Mira Holopainen

MANAGING COMPANIES' PERFORMANCE IN DIGITAL TRANSFORMATION

ACTA UNIVERSITATIS LAPPEENRANTAENSIS 1138

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Dissertation for the degree of Doctor of Science to be presented with due permission for public examination and criticism in the Auditorium 1 of the Lahti campus at Lappeenranta-Lahti University of Technology LUT, Lahti, Finland on the 14th of June 2024, at noon.

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Abstract

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Digital transformation brings manifold changes within organizations, affecting essential elements such as key products, services, processes, and business models, as well as organizational culture, structure, and capabilities. However, effectively managing performance in digital transformation is a challenging task, given the high failure rate of related initiatives. Therefore, to facilitate successful performance, this dissertation aims to develop an understanding of the integration of digital technologies with management practices. This involves bridging the realms of strategic management, performance management, and digital transformation. In addition, the dissertation presents empirical evidence sourced from multiple channels, employing a concurrent mixed-method approach. Specifically, the dissertation is based on two multiple case studies and a survey conducted between 2019 and 2021. The companies that participated in the research operated in diverse industries in Finland and encompassed both small and medium-sized enterprises (SMEs) as well as large companies.

The results of the dissertation are based on five publications. They show that most companies experience challenges in using digital technologies to gain business value. Consequently, the dissertation puts forth a conceptual framework to facilitate managing performance in digital transformation. This framework encompasses key concepts such as strategic readiness, the use of digital technologies, digital strategy, changes in value creation, structural factors and barriers, performance measurement and management (PMM), and overall performance. In addition, the dissertation proposes that companies should consider the impact of the use of digital technologies and digital strategy on (1) their value creation paths and activities, (2) the development of related management capabilities, (3) integration of both perspectives into their PMM systems, and (4) fostering collaboration in the digital realm to facilitate performance growth. Finally, the dissertation provides practical insights for managers by elucidating various strategic mechanisms for managing the use of digital technologies within companies and illustrating how these technologies influence company performance in diverse ways.

Keywords: strategic management, performance management, digital transformation

Acknowledgments

The inception of this dissertation dates back to 2019 when, serving as a project researcher, I embarked on data collection for my research. At that point, the idea of attaining a doctoral degree was not part of my aspirations. Gradually, and step by step, the dissertation evolved into its ultimate structure. The journey has been both instructive and enlightening, offering insights into various facets of the researcher's role. Yet, recognizing that everything has its conclusion, now marks an opportune moment to conclude this phase of my life and eagerly anticipate new adventures ahead.

With these words, I express my sincere gratitude to my supervisors, Professor Juhani Ukko and Associate Professor Minna Saunila, for their invaluable guidance and unwavering support during this journey. Their mentorship has imparted numerous lessons about the essence of being a researcher, and without their brilliant contributions, the completion of my dissertation would have been a formidable task. I extend my heartfelt thanks to my former supervisor, Professor Hannu Rantanen, who not only selected me to work for LUT in 2018 but also facilitated my integration into our community. Special appreciation goes to Dr. Tero Rantala, whose contribution to one of the publications in my dissertation was significant and who has been a cherished colleague. In addition, I want to thank all my other colleagues who have left an indelible mark on this dissertation, shared insights through discussions, and infused enthusiasm into my work.

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Finally, I thank my family and friends, whose unwavering belief in me and steadfast support have been a cornerstone throughout this journey. A special acknowledgment is reserved for my sister Marianne, who shared this expedition with me, and my beloved Sami, who patiently listened to my thoughts and concerns day after day. I am also thankful to my other family members and close friends who continually reminded me of what truly matters in life.

Mira Holopainen
May 2024
Lahti, Finland

This dissertation is dedicated to my mother, who taught me what strength is, and to my dear sister Marianne, who encouraged and believed in me.

Contents

List of publications

This dissertation is based on the following papers. The rights have been granted by publishers to include the papers in the dissertation.

I. Holopainen, M., Ukko, J., & Saunila, M. (2022). Managing the strategic readiness of industrial companies for digital operations. *Digital Business*, *2*(2), 100039.
II. Holopainen, M., Saunila, M., & Ukko, J. (2023). Value creation paths of organizations undergoing digital transformation. *Knowledge and Process Management*, *30*(2), 125–136.
III. Holopainen, M., Saunila, M., & Ukko, J. (2023). Facilitating performance measurement and management through digital business strategy. *Measuring Business Excellence*, *27*(2), 246–260.
IV. Holopainen, M., Saunila, M., & Ukko, J. (2024). The effects of digital business strategy on the collaboration performance of companies: The moderating effect of digitally enabled performance measurement. *International Journal of Industrial Engineering and Operations Management*, *6*(1), 64–81.
V. Holopainen, M., Saunila, M., Rantala, T., & Ukko, J. (2022). Digital twins' implications for innovation. *Technology Analysis & Strategic Management*, 1–13.

Author's contribution

In Publication I, the author Mira Holopainen had the main responsibility for designing, conducting, writing, and finalizing the research. This encompassed the formulation of the research design, conducting data collection and analysis, writing the introduction, conducting and drafting the literature review, shaping the research framework, writing the methodology and results sections, partially contributing to the design and composition of the research discussion and conclusions, and finally making corrections and finalizing the publication.

In Publication II, the author Mira Holopainen had the primary responsibility for designing, conducting, writing, and finalizing the research. This involved the design of the research, execution of data collection and analysis, and formulation of conclusions. The author specifically contributed to the writing of the introduction, methodology, and findings and contributed partly to discussions. The author made final corrections and finalized the publication.

In Publication III, the author Mira Holopainen had the main responsibility for designing, conducting, writing, and finalizing the research. This encompassed tasks such as research design, data collection, and analysis. Additionally, the author was involved in writing the introduction, methodology, and findings and contributed partly to the discussions and conclusions. Finally, the author oversaw corrections and the finalization of the publication.

In Publication IV, the author Mira Holopainen had the primary responsibility for designing, conducting, writing, and finalizing the research. This involved tasks such as research design, data collection, and analysis. The author also played a key role in writing the introduction, methodology, and findings and contributed partly to the discussions and conclusions. Finally, the author was responsible for making corrections and finalizing the publication.

In Publication V, the author Mira Holopainen had the main responsibility for designing, conducting, writing, and finalizing the research. The author's role encompassed writing the introduction, methodology, and findings and contributing partly to the discussions and conclusions. Lastly, the author was involved in making corrections and finalizing the publication.

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Nomenclature

Abbreviations

ANOVA	analysis of variance
AVE	average variance extracted
B2B	business-to-business
B2C	business-to-customer
CR	composite reliability
IoT	Internet of things
IS	information system
IT	information technology
PMM	performance measurement and management
SMEs	small and medium-sized enterprises

1 Introduction

1.1 Research background

The 2020s have witnessed significant and widespread changes, impacting various facets of both human and corporate life (Cennamo et al., 2020; Correani et al., 2020; Kraus et al., 2021). One contributing factor to this transformation is the continuous evolution of digital technology, exerting pressure on traditional companies, reshaping many markets, and thus forcing companies to reevaluate their operational strategies (Verhoef et al., 2021). For businesses, this translates into a contemporary challenge of addressing the existential threat posed by digital disruption (Li, 2020). Investments in digital technologies, such as social, mobile, analytics, cloud, and Internet of things (IoT) technologies, present new opportunities for companies and serve as pivotal components supporting organizational change in the realm of digital transformation (Sebastian et al., 2017; Venkitachalam and Bosua, 2019).

