitalization process.

3. Adopting an emergent perspective on executives' participation in digital transformation

As noted by Markus and Mao [18], the nature of the participation process itself is emergent because it can be characterized in terms of actors' attempts at communication, influence, negotiation, creativity, and conflict resolution, all of which have highly uncertain outcomes. In this view, the relationships between participation activities and outcomes are neither necessary nor sufficient, but merely influential [18]. This conceptual paper then adopts an emergent perspective to conceptualize executives' participation as a dynamic process, in which any outcome emerges unpredictably from complex and reciprocal interactions between the TMT and digital technologies within an organizational context [48]. How people design, interpret, and use technology is a function of the material components comprising the artefact, the institutional context in which a technology is developed and used, and the power, knowledge, and interests of human actors [49]. Making reliable predictions in the emergent perspective requires detailed understanding of dynamic organizational processes in addition to knowledge about the intentions of actors and the features of digital technology [50]. Consequently, our theoretical posture represents a departure from both, variance, and process approaches. Instead, we believe that our assumption of neither necessary nor sufficient relationships is best captured by the imbrication perspective, where the TMT and digital technologies can be widely viewed as cooperatively involved.

3.1 Further elaboration of TMS with the imbrication perspective

The term "imbrication" specifically refers to overlapping but mutually enabling layers, as used in tiling [51]. The notion of imbrication was proposed to describe how social and digital practices can become interconnected [21, 52]. The term 'affordance' refers to the potential for action that new technologies provide to users, and is useful in explaining why human and material agencies become imbricated, or function interdependently [19]. Through the notion of imbrication we suggest that it might be possible that top managers and digital technologies can become interconnected in such a way that they become interdependent [53]. For example, when new digital technologies emerge with the promise of novel affordances, there might be a corresponding shift in the characteristics of the TMT. Deliberate efforts to realign managerial profiles with the new digital technologies' requirements might result in recruiting executives whose expertise and skills fill the existing gaps among the incumbent executives. Therefore, by adopting the metaphor of imbrication [19] we recognize that: first, the TMT and digital technologies are distinct but fundamentally interdependent; second, past imbrications accumulate to help explain, although certainly not predict future imbrications; and third, top managers must proceed within the framework established by previous imbrications to reconcile their goals with the things that a technology can or cannot do. Thus, in the presence of flexible routines and flexible technologies, when top managers are unable to achieve their goals in that setting, they should either change the pattern of their routines or the technologies they use. Perceptions of constraint lead top managers to change their technologies while perceptions of affordance lead them to modify their routines. We suggest that digital affordances and constraints, the catalysts for imbrication, are perceived by top managers in developing their executive functions. In doing so, top managers consider the potential benefits of digital technologies and how to obtain them. For example, the deputy CEO of a manufacturing company adopting the SAP/R3 enterprise system saw an opportunity for improving the account managers' planning and reporting activity. In response, changes in the customer relationships management module of the enterprise system were introduced and mobile functionality for their users was developed. Now, account managers can request a full report to set up a meeting with customers and then provide immediate feedback. Therefore, the deputy CEO paid close attention to the possibilities for action due to the new SAP/R3 functionality. As a result, SAP/R3 was adjusted to fit the top manager's goals and intentions [48]. These successive changes create the technological infrastructure that people use to get their jobs done.