In digital transformation, companies are reassessing the most valued aspects by customers and devising operational models to capitalize on emerging opportunities, ultimately aiming for a competitive edge and enhanced performance (Berman, 2012). Incumbent companies can initiate their digital journey by implementing incremental changes, progressively transforming their business practices while finding a balance between existing methodologies and adopting novel approaches (Li, 2020; Verhoef et al., 2021). This evolution may manifest in innovations related to products, services, or processes, the exploration of new collaborative methods with customers and partners, or an upskilling of employees in digital competencies. The paths to value creation in the context of digital transformation are diverse and contingent upon a company's strategy, industry, competitive environment, and customer expectations (Berman, 2012; Vial, 2019).

Kraus et al. (2021) noted that organizations that connect digital transformation to a part of their strategy experience enhanced performance benefits and remain competitive in the market. A digital strategy guides managerial efforts in generating a new kind of value by integrating the company's existing capabilities with those enabled by digital technology. According to Sebastian et al. (2017), companies should commit strategies related to customer engagement or digitized products to support decision-making, resource allocation, and planned actions for achieving digital success. Berman (2012) identified three basic strategic paths to digital transformation: concentrating on customer value propositions, changing the operating model, or concurrently integrating both. Finally, Li (2020) recommended the following strategic approaches to companies: (1) fostering innovation through experimentation, allowing cost-effective trials of new ideas, (2) pursuing radical transformation incrementally to mitigate excessive risks, or (3) striving for a dynamic sustainable advantage through the development of a portfolio of temporary advantages.

In today's world of digital technologies, the concept of developing a long-term strategy is becoming obsolete (Li, 2020). Instead, a digital strategy is increasingly viewed as a broad direction, often assessed and refined through experiential learning during implementation. According to Verhoef et al. (2021), to unlock the full potential of digital transformation and foster performance growth, companies must actively measure performance improvements to facilitate ongoing learning. Thus, companies should also integrate digital transformation into their performance measurement and performance management systems, collectively forming a performance measurement and management (PMM) system. These integrated systems play a pivotal role as key elements, enabling organizations to thrive in an ever-changing environment, and critically evaluate the effects of their strategic decisions (Taticchi et al., 2010).

1.2 Research problem, purpose, and questions

Digital transformation has attracted an increasing number of researchers and practitioners (Cennamo et al., 2020; Leão and da Silva, 2021; Vaska et al., 2021). However, it consistently poses challenges for companies, emerging as one of the most pervasive management hurdles for established companies in both past and future decades (Li, 2020; Nadkarni and Prügl, 2021; Tabrizi et al., 2019). For instance, Fitzegerald et al. (2014) emphasized the critical nature of digital transformation for businesses, highlighting the frustration leaders often face in achieving performance improvements from digital technologies. Studies suggest a substantial failure rate, estimating that 66–84% of digital transformation projects end unsuccessfully (Libert et al., 2016), with the benefits of such transformations often taking time to materialize (Jardak and Ben Hamad, 2022). However, maintaining the status quo without continuous updates for digital transformation readiness can erode a company’s competitiveness. Therefore, the option of keeping things unchanged is not viable; instead, companies must constantly update their digital resources to facilitate successful digital transformation and prevent failure (Li, 2020).

Digital transformation is often described as a multidisciplinary phenomenon transcending organizational boundaries, instigating various changes in how organizations operate and are managed (Gong and Ribiere, 2021; Tekic and Koroteev, 2019). As an essential part, digital transformation requires investments and the adoption of digital technologies (Gong and Ribiere, 2021; Hess et al., 2016; Tabrizi et al., 2019). In addition, changes associated with digital transformation extend to an organization’s strategy and vision (Bharadwaj et al., 2013; Li, 2020; Yeow et al., 2018), business models and value creation (Berman, 2012; Hess et al., 2016; Matt et al., 2015; Vial, 2019), processes and structures (Gong and Ribiere, 2021; Gurbaxani and Dunkle, 2019), culture (Gong and Ribiere, 2021; Gurbaxani and Dunkle, 2019), and capabilities (Konopik et al., 2022; Nadkarni and Prügl, 2021). Consequently, the phenomenon is characterized by a new organizational identity and mindset (Gong and Ribiere, 2021; Wessel et al., 2021). Importantly, the changes extend beyond individual companies, as digital transformation also redefines entire industries and markets (Gurbaxani and Dunkle, 2019). To manage this complex entity successfully and to perform in digital transformation, managers should have a clear understanding of what they know and believe, facilitating informed decision-making rather than relying on a single large bet (Li, 2020). Therefore, in addressing this multifaceted research problem, the dissertation draws upon insights from several management fields, including strategic management and performance management.

Hence, it can be stated that digital transformation must be connected to the company's management systems, enabling the development and reinvention of the company in its various areas. In line with this, the dissertation aims to establish a connection between digital transformation and strategic management while investigating its effects on the company's performance. Furthermore, the study seeks to evaluate the roles of performance measurement and performance management, collectively forming a PMM system, in this endeavor. Specifically, the dissertation endeavors to understand how a performance is shaped through the company's strategy, taking into account the utilization and evolution of digital technology and aligning them with strategic aspirations and value creation paths (Berman, 2012; Bharadwaj et al., 2013; Li, 2023). Then, with the help of PMM, the company translates the strategy into actionable objectives at lower levels, enabling the measurement and evaluation of performance against predefined goals (Nudurupati et al., 2016). Thus, the purpose is to search for answers on how to effectively manage the use of digital technologies and achieve different performances in digital transformation. To explore answers to the research problems and fulfill the research purposes, the following research questions have been formulated.

1. How can the use of digital technologies in companies' digital transformation be effectively managed?
    1.1. What kind of strategic mechanisms can be used to manage the use of digital technologies in companies' digital transformation?
    1.2. What is the role of PMM in managing the use of digital technologies in companies' digital transformation?
2. How does the use of digital technologies influence the performance of companies in digital transformation?
    2.1. How does the use of digital technologies influence the different performances of companies in digital transformation?
    2.2. What are the influences of the use of digital technologies connected to digital strategy on the performance of companies in digital transformation?

1.3 Key concepts

1.3.1 Scope of the research

This dissertation combines two research fields of management: strategic management and performance management. In addition, the impact of digital transformation, as a multidisciplinary field, on both management fields has been identified in the literature. Thus, the scope of the research is derived from the convergence of these three scientific areas, as shown in Figure 1. The figure depicts strategic management as the primary research field that encompasses and influences other related domains. Subsequently, how the research fields and concepts are interconnected to contribute to the overall research objectives is explored.