The imbrication metaphor suggests how a human agency approach to technology can usefully incorporate notions of material agency into its explanations of organizational change [19]. This perspective allows a return to a middle ground between the poles of voluntarism and technological determinism, by recognizing that technologies have certain material and institutional orders that transcend the particularities of the contexts in which they are used [54]. Accordingly, materiality has been defined as the arrangement of an artifact's physical and/or digital materials into particular forms that endure across differences in place and time and are important to users [55]. Hence, technology has a materiality that makes some actions possible and others difficult or impossible [56]. Human agency is usually defined as the ability to form and realize one's goals [57], and this perspective suggests that people's work is not determined by the technologies they employ. Even using the most seemingly constraining technologies, human agents can exercise a great deal of discretion in shaping the effect of technology on their work [58]. Otherwise, material agency is defined as the capacity for nonhuman entities to act without human intervention. Digital artifacts exercise agency through their performativity, i.e., through the things they do that users cannot completely or directly control [59]. Coordinated human (social) and material agencies both represent capacities for action, but they differ with respect to intentionality. As noted by Leonardi [55], people often enact their human agency in response to technology's material agency. Given this important difference with respect to intentionality, social and material agencies might be equally important in shaping practice but in different qualitative ways. Thus, people have intentionality, and technological artifacts have materiality. Figure 1 exhibits the mutual shaping over time of social –TMT– and material agencies –digital technologies–. This view, where the TMT and digital technologies become constitutively entangled, is useful for moving from static to dynamic patterns of analysis such that each layer of sociomaterial imbrication becomes more substantial in that it shapes action in a path-dependent manner because of its history of accumulation.

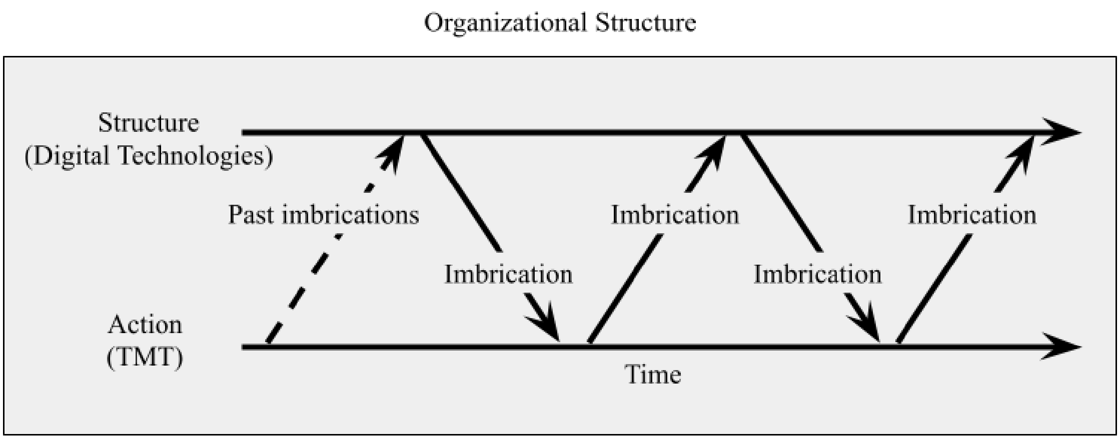

Figure 1. TMT-digital technologies imbrication framework. Adapted from Leonardi [60]

As noted by Leonardi [60], in Figure 1, the activity occurring within the grey square represents actions constitutive of broader organizational structure or technological infrastructure, horizontal arrows symbolize time, diagonal arrows signify the imbrication of material and social agencies, and the dashed line represents imbrications that occurred before the current TMT began using digital technologies in this organizational setting. When adopting this framework, we are directed to explain three issues. First, how, and why imbrication occurs, the mechanisms by which imbrication occurs. Second, the role the TMT play in the creation of the sociomaterial over time, how the TMT come to understand, interpret, and deal with the materiality that pre-exists their interaction with digital technologies, i.e., the digitalization status of the organization as a whole [61, 62]. And third, how current digital technologies becomes imbricated with the social contexts into which they are introduced [60]. To that end, we rely on an attention model of top managers' opportunity beliefs for strategic action [see 20]. Specifically, the model presented in Figure 2 provides insights into how TMT's attention is allocated to identify potential opportunities. Moreover, this model also explores the intervening processes that might impact the likelihood of forming beliefs about radical and incremental opportunities requiring strategic action. Opportunity belief arises from a two-stage process. The identification stage elucidates how the TMT identifies technology novelty or change as potential opportunities. The evaluation stage explains how the TMT forms a belief that these identified technological changes may represent an opportunity worthy of exploitation. We added a new stage, called action, where the TMT decides how to imbricate agencies, either by changing routines or by changing technologies.