Strategic management transcends many fields of science, such as economics, sociology, finance, and marketing (Naq et al., 2007), and is nowadays primarily focused on helping organizations succeed in dynamic and complex environments (Hunger and Wheelen, 2010). Strategic management includes internal and external environment analysis, strategy planning and formulation, strategy implementation, and strategy evaluation and controlling (Fuertes et al., 2020; Kazmi, 2010). Thus, strategic management research has focused, among other things, on the assessment of external threats and opportunities, in view of the company's strengths and weaknesses, and supporting the creation and implementation of a new strategic direction (Bracker, 1980; Fuertes et al., 2020; Hunger and Wheelen, 2010). In addition, strategic management research has emphasized its effects on company performance (Nag et al., 2007; Yadav et al., 2014). For example, according to Yadav et al. (2014), the theories of strategic management and how it affects the company's performance have been studied to some extent, revealing the connection between them.

Some research in the field of strategic management has explored the intersection with digital transformation (e.g., Berman, 2012; Bharadwaj et al., 2013; Li, 2020; Lipsmeier et al., 2020; Matt et al., 2015). Notably, prior studies have emphasized the capability of strategic management to support and drive the digital transformation of companies, leading to a competitive advantage (Chi et al., 2018; Kane et al., 2017; Ukko et al., 2019). Digital transformation can be seen as a complex and uncertain environment in which companies must strive to succeed. It forces companies into strategic change, modifying their value creation paths to increase performance (Berman, 2012; Gong and Ribiere, 2021; Rêgo et al., 2022). The changes enabled by digital technologies should be aligned with a company's strategic thinking, necessitating the effective management of digital strategy (Bharadwaj et al., 2013; Lipsmeier et al., 2020; Yeow et al., 2018). This includes, for example, an understanding of the external environment, goals, resources, management, and responsibilities related to the use of digital technologies (Fuertes et al., 2020; Hill and Jones, 2008).

Along with strategic management, performance management plays a fundamental role in evaluating the influence of digital technologies on companies' performance (Feurer et al., 1995). Performance management is described as a multidisciplinary field containing different functional areas, such as business strategy (Franko-Santos et al., 2012). Atkinson et al. (1997) realized that the lack of integration of performance measurement with strategic planning and its development are common reasons why these systems fail to meet stakeholder expectations. In addition, the importance of integrating strategic aspects into PMM systems has been emphasized by other studies (e.g., Chenhall, 2005; Franco-Santos et al., 2012; Gates, 1999; Hall et al., 2008). Thus, the dissertation combines two management research fields: strategic management and performance management.

Finally, digital transformation, a wide-ranging phenomenon, crosses disciplines and intends to improve companies' performance (Tekic and Koroteev, 2019; Westerman et al., 2011). Nudurupati et al. (2016) reasoned that companies have to integrate the use of digital technologies into their strategies and evaluate them through PMM to reveal better performance. Thus, in the dissertation, performance is seen as an outcome and is aimed at by combining and searching for answers from three different fields of research. More precisely, Figure 1 describes the combinations of the fields and how the dissertation examines the various direct and indirect effects of the different concepts. The dissertation assumes that integrating these fields and concepts into the scope of the research can provide support for managing companies in digital transformation, ultimately leading to diverse performance outcomes.

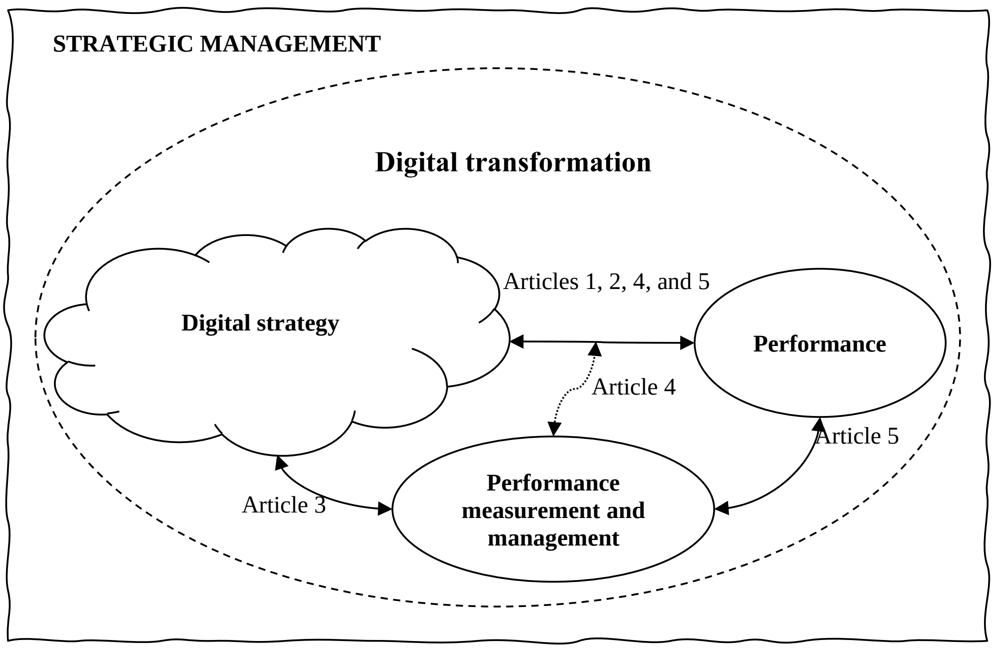

Figure 1. The research scope including the research fields and concepts.

1.3.2 Concepts related to strategic management

Strategic management

Strategic management supports managing companies in a complex and changing environment through a clearer understanding of the company's strategic vision and mission and focuses on what is strategically important, i.e., goals (Hill and Jones, 2008; Wheelen et al., 2017). Strategy plays the leading role in strategic management and has been described as a long-term direction (Johnson et al., 2020) or as a plan (Mintzberg, 1987) of an organization, including the definition of long-term goals, the implementation of measures, and the allocation of resources to achieve defined goals (Chandler, 1962). According to Porter (1996, p. 39), a strategy is different through a purposeful and unique combination of resources styled for "deliberately choosing a different set of activities to deliver a unique mix of values." Thus, it is stated that every company should formulate a strategy (Wheelen et al., 2017) that delineates the effectiveness of achieving objectives (Fuertes et al., 2020). This strategy aims to improve competitive positions and exerts a significant influence on the overall performance of the companies.

Management has been described as the cornerstone of strategy (Hill and Jones, 2008; Johnson et al., 2020). According to Fuertes et al. (2020), strategic management provides companies with added value by evaluating future actions to create a competitive advantage. It is described as the analysis of the internal and external environment to maximize the use of resources in relation to goals (Bracker, 1980) or noted as a set of management decisions and actions that can be used to promote performance compared to other organizations (Kong, 2008). Nag et al. (2007) endeavored to integrate various elements of strategic management and encapsulated it as the management of "the major intended and emergent initiatives taken by general managers on behalf of owners, involving utilization of resources to enhance the performance of firms in their external environments" (p. 942).

Kazmi (2010) described strategic management as a dynamic process that includes strategy formulation, implementation, evaluation, and control to reach the organization's strategic purpose. The formulation is related to the analysis of internal and external environments and strategic problems (Hill and Jones, 2008; Sadler, 2003). The strategy should be designed by defining simple long-term goals, considering and evaluating the current competitive environment, resources, and effective implementation (Fuertes et al., 2020; Hill et al., 2014; Peppard and Ward, 2016). In addition, strategies should be translated into action through implementation, including the establishment of short-term goals, assignment of roles and responsibilities, allocation of resources, and the design of the organization's reward and control systems (Hill and Jones, 2008). The outcomes of the implementation process should be evaluated by measuring their impact and taking the necessary corrective actions (Feurer et al., 1995; Fuertes et al., 2020).

The dynamic nature of strategic management enables the strategy to be constantly reviewed, changed, communicated, and adjusted (Feurer et al., 1995; Kazmi, 2010). In addition, strategic management must consider the consistency of the strategies at different levels: corporate, business, functional, and operational levels (Feurer et al., 1995; Fuertes et al., 2020). Finally, Jasper and Crossan (2012) summarized the characteristics of strategic management as follows: (1) it is a process of organizational leadership that recognizes and involves the entire workforce, (2) enables coordination between the organization and the external environment, (3) involves visioning and planning the future through foresight and innovation, (4) provides the processes to support changes and organizational development with a focus on performance and achieving goals, and (5) enables consistent decision-making and communication.

Given the arguments presented above, the field of strategic management is perfectly suited to managing companies' performance in digital transformation. The dissertation follows Nag et al.'s (2007) definition of strategic management. In the context of this dissertation, this implies the digital initiatives undertaken by managers, including the use of digital resources, such as digital technologies, to improve companies' performance in digital transformation. Consequently, it becomes imperative to provide clear definitions for the concepts of digital strategy, digital transformation, and digital technologies.

Digital strategy

Digital technologies fundamentally modify traditional business strategies (Bharadwaj et al., 2013; Lipsmeier et al., 2020). In digital transformation, the use of digital technologies should be guided by a digital strategy, which is also a key part of the strategic management of this transformation. In this context, the digital strategy offers an overall vision, including strategic goals and initiatives to achieve them in relation to services, products, and value creation, as well as the company's organizational culture and structure (Lipsmeier et al., 2020). Otherwise, Bharadwaj et al. (2013, p. 472) summarized a digital business strategy as an "organizational strategy formulated and executed by leveraging digital resources to create differential value." Furthermore, Mithas et al. (2013) described a digital transformation strategy as a strategy that leverages digital technology to transform the way to create and deliver value. In addition, Matt et al. (2015, p. 340) formulated a digital transformation strategy as "a blueprint" that promotes companies in managing changes resulting from the integration of digital technologies and in their operations after the transformation.

Contrary to the traditional view, a digital strategy is defined as the fusion of information systems (IS) and business strategy, which eliminates the difference between them (Bharadwaj et al., 2013; Chanias et al., 2019). According to this view, it is not merely about aligning the information technology (IT) functional strategy with the business strategy (Yeow et al., 2018). Instead, digital strategy explicitly recognizes the integration of IT into the entire organization, intertwining IT strategy with business strategy (Bharadwaj et al., 2013; Yeow et al., 2018). Therefore, digital strategy is characterized as transfunctional, which goes beyond traditional functional areas (e.g., logistics, marketing, operations), IT-based business processes (e.g., customer service, order management), and even organizational boundaries (Bharadwaj et al., 2013; Yeow et al., 2018).

According to Li (2023), a digital strategy encompasses an overarching concept that includes the organization's IT strategy, digitization, digitalization, and digital transformation strategy, as well as the business strategy facilitated by digital technologies. It combines these diverse perspectives and is defined as a strategic plan aimed at achieving business objectives through the exploitation of digital technology in the digital economy (Li, 2023; Westerman, 2018). Therefore, in this dissertation, the term digital strategy will be employed to encompass these various perspectives.

A successful digital strategy is not about using digital technologies to become as digital as possible but about identifying opportunities to achieve the greatest business impact, i.e., performance (Kane et al., 2017). Also, in a modern-day nonpredictive digital environment, it is not necessary to develop a new strategy that will be implemented for years (Li, 2020). Conversely, a digital strategy increasingly defines a general direction (Johnson et al., 2020), and its path is often evaluated using learning through implementation (Li, 2020).

Thus, digital strategy is an integrated and central part of strategic management in digital transformation (Lipsmeier et al., 2020). The dissertation follows the views of Bharadwaj et al. (2013) and Lipsmeier et al. (2020) on digital strategy. In the dissertation, the term digital strategy is used to refer to strategic direction defining an organization's vision and goals in digital transformation and is formulated and executed through the use of digital technologies and other key resources to create different value and enhance performance.

Digital transformation

Digital strategy serves as a catalyst for a successful digital transformation, aimed at enhancing company performance. Thus, digital transformation as a concept requires a detailed description. Digital transformation has been illustrated as a multi-faceted phenomenon with multi-level aspects and implications for companies (Tekic and Koroteev, 2019). It emphasizes the use of digital technologies (Gong and Ribiere, 2021; Tabrizi et al., 2019) and refers to the changes (Legner et al., 2017) or improvements (Fitzgerald et al., 2014) they bring or enable. Some researchers highlight these perspectives and define digital transformation as the use of digital technology to profoundly improve a company's performance or reach (Westerman et al., 2011) or to enable significant business improvement (Fitzgerald et al., 2014). Tabrizi et al. (2019) summarized that digital technologies are critical components of the success of digital transformation, offering opportunities for development and growth.

The phenomenon of digital transformation spans various scientific disciplines, and attempts have been made to describe it in numerous ways. Vial (2019) notes the absence of a comprehensive picture of digital transformation. He addresses this gap by analyzing 282 works related to digital transformation and defines it as "a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, communication, computing, and connectivity technologies" (p. 121). The definition justifies different observations: (1) it is not organization-centric, taking into account the broader organizational, individual, and societal contexts; (2) it recognizes improvement as an expected result of digital transformation, although it does not assume its realization; and (3) it also does not utilize the commonly used term digital technologies with the purpose of achieving digital transformation (Vial, 2019). Gong and Ribiere (2021, p. 12) contribute to the theory by trying to give a unified definition of digital transformation. They describe it as "a fundamental change process, enabled by the innovative use of digital technologies accompanied by the strategic leverage of key resources and capabilities, aiming to radically improve an entity and redefine its value proposition for its stakeholders." They continue that digital transformation is not limited to a specific entity; it crosses organizational boundaries and requires different changes in companies, such as in strategies and mindsets, processes, and operations, as well as in cultures and structures.

Digital transformation can be considered a special type of strategic change that alters value creation methods and paths within a company (Berman, 2012; Gong and Ribiere, 2021; Rêgo et al., 2022; Vial, 2019). It has been observed to affect essential elements such as key products, services, processes, and business models, leading to enhancements in existing aspects and the creation of novel ones. Furthermore, digital transformation induces changes in organizational culture, structure, and capabilities (Gurbaxani and Dunkle, 2019; Tabrizi et al., 2019; Vial, 2019). Due to its multidimensional nature, companies must create appropriate management practices to manage these complicated transformations. Thus, in this study, digital strategy, as well as different management mechanisms, is recognized as the driving force behind digital transformation (Hess et al., 2016; Li, 202; Tekic and Koroteev, 2019).