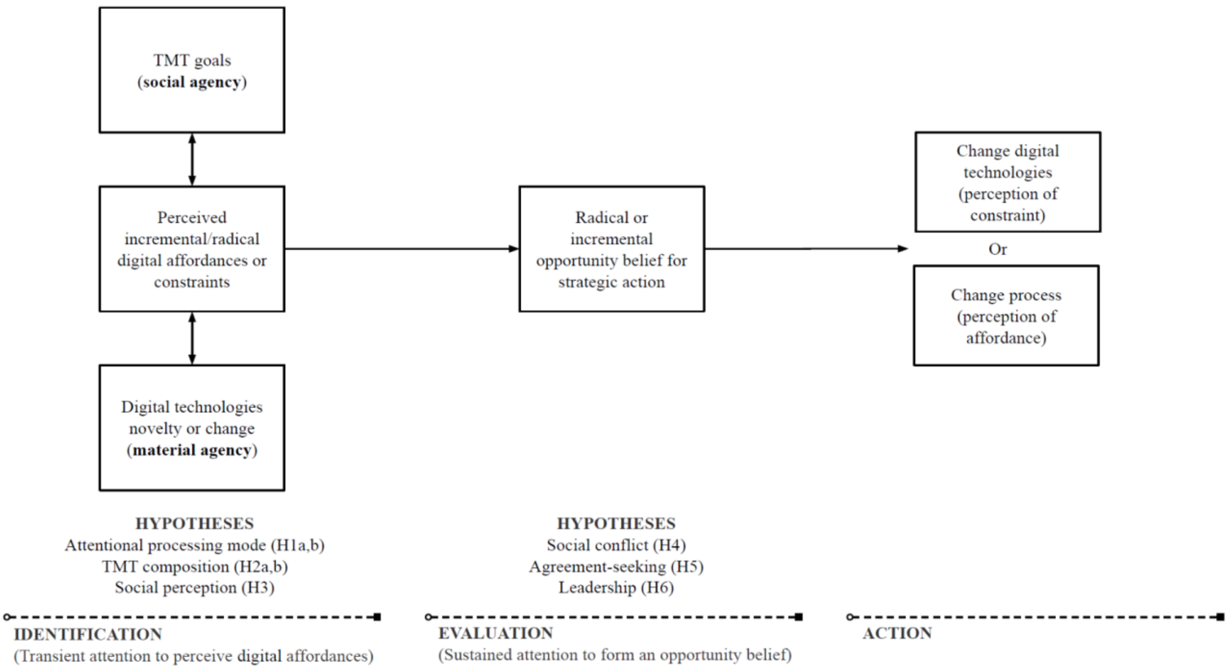

Figure 2. An attention model of top managers' opportunity beliefs for an imbrication layer

3.2 Transient attention to perceive digital technologies' affordances

In the identification phase, by allocating transient attention, top managers may perceive affordances or potentialities for either incremental or discontinuous changes in their organizations. We suggest that this noticing varies according to the allocation of TMT's attention, TMT composition, and social perception.

As shown in Figure 2, digital technologies have material properties that afford different possibilities for action based on the contexts in which they are used. Therefore, affordances are unique to the particular ways in which a TMT perceives what digital technologies do. The relational character of affordances emphasizes that digital technologies exist independently of the TMT, but affordances and constraints do not [63]. Because the TMT using digital technologies has diverse goals, they perceive a specific technology as affording distinct possibilities for action [5, 64]. On the other hand, the TMT may perceive that technology constrains their ability to carry out their goals. According to this relational view, affordances and constraints are constructed in the space between human and material agencies [19]. TMT's goals when using digital technologies are formulated, basically, by their perceptions of what digital technologies can or cannot do, just as those perceptions are shaped by TMT's goals. For this reason, as the TMT attempts to reconcile their own goals with the digital technologies, they actively construct perceptual affordances and constraints. Next, we delve into how the TMT's attentional processing mode, TMT composition and social perception influence the identification and evaluation of potential opportunities.