To conclude, the study follows Gong and Ribiere's (2021, p. 12) definition of digital transformation. In the dissertation, digital transformation describes companies' fundamental change, which includes innovative use of digital technologies and strategic leverage of key capabilities and resources to enhance performance by redefining value creation activities.

Digital technologies

As stated, digital technologies are closely related to digital transformation, enabling changes and performance improvement. Therefore, defining the concept is appropriate. Digital technologies are described as enablers of business transformation, meaning the achievement of the strategic goals of the digital transformation, not the digital transformation itself (Tekic and Koroteev, 2019). They are considered combinations of information, communication, connectivity, and computing technologies (Bharadwaj et al., 2013). On the other hand, digital technologies comprise social, mobile, analytics, cloud, and IoT technologies, referring to the popular acronym SMACIT (Sebastian et al., 2017; Vial, 2019). According to Spremic (2017) and Gong and Ribiere (2021), digital technologies can be divided into two categories: primary and secondary technologies. The first includes established and mature technologies, such as SMACIT technologies. Emerging and still evolving technologies belong to the second category, such as wearables, 3D printing, virtual reality, artificial intelligence (AI), robotics, drones, and learning algorithms. The most prominent digital technology, or a combination of these, for a specific company varies on a case-by-case basis, as concrete goals are needed to support their implementation (Tabrizi et al., 2019). Thus, digital transformation is not just about exploiting as many technologies as possible (Schwertner, 2017; Tabrizi et al., 2019). They must be connected to the organization's strategy, enabling the utilization of unlimited opportunities when developing business and operations in the desired direction.

The dissertation follows Bharadwaj et al.'s (2013) view of digital technologies, defining them as sets of information, communication, connectivity, and computing technologies. Given the continuous evolution of digital technologies, the dissertation does not restrict the concept to reference only specific technologies.

1.3.3 Concepts related to performance management

Performance

The concept of performance is the main element of strategic management (Nag et al., 2007), as companies strive to modify their business and operations to cope with the changing competitive environment and thus innovate, achieve, and sustain better performance (Taouab and Issor, 2019). When conceptualizing performance, it should be noted that many definitions have been given to it in the literature. Performance is often associated with output, i.e., the achievement of quantified goals, but it is also important to assess how the output is achieved through appropriate behavior, i.e., input (Armstrong, 2006). Sonnentag and Frese (2002) describe performance as a multidimensional and dynamic concept comprising both action and an outcome aspect. The action (or behavior) perspective refers to what an individual does in a work situation, while the outcome perspective refers to the results of this behavior. According to them, performance is not determined by the activity itself but by judging and evaluating processes. This suggests that actions that can be measured in isolation are considered as performance (Campbell et al., 1993; Sonnentag and Frese, 2002).

Other definitions of performance have also been suggested in the previous literature. It is about the capability to achieve certain goals (Lebas, 1995). Alternatively, it is described as the efficiency and/or effectiveness of an action (Bititci, 2015). In addition, Sonnentag and Frese (2002) noted that only actions that are relevant to organizational goals constitute performance. By considering these perspectives, performance is about how organizations achieve their goals and thus, by performing, satisfy their customers more efficiently and effectively than their competitors (Neely et al., 1995). In this context, efficiency measures how economically resources are used, while effectiveness gauges the extent to which customer needs are met. Atkinson (2012, p. 48) describe performance as "the achievement of results ensuring the delivery of desirable outcomes to an organization's stakeholders."

Thus, performance is about how effectively/efficiently the goals set for the activity are achieved. The components of performance for any successful business include (1) goals to be achieved, (2) time elements when the goal or milestones to reach that goal are achieved, and (3) rules for prioritizing ways to get there (Lebas, 1995). In addition, appropriate behavior and effective use of skills, knowledge, and competence are needed to achieve high performance (Armstrong, 2006). To continue, performance does not describe an objective concept but is a way of defining where someone wants to go (Lebas, 1995). The author further notes that performance, therefore, is something that each organization (such as a company, stakeholder group, or organization actor) defines using various parameters to align with its strategy and vision. Performance is not a stable but a dynamic concept that changes over time (Sonnentag and Frese, 2002). It can be affected over time by factors such as learning or various temporary changes.

To summarize, the dissertation follows Bititci's (2015) and Neely et al.'s (1995) views. Thus, performance refers to the efficiency/effectiveness of an action related to a company's goals. In the dissertation, this means how economically digital resources are used and how the demands of different stakeholders are met in connection with the goals set for the use of digital technologies.

Performance measurement

Performance measurement is a broad topic, serving as a key element in the development of organizations and the enhancement of business performance (Najmi and Kehoe, 2001; Sharma et al., 2005). Measurements are described as "yardsticks" that tell how someone has performed and motivate them to perform (Najmi and Kehoe, 2001; Zairi, 1994). Neely et al. (1995, p. 80) suggest that performance measurement is "the process of quantifying the efficiency and effectiveness of an action." The term efficiency reflects the speed or cost-effectiveness of how the task is performed, measuring how the organization's resources are utilized (e.g., Keong Choong, 2013; Najmi and Kehoe, 2001; Neely et al., 1995). The term effectiveness reflects the extent to which a certain requirement or goal is achieved (e.g., Keong Choong, 2013; Najmi and Kehoe, 2001; Neely et al., 1995). In addition, Moullin (2007) recommends the definition "evaluating how well organizations are managed and the value they deliver for customers and other stakeholders" (Moullin, 2002, p. 188). Finally, from the point of organizational control, performance measurement can be reviewed through a technical control mechanism, referring to a process/processes that include setting and developing goals and related performance measures and then gathering, analyzing, elaborating, reporting, and acting on performance data (Melnyk et al., 2014; Neely et al., 1995; Smith and Bititci, 2017).

When explaining the concept of performance measurement, it is also good to define concepts of performance measurement systems and performance measures that are closely connected to performance measurement. Performance measurement systems are described as "the set of metrics used to quantify both the efficiency and effectiveness of actions" (Neely et al., 1995, p. 81). The authors continue that the performance measurement system can be reviewed through different levels, considering (1) the individual measures, (2) the entity of the performance measurement system, and (3) the relationship between the performance measurement system and the environment. The performance measurement system is also described as a process that covers the setting of goals and the collection, analysis, and interpretation of performance data (Melnyk et al., 2014). Performance measures are, however, the necessary feature of the performance measurement system (Franco-Santos et al., 2007) being defined as "a qualitative or quantitative assessment of the efficiency and/or effectiveness of an action" (Bititci, 2015, p. 17). Bourne et al. (2003) noted that performance measurement utilizes a multidimensional group of measures: external and internal measures, financial and nonfinancial measures, and future and history-based measures. The performance measures should be connected to the organization's strategy and vision, and they should describe the performance in terms of time, target, and path to the target (Bititci et al., 1997; Lebas, 1995).

Performance measurement is about the gathering, elaborating, analyzing, and reporting of data to monitor how the action has progressed and to support decision-making processes (Atkinson, 2012; Melnyk et al., 2014; Neely et al., 2002). In addition, the common purpose of performance measurement is to achieve organizational objectives (Atkinson, 2012; Franco-Santos et al., 2007). This often means connecting performance measurement to strategy or strategic objectives. In addition, it has been established that performance measurement should be a balanced and dynamic entity, giving a holistic view of the organization (Neely et al., 2002; Taticchi et al., 2010). For example, according to Franco-Santos et al. (2012), performance measurement combines the use of financial and nonfinancial measures in connection with an organization's business strategy. In addition, Gates (1999, p. 4) describes performance measurement as the process that "translates business strategies into deliverable results" by connecting financial, strategic, and operating business measures to assess how well the company is achieving its goals. However, it is important to note that there is no predetermined performance objective on which performance measurement of the organizations should specifically focus (Franco-Santos et al., 2007).

As described above, performance measurement is recognized as multidimensional (Garengo et al., 2005). It is a tool for more effective management by showing what happened and evaluating measurement outcomes against predetermined goals (Amaratunga and Baldry, 2002). In addition, the ultimate goal of performance measurement is often stated to be learning rather than control (Davenport, 2006). However, it is important to note that performance measurement typically does not analyze why something happened or suggest actions for improvement. Thus, for an organization to use performance measurement results effectively, there is a need to transition from mere measurement to active management.

To conclude, the dissertation follows the views of Neely et al. (1995) and Melnyk et al. (2014) that performance measurement is the process of quantifying the efficiency and/or effectiveness of an action that includes setting goals, developing performance measures, and also collecting, analyzing, reporting, interpreting, reviewing, and acting on performance data. In the research context, performance measurement is a process of quantifying the efficiency and/or effectiveness of the use of digital technologies in relation to strategic objectives. Thus, the company must set goals and metrics for the use of digital technologies and collect, analyze, and report data on their achievements.

Performance management

Performance management is an important concept alongside performance measurement because, in order for performance measurement (what to measure) to be meaningful, its results should be utilized through performance management to manage organizations' performance (Amaratunga and Baldry, 2002; Bititci et al., 2018). Thus, performance management is related to the utilization of information obtained from measurement. It is also described as a systematic process for enhancing the performance of organizations through development (Armstrong, 2006). Performance management offers organizations the opportunity to focus on things perceived as important, manage effectively and efficiently, and encourage continuous development and learning (Amaratunga and Baldry, 2002; Atkinson, 2012). Together, performance management and performance measurement form the PMM system, which is used in this dissertation as an abbreviation to describe this entity.

In an attempt to define the concept of performance management, Bititci et al. (2015, p. 29) describe it as "cultural and behavioral routines", outlining how to utilize the performance measurement system to manage organizational performance. From the point of view of organizational control, this definition emphasizes performance management as a mechanism of social control (Bititci, 2015; Smith and Bititci, 2017). Performance management is also described as a "systematic process for improving organizational performance by developing performance of individuals and teams" (Armstrong, 2006, p. 1). In addition, Lebas (1995) described performance management as "a philosophy which is supported by performance measurement." Finally, Amatunga and Baldry (2002) define performance management as the pursuit of positive change in an organization's culture, system, and processes through performance measurement.

Performance management is described as "a continuous process of identifying, measuring, and developing the performance" (Aguinis, 2009, p. 2), which should be aligned with corporate and functional strategies and their goals (Aguinis, 2009; Bititci et al., 1997). It includes the processes that are used to identify, evaluate, and mark the differences between results and goals, which helps to understand the occurrence of deficiencies and the planning and implementation of corrective actions (Melnyk et al., 2014). It is also a social phenomenon that is influenced by the feelings, values, and beliefs of individuals, organizations, and the community (Bititci et al., 2012). Furthermore, in order to move to performance management, companies need the right structures to enable the effective use of measurement results and the ability to use measurement results to make changes (Amaratunga and Baldry, 2002). Ledas (1995) concluded that performance management is built on measures that empower, involve, and give autonomy to individuals. Moreover, these measures should reflect causal relationships, provide the basis for development and discussion, and support decision-making.

The dissertation follows the views of Bititci (2015), Aquinis (2009), and Melnyk et al. (2014). Thus, in this research, performance management refers to a continuous process that includes cultural and behavioral routines that are used to identify, evaluate, and develop the performance of companies.

1.4 Structure

The structure of the dissertation is formed from the introduction and publications. First, the background of the dissertation, the research problem and purpose, and the research questions are described in the first part of the introduction. In addition, the scope, concepts, and structure are described. Then, the theoretical background is explored in the second part of the introduction. The third part defines the research approach of the dissertation, including the philosophy of the research, the methodological choices, the research strategy, and the methods of data collection and data analysis, ensuring the quality of the dissertation. In addition, the results and their summary are shown in the fourth section. After discussing the results in relation to the existing literature, the fifth and sixth sections of the introduction provide summarized interpretations.

The second main part of the dissertation consists of five distinct publications. The contribution of these to the research questions is shown in Figure 2. Each article serves as an independent entity that focuses on the research topic and questions from different perspectives. The data for these articles were collected through two multiple case studies and one survey, ensuring versatile and high-quality answers to the research questions.