3.2.1 Top-down and bottom-up allocation of managerial attention

Attention is shaped by both top-down –i.e., goal or schema-driven– and bottom-up –i.e., data or stimulus-driven– processes [65]. Top-down processes of attention allocation are directed toward aspects of the environment that are expected to be important and away from aspects that are not. Bottom-up processes instead are stimulus-driven allocations of attention from striking aspects of the environment [65]. Because incremental changes to the environment typically occur when and where they are expected to occur, they are likely to be noticed by transient attention being allocated to them through high top-down processing; however, bottom-up processing may better enable top managers to be drawn to unexpected signals of environmental change [20], e.g., disruptive digital technologies.

In the transient attention phase, whether top managers notice incremental or discontinuous digital technologies' affordances vary according to the degree to which they rely more heavily on top-down or bottom-up attention allocation. As an example, Venkatraman's [66] frequently cited framework breaks digital technologies' potentialities for business transformation into five levels: localized exploitation, internal integration (considered as two evolutionary or incremental levels), business process redesign, business network redesign, and business scope redefinition (as three revolutionary or discontinuous levels). Top-down attention allocation, i.e., the allocation of attention to core concepts, directs TMT's attention to noticing incremental potential opportunities more concerned with efficiency impacts. However, by engaging in more bottom-up processing, the TMT allows the emerging digital technologies to capture their attention even when they are not actively searching for them, then is more likely that they perceive discontinuous affordances [cf. 20], more related to competitive effects.

Hypothesis 1(a): The greater the increase in TMT's attentional top-down processing –i.e., goal-driven–, the greater the likelihood of noticing incremental digital technologies' affordances (relative to discontinuous digital technologies' affordances).

Hypothesis 1(b): The greater the increase in TMT's attentional bottom-up processing –i.e., technology-driven–, the greater the likelihood of noticing discontinuous digital technologies' affordances (relative to incremental digital technologies' affordances).

3.2.2 TMT composition

The composition of the TMT refers to the collective characteristics of its members such as demographic attributes (e.g., tenure, age, functional specialties, and educational background) and/or psychological profiles (values, cognitive styles and personalities). Such composition affects the TMT's internal processes, which in turn affect its decisions and other outcomes. Executives of diverse experiences and tenures bring varied frames of reference to a TMT's deliberations, which are especially valuable for ongoing innovation and change [67]. For example, incumbent and new owner-managers focused on incremental or efficiency-related digitalization activities during family succession processes [68]. An heterogeneous TMT, though probably triggering social friction, facilitates to open up debate and expand problem solving, then more likely attending to a broader range of new stimuli [69]. Thus,

Hypothesis 2 (a): The greater the increase in TMT's demographic heterogeneity –i.e., the degree of diversity among executives' experience manifested in tenure, functional background, and so forth–, the greater the likelihood of noticing discontinuous digital technologies' affordances (relative to incremental digital technologies' affordances).

On the other hand, the time of entry into a group is an important determinant of a person's communication patterns within the group [70]. A long average group tenure results in decreasing levels of overall communication because group members feel that they can anticipate other members' perspectives. Therefore, a long TMT tenure may lead to increased isolation with respect to external sources of information, which may lead members to become less receptive to disruptive digital changes and innovation. However, tenured TMTs have experienced past imbrications and will likely have a distinctive understanding of incremental potential opportunities compared to someone who recently joined the TMT [71]. In fact, a group's tenure is positively related to the degree to which their members have shared outlook and perceptions [72]. Thus,

Hypothesis 2 (b): The greater the increase in TMT tenure, the greater the likelihood of noticing incremental digital technologies' affordances (relative to discontinuous digital technologies' affordances).

3.2.3 Social perception

Variability frequently appears among group members in terms of their a priori preferences and/or attitudes regarding a technology [73]. However, widely held perceptions are gained through information exchanges by way of sharing attitudes and beliefs about digital technologies. Indeed, exposure to others' attitudes through membership in a group shapes peoples' perceptions of a new technology [74]. Then, assuming that perceptions are a social phenomenon [75], why do TMT members come to share similar perceptions of a technology's affordances? Social constructivists of technology have shown that contagion and other social influence processes are seen as the primary cause of convergence of attitudes, values, and beliefs among the potential users of a technology. In this view, adoption is a collective rather than an individual process that stands apart and may sometimes be divorced from the technology's physical capabilities [76]. Thus, groups have their own personalities, distinct from a summation of individual personalities [77]. However, interdependence of members is a key criterion for an entity to be considered as a group [78] where the relational and interactional patterns among its members play a key role [79]. In fact, TMTs vary widely in how they are fundamentally structured. Some are structured such that members operate largely independently of each other, while others are set up such that executives' roles and responsibilities are highly interdependent [67]. When interdependence is high, then teams might meet often, share a great deal of information, and engage in collective decision-making —referred to as "behavioral integration" [80], the degree to which the group engages in mutual and collective interaction—. The more a TMT is behaviorally integrated, the more it shares information and resources that are critical for making quality strategic decisions. The more dynamic the organization's task environment, and the need to foster innovation and discontinuous changes in their organizations, the greater the behavioral integration of the TMT [80]. The less the behavioral integration of the TMT, the slower the group will be to arrive at a shared awareness and interpretation of new environmental changes [80]. Thus,

Hypothesis 3: The likelihood of noticing *discontinuous digital technologies' affordances* is higher when the TMT interdependence (or behavioral integration) is high than when it is low.

3.3 Sustained attention to form opportunity beliefs

Top managers require sustained attention to evaluate whether what has been noticed represents an opportunity for the focal organization –i.e., an opportunity belief– that is worthy of strategic action [20]. Therefore, once top managers notice digital technologies' affordances and/or constraints, they enter the phase of sustained attention, in which they form beliefs about whether these potentialities are opportunities for strategic action. However, the outcome of this assessment depends on the mode of attentional engagement and the TMT processes employed in the development. Attentional engagement involves mindful information processing and views attention as a process involving the application of time, energy, and effort on a selected set of environmental stimuli, a repertoire of action responses, and the relationships between them [81]. Attentional engagement is the process of intentional, sustained allocation of cognitive resources to guide problem-solving, planning, sensemaking, and decision-making [65]. Opportunities may be classified in terms of being *incremental* and *radical*. Therefore, noticed discontinuous digital technologies' affordances are more likely to lead to the formation of a belief in radical opportunities, whereas noticed incremental digital technologies' affordances are more likely to lead to the formation of a belief in incremental opportunities. However, how do TMT members reach a consensus regarding an opportunity belief?

Executives with clear visibility of different business processes can sense from experience or from interactions with others where and how much business value is being created by digital technologies [82]. When they evaluate digital technologies impacts similarly, it can be easier to approve future digital technologies' investments or to initiate corrective action for failing digital technologies' investments. However, they may rate digital impacts differently because of either having divergent personal goals or belonging to extremely narrow functional responsibility domains [39]. The degree of consensus among TMT members as to the extent and locus of digital technologies' impacts is crucial to defining and maintaining a strategic direction for digital technologies [83]. Group processes are likely to influence the level of strategic consensus within a TMT [84], i.e., shared cognitions can result because effective group processes have been utilized to resolve differences in a-priori individual preferences. Now we focus on the specific process of consensus formation and how the leadership style influences the evaluation of different opportunity beliefs. Accordingly, we examine two important group processes: interpersonal (or social) conflict and agreement-seeking.