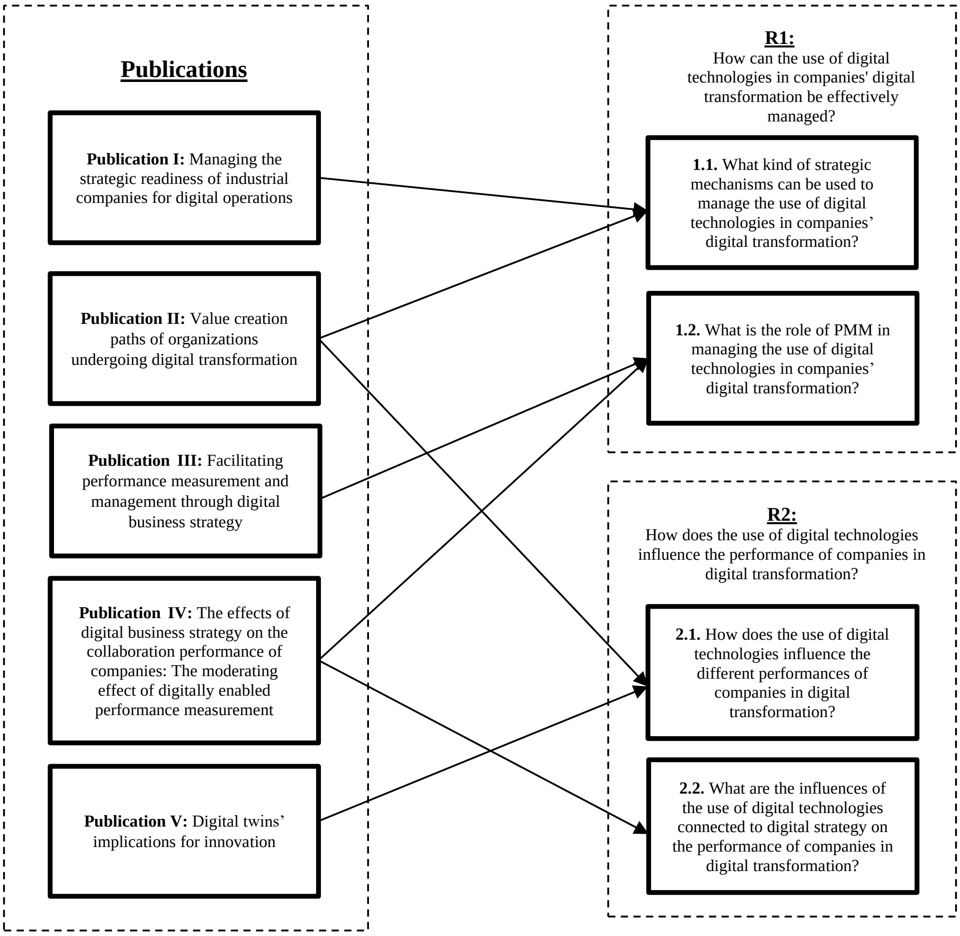

Figure 2. The publications of the dissertation and their contribution to research questions.

2 Theoretical background

2.1 Strategic use of digital technologies in digital transformation

2.1.1 Different digital technologies

Digital transformation is a multifaceted phenomenon that affects the entire operation of an organization. It extends beyond a mere IT change or technological shift, playing a pivotal role in shaping the boundaries, processes, structures, capabilities, and roles within companies (Cennamo et al., 2020; Tekic and Koroteev, 2019; Vial, 2019). The term “digital” in this context refers to digital technologies that have been described as enablers of digital transformation, while “transformation” means a change in form or shape meeting the criteria of three Bs (bold, big, and steer better results) (Gong and Ribiere, 2021; Tekic and Koroteev, 2019). Thus, while digital technologies, including information, communication, connectivity, and computing technologies (Bharadwaj et al., 2013; Vial, 2019), facilitate business transformation and offer game-changing opportunities, they also pose existential threats to companies (Sebastian et al., 2017). Therefore, in digital transformation, companies should strategically manage the use of digital technologies to achieve better performance and survive in a competitive environment.

The use of digital technologies has many possibilities. For example, they provide an opportunity to enhance traditional products by imbuing them with smart features, making them addressable, programmable, communicable, traceable, sensible, associable, and memorable (Teubner and Stockhinger, 2020; Yoo et al., 2010). Similarly, digital technologies can be leveraged to improve customer service by streamlining processes such as ordering, inquiries, payments, and support (Sebastian et al., 2017). There are many types of digital technologies, but they can be categorized as established and still evolving technologies (Spremic, 2017). The next focus is on technologies that are already widely used in business: social, mobile, big data and data analytics, cloud computing, and IoT (Vial, 2019). However, developing technologies such as digital twins, artificial intelligence, drones, wearables, and virtual reality are already making significant impacts on various industries, with even greater potential in the future. These technologies provide companies with diverse options for enhancing performance development.

Social networks affect organizations around the world. They include a group of internet-based applications that enable the creation and exchange of user-specific content (Kaplan, 2015). For example, X, Instagram, Facebook, YouTube, etc., are acting as communication platforms and shaping interaction dynamics in business (Spremic, 2017). They make it possible to respond to customer requests in real time on various social media platforms, where slowness can mean losing a customer (Bharadwaj et al., 2013). In addition, social networks can also be used to renew the organization’s culture to remove work silos and facilitate knowledge sharing (Warner and Wäger, 2019).

Mobile technology is an important technological aspect of digital transformation as the mobile internet with millions of smart devices has revolutionized industries (Mourtzis et al., 2021). Through mobile technology, users can transfer and share data on the go; however, it also offers the opportunity to interact and communicate with the customer or partners in real time regardless of the place (Schwertner, 2017; Spremic, 2017). In addition, companies can use the technology to sell or offer new services such as mobile payments and mobile orders (Fitzgerald et al., 2014; Warner and Wäger, 2019), support the existing customer service and experience (Spremic, 2017), and/or increase their productivity (Schwertner, 2017).

Big data and data analytics are the rapid discovery of information from different data sets, including a huge amount of fast-moving, structured, and unstructured data (Davenport, 2014; Spremic, 2017). Loebbecke and Picot (2015) described the concept as a way to analyze and interpret all kinds of digital information. The use of this digital technology enables multiple business opportunities; for example, data as a resource can increase operational efficiency, help managers in decision-making, and create new business models (Loebbecke and Picot, 2015; Tsvetkov and Chekanov, 2021).

Cloud computing has the potential to deliver business value by offering anytime and anywhere services (Berman et al., 2012; Spremic, 2017). This technology is described as a "pay-per-use consumption and delivery model that enables real-time delivery of configurable computing resources," such as networks, servers, storage, applications, and services (Berman et al., 2012, p. 28). In other words, cloud computing enables companies to use and pay for these scalable resources only when they are used with no capital investment (Spremic, 2017). This leads to business benefits such as predictable and reduced costs and access to the best technology (Schwertner, 2017). According to Berman et al. (2012), the power of the cloud is its cost flexibility, business scalability, market adaptability, masked complexity, context-driven variability, and ecosystem connectivity, which drive innovation and novel value creation.

The *IoT* describes a vision of an IT infrastructure that combines the physical and digital world, where all objects are intelligent, can collect data, and communicate with each other using tags, sensors, actuators, mobile phones, etc., in the online world (Atzori et al., 2010; Tesch et al., 2017). Its possibilities in different industrial sectors are manifold (Spremic, 2017). For example, it facilitates real-time monitoring and management of the performance of machines and processes (Aheleroff et al., 2021; Dweekat et al., 2017) and thus the innovation of new service business models (Haaker et al., 2021; Paiola and Gebauer, 2020).

To conclude, digital technologies do not exclusively increase business value; value is created by doing business in a new way (Westerman, 2018). This is reflected, for example, in the fact that analytics are not only data sources and algorithms but also a way to better understand the customer. Matt et al. (2015) suggested that companies should address their attitude and ability to exploit these technologies in their strategic approach, for example, whether they want to be market leaders by creating their own technology standards or utilizing already established standards as a means to fully fill business operations. Teubner and Stockhinger (2020) also stated the need to think about digital technology and business in an integrated way at a strategic level.

2.1.2 Digital strategy as a driver for change

As the use of digital technologies is changing business environments and has become the main part of products, services, and processes, many scholars have argued that companies should evaluate their strategies (Li, 2023; Teubner and Stockhinger, 2020). Digital strategy has been identified as a driving force of digital transformation (Kraus et al., 2022; Tekic and Koroteev, 2019); thus, digital technologies should be connected to companies' strategic development (Holotiuk and Beimborn, 2017). Research related to digital strategy is quite limited, making it a fairly new research topic (Li, 2023; Lipsmeier et al., 2020). According to Li (2023), it has evolved from the IT strategy toward the digitization, digitalization, and digital transformation strategy of various organizational functions and processes and then to the business strategy for the organization enabled by digital technologies. Therefore, in this dissertation, the term digital strategy will be employed to encompass these various perspectives.