3.3.1 Social conflict

Social conflict, i.e., the perception by the TMT members that they hold either discrepant or imperfect compatibility of their views, necessarily follows from the variety of human beings [85]. Technologies are likely to serve symbolic as well as instrumental purposes. Thus, interpretations of a technology's opportunities are potentially limitless, can only be understood in situ, and may even trigger political conflict [76]. TMT members with strong general negativity are less likely to actively participate in the decision-making process, and thus their nonparticipation can adversely affect both current and future decisions [86]. Interpersonal, social or affective conflict may result in different interpretations about what is an opportunity worthy of exploitation, and this is particularly true when dealing with strategic choices involving a high degree of uncertainty and ambiguity [87]. Then, when interpersonal conflict is high within the TMT, the differences among TMT members' interpretations of what is a radical opportunity will be greater and then strategic consensus will be lower. Thus,

Hypothesis 4: The likelihood of noticing *radical digital technologies' opportunities* is higher when the level of social conflict within the TMT is low rather than high.

3.3.2 Agreement-seeking

Decision quality, consensus, and affective acceptance are all necessary for sustainable high performance in producing and implementing strategic decisions [86]. However, how can a TMT use conflict to enhance their decisions quality without sacrificing consensus and affective acceptance among their members? The implementation of decisions rests on securing the cooperation of other parties to the decision [88]. Therefore, TMT members must both understand and commit to the decision to be successfully implemented [89]. Thus, decision processes promoting consensus among team members are more likely to enhance organizational performance [90].

Groups using agreement-seeking behaviors achieved higher levels of consensus than groups using structured techniques of task-oriented conflict such as dialectical inquiry or devil's advocacy [91]. However, such structured decision making techniques designed to facilitate the adoption of the best solution by optimizing the level of cognitive conflict during group discussion will, paradoxically, strengthen group consensus, increase member satisfaction and decision acceptance

[92]. Cognitive conflict, inevitable in TMTs, is functional, generally task-related, focused on judgmental differences about how best to achieve common objectives, and then enhances decision quality, understanding and commitment [86]. Thus,

Hypothesis 5: The likelihood of achieving consensus about *radical digital technologies' opportunities* is higher when cognitive conflict within the TMT is high rather than low.

3.3.3 Leadership

The nature, scope, and intensity of organizational changes will require very different styles of leadership behavior in initiating, energizing and implementing change [93]. Leadership of strategic reorientations requires not only charisma, but also building executive teams in support of the change [93]. Therefore, during times of significant organizational change, the challenge is to broaden the range of individuals who can perform the critical lea dership functions. As many organizations are too large and complex for any one executive to directly manage big changes, responsibility for large scale change must be institutionalized, then empowering other TMT members. Applied at the TMT level, shared leadership is a practice in which the CEO and other TMT members share the responsibility for and fully participate in the tasks of leadership [94]. TMT shared leadership promotes a cooperative conflict management style within TMT members [95] while experiencing higher commitment to the overall firm's success, thus more likely approaching conflicts as joint problems that need commonly beneficial solutions [96]. Moreover, shared leadership can improve groups' information processing capacity and is associated with increased team problem solving [94]. Therefore, shared leadership provides a wider pool of resources for a major strategic change process as it brings together the skills, perspectives and commitment of a diverse set of TMT members rather than drawing solely on CEO's expertise. Although no single individual imposing their own vision and preferences can bring about substantive organizational changes, a team assembling a variety of skills, expertise, sources of influence and legitimacy might be able to achieve such major changes [97]. Thus,

Hypothesis 6: The likelihood of positive evaluation of radical digital technologies opportunities implementation is higher when the digital technologies leadership is shared than when it is centralized.

3.4 Action

Finally, depending on whether the TMT perceives that digital technologies afford or constrain their goals, they decide how they will imbricate human and material agencies [19]. If the TMT perceives that digital technologies afford possibilities for action, they most likely will change their routines. Conversely, if they perceive that digital technologies constrain their goals, they will change or modify the technologies. For example, the TMT may perceive an opportunity for enhancing decision-making by visualizing entire work processes [5]. Then, technology features provided by e.g., enterprise systems, business intelligence, business process management tools, real-time tracking devices, etc., need to be coupled with important organizational features such as process standardization, identification of key performance indicators, etc., to enact these particular affordances. By iteratively taking decisions of changing either routines or technologies, top managers develop digital infrastructure that creates business value relative to either efficiency or competitive impacts.

4. Implications and concluding remarks

4.1 Theoretical contributions

Previous research on digital transformations highlighted the complementarity argument, i.e., digital and non-digital factors must be integrated to achieve business goals [98, 99]. We addressed this issue by focusing on the role of top managers as the crucial social agency and key complementary resource for digital transformation. The imbrication view recognizes that both TMT and digital technologies are necessary for digital transformation to occur; their imbrication is what produces complementary changes in digital technologies and in internal processes, and this chain of imbrications occurs in a path-dependent manner to create technological infrastructure.

This conceptual article offered three primary contributions to the TMS literature. First, this paper covers philosophical discussions and provides a critical review of other authors' work and thinking on TMS. This manuscript summarizes recent developments and highlights various limitations that offer opportunities for this examination. Second, in the view that every organizational practice is always bound with digital technologies, we reconstructed the role of top managers in digitalization by adopting an emergent perspective. Therefore, in this paper, top managers' participation is conceptualized as a dynamic process, in which any outcome emerges unpredictably from complex and reciprocal interactions between the TMT and digital technologies within an organizational context. Scholars defined TMS as a set of desirable attitudes and behaviors–[e.g., 100, 101]–, but also as a scarce and valuable resource whose availability depends on diverse aspects [9]. However, the nature and form of TMS is built over time and depends on several contextual factors [102]. The metaphor of imbrication sensitizes us to the production of durable patterns in a path dependent manner [19]. The metaphor of imbrication expresses the idea of a tighter and more continuous relationship between the TMT and digital technologies, a relationship that goes beyond mere support. The concept of imbrication suggests how a human agency approach to technology can usefully incorporate notions of material agency into its explanations of digital transformations. Third, we argue that each imbrication layer can be viewed as a process where top managers form beliefs to act on digital opportunities for strategic action. Opportunity belief arises from a two-stage process. The identification stage elucidates how the TMT identifies digital technologies' novelty or change as potential opportunities. The evaluation stage explains how the TMT forms a belief that these identified technological changes represent an opportunity worthy of exploitation. The identification of radical or incremental opportunities depends on several intervening processes.

4.2 Practical contributions

Because we view digital transformation as a process that occurs in a path-dependent manner, top managers' situated experience and organizational tenure are then valuable characteristics. Therefore, recruiting new top managers who show the required digital competence can be a starting point but not a realistic solution to produce good results immediately. Moreover, as we capture the interplay between digital technologies and the TMT using the concept of affordances, then it is reasonable to expect that TMT characteristics and processes influence potential opportunities recognition. Specifically, we suggest that the more heterogeneous, behaviorally integrated, and intensive in technological vigilance the TMT, the more likely they notice discontinuous digital affordances. However, TMT tenure can hinder that possibility because theoretically is expected that tenure will lead top managers to become less receptive to disruptive changes. On the other hand, we propose that consensus for radical opportunity beliefs can be easily achieved with low level of social conflict but in the presence of a high degree of cognitive conflict within the TMT. Furthermore, we suggest that TMT shared leadership can improve the likelihood of positive evaluation of the implementation of radical opportunities because it approaches the inevitable conflicts during implementation as joint problems that need commonly beneficial solutions.

4.3 Suggestions for future research

Future research may wish to examine the relationship between TMT and digital technologies by seeking patterns across certain contexts and certain types of either digital technologies or TMTs. Further research could examine to what extent different digital technologies require different types of imbrications, or how institutional and technological contexts explain, shape, or inhibit various top management behaviors and actions. Top managers' imbrication with digital technologies is a fruitful research area that still presents numerous questions unanswered. Case studies would help to refine the potential antecedents of this imbrication. Moreover, longitudinal studies should test whether the imbrication process maintains the continuous commitment of the entire TMT and how and why digital leadership might change among individual TMT members.