One of the first research papers on the topic was by Bharadwaj et al. (2013), who studied the scope, scale, speed, and sources of value creation of digital strategy. They stated that the scope of the digital strategy is transfunctional, which goes beyond traditional functional areas and IT-enabled business processes being broader, more visible, more integrated, and more comprehensive than other functional strategies (Bharadwaj et al., 2013). However, Lipsmeier et al. (2020) noted that there is still no consensus on the scope of the digital strategy, whether digital strategy should be integrated into existing strategies (corporate, business, functional strategy) or whether a separate strategic document should be made to orchestrate digital transformation. After the analysis of 12 different studies, they decided to follow the understanding of Bharadwaj et al. (2013), who argue that it is time to merge functional IT strategy and business strategy. From this point of view, the digital strategy should be a separate document at the business level when companies are at the beginning of the digital transformation. Then, as the digital transformation progresses, the digital strategy is no longer distinguished from the business strategy. In addition, a company can have several digital strategies in connection with different business units, but the general strategic direction of digitalization should also be determined at the corporate level of the organization to ensure that digital strategic projects are consistent (Lipsmeier et al., 2020).

On the other hand, Teubner and Stockhinger (2020) argued that the digital strategy should be its own strategy and not an update of the IT strategy or the modernization of the business strategy. They suggested that digital strategy operates at the intersection of IT and business strategy instead of fusion, where the use of digital technology is directly and deeply involved in value creation rather than in a supporting role.

To continue, a digital strategy refers to the “overall vision of a company in the context of digitalization” (Lipsmeier et al., 2020, p. 175). It considers both the formulation and implementation of an organizational strategy and utilizes digital resources to create different values (Bharadwaj et al., 2013; Correani et al., 2020). In addition, the digital strategy includes defining strategic goals, initiatives, and measures for different time periods, considering products, services, and value creation, as well as cultural and organizational factors related to the use of digital technologies (Lipsmeier et al., 2020). In addition, the digital strategy extends to partners, competitors, and business ecosystems. This extension gives rise to new collaborative networks, necessitating the sharing of digital strategies with different actors (Bharadwaj et al., 2013; Senyo et al., 2019; Sousa-Zomer et al., 2020). The leading role of formulating and implementing the digital strategy should not necessarily be from the IT department because it is business-oriented and customer-focused, covering the entire organization (Chanias et al., 2019). For example, Matt et al. (2015) and Singh et al. (2020) suggested that companies consider the chief digital officer as a new management role responsible for digital strategy.

Digital strategy is a strategic plan formulated in an organization to achieve long-term business objectives by exploiting digital capabilities and resources (Bharadwaj et al., 2013; Li, 2023). As resources are an essential part of companies’ operations, being both tangible and intangible, a digital resource has been described as “a specific class of digital objects that are modular, encapsulate objects of value, and are accessible by way of a programmatic bitstring interface” (Piccoli et al., 2022). They continue that, for example, Google maps or Uber drivers can serve as digital resources. On the other hand, capability is a company’s ability to use resources to achieve the desired outcome (Helfat and Lieberman, 2002); thus, digital capabilities relate to the knowledge and skills needed to acquire, use, absorb, adapt, improve, and create new digital technologies (Heredia et al., 2022) but also to repeatable patterns of actions (Piccoli et al., 2022). When formulating the digital strategy, the down-up approach, which is a combination of bottom-up and top-down approaches, has been suggested for the development of digital strategy, including higher coordination with both directions (Lipsmeier et al., 2020). To continue, the authors present the process of eight steps to develop a digital strategy considering different organizational levels:

(1) Formulation of a strategic direction, including a digital vision, a digital mission, digital policies, digital targets, and digital terms, together with corporate and business levels

(2) Identification of detailed digitalization initiatives and topics at functional levels

(3) Definition of concrete strategic objectives in digital transformation about cross-functional topics on the business level based on topics on single functional levels

(4) Identification of cross-functional topics with concrete quantitative values on corporate and business levels

(5) Development of a digital strategy for each business unit at the business level

(6) Definition of concrete digital projects for implementation of the digital strategy and its objectives at business and functional levels

(7) Selection of major digital projects together with corporate and business levels

(8) Designing an implementation roadmap at the business level.

To effectively develop a digital strategy, companies should focus on different digital capabilities (Li, 2023), owing to their strategic readiness to successfully implement the designed digital strategy. Holotiuk and Beimborn (2017) introduced a digital strategy framework with eight dimensions, including 40 critical success factors, to ensure successful competitiveness in digital transformation. In the framework, (1) the sales and customer experience dimension focuses on integrated offline and online channels, new digital products and services, and the digitalization of customer interaction to build a better customer experience. (2) The organizational dimension focuses on agility to reallocate resources, change management, and alignment toward digital transformation. (3) The culture and leadership dimension focuses on the digital mindset, values and value creation, and the culture of collaboration, risk-taking, and failure. (4) The capabilities and HR competencies dimension focuses on reinventing the value chain and new business models, concentrating on new skills, resources, and capabilities. (5) The foresight and vision dimension focuses on seeing the future state of the organization in digital transformation through innovation and improvement. (6) The data and IT dimension focuses on the utilization of information and knowledge as key sources. (7) The operations dimension focuses on data-driven and digitally automated processes and operating model changes to increase efficiency. Finally, (8) the partner dimension focuses on networks and cooperation across company boundaries. The framework can be utilized to enable better digital strategy development and concept understanding.

To continue, a digital strategy will not achieve performance improvements without its effective implementation. In this way, companies translate the formulated digital strategy into concrete actions, which ensures consistency between actions and formulated goals (Correani et al., 2020). In addition, Chanias et al. (2019) pointed out that digital strategy is a continuous learning process in which formulation and implementation activities vary or even happen in parallel. Thus, digital strategy has been described as always in the making (Chanias et al., 2019; Lipsmeier et al., 2020), where data are utilized for continuous development (AlNuaimi et al., 2022).

To assist in the implementation of a digital strategy, Correani et al. (2020) studied three case companies and built a framework based on their analysis. The framework considers ten elements: scope; internal and external data sources; data platform; people; partners; artificial intelligence; information and knowledge; processes and procedures; transformed activities, tasks, and services; and customers. The scope tells the vision of how the company creates value for its customers and is defined by the goals related to the strategic formulation process. The company must also clearly define the data sources, platforms, and analytics required to transform data into information and knowledge. Additionally, it is crucial to consider the human aspect, involving both internal personnel and external partners, as new professional roles, skills, and capabilities may be needed for the successful implementation of the digital strategy. In addition, processes and procedures should be revised to enable companies to adapt to changes and seize opportunities. Finally, digitally advanced companies use these to their advantage to perform their core activities, tasks, and services efficiently and create superior value for customers. The authors conclude that two building elements (scope, customers) are related to companies' value proposition and market segments. The central part (data, data platform, AI, information and knowledge, people, and partners) includes the value chain structure of the digital business model, and transformed activities, tasks, and services represent the company's ability to "extract rent" from the value created.

As described above, digital technologies change companies' value creation by strengthening existing or redefining new value propositions (Gong and Ribiere, 2021, Vial, 2019). Companies