Future researchers should also study differences that exist in the imbrication process between diverse, highly decentralized organizations and single businesses that are highly centralized. As Jarvenpaa and Ives [31] noted, when contact with digital functions is frequent and direct, the TMT's attention to digital technologies could be more directed toward specific business needs than in the case of highly decentralized or multi-business firms. Organizational size may also influence the role of the TMT in digital transformations. Hands-on management might be much more important for small organizations in which the CEO or TMT usually makes most of the key decisions and is the only actor(s) who can attach digital technologies to corporate objectives and strategy [31]. Most likely, in large companies, digital technologies' attention might be more adequately placed at the line management level. Future research could also extend to boards lacking oversight of digital technologies [103], as well as attention deficits in board scrutiny of digital technologies matters in favor of focusing on only digital technologies' risk [104], and how either of these situations might affect the role of top managers in digital technologies activities in large organizations.

Describing affordances reasonably requires specifying the subject for whom an object is an affordance, and its action-oriented goals and characteristics or abilities [105]. Consequently, future research could most likely identify demographic and competence traits of the TMT and the effects of those traits on their goals and intentions when using digital technologies (social agency). How analyze users' goals and capabilities concerning digital artifacts represents an important direction for further development [64]. Moreover, executive characteristics affect perception and interpretation [69]. Furthermore, TMT's strategic digital knowledge, i.e., TMT's understanding of the merits, opportunities and advantages of digital technologies in supporting the organization's business strategy [106], also encompasses TMT's awareness of the organizational needs of digital technologies and TMT's attentiveness to the organizational impacts of digital technologies [107]. Otherwise, the lack of TMTs' digital knowledge limits their level of involvement in digital projects [108].

Of course, any explanation of digital technologies' effects is incomplete without careful conceptualizations of users and use environments [64]. Hence, future research, while exploring the TMT's characteristics, could study the effects of the environment, which is beyond the scope of this paper.

Future research could also analyze how the TMT and digital technologies imbrication may differ in situations involving different or a more heterogeneous mix of TMT members. Consider a case in which not all an organization's managers imbricate homogeneously. Diversity can be a double-edged sword, increasing both the opportunity for creativity and the likelihood that group members will be dissatisfied and fail to identify with the group [109]. Scholars suggest that measures of dispersion or variation of characteristics among members of a group are crucial to understanding the effects of demographic indicators on organizational outcomes [110, 111]. When people hold different goals, each member of the same social group can enact a different affordance or set of affordances when using the same technology [112]. With multiple members in a group and multiple features available for use, the number of possible affordances that may be enacted when different individuals use the technology is very large [113].

On the other hand, scholars within the sociomateriality stream have recently begun to consider the role of emotions in sociomaterial accounts [114] as generative forces that mobilize reflection and action [115]. Thus, future research may attach affect a central role in the emergence and change of sociomaterial practices, as it conditions human agents' encounters with technological artefacts. Emotions can be seen as relationally produced, emerging not just from interpersonal social relations, but from sociomaterial relations [114].

We also hope that this paper will encourage additional qualitative and quantitative studies on the role of executives in digital transformation.

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Biographical notes

José Fernando López-Muñoz
is associate professor for Information Systems and Management at ESIC Business & Marketing School (Spain). Before joining ESIC, he was an entrepreneur and a technology consultant in the ITC industry for more than 20 years. He graduated in Computer Science, MSc in Business Strategy, and PhD in Management. He has published in European Research on Management and Business Economics, International Entrepreneurship and Management Journal, International Journal of Information Systems and Project Management, and others. His research interests focus on executives, entrepreneurship, and digitalization.

Alejandro Escribá-Esteve
is full professor of strategic management at the University of Valencia (Spain). His research interests focus on the interface between the characteristics and processes of Top Management Teams and Business and Corporate Strategies in SMEs and Family Firms. His research has been published in international peer reviewed journals such as Journal of Management Studies, International Journal of Information Systems and Project Management, Long Range Planning, British Journal of Management, Journal of Family Business Management or Group and Organization Management, among others.

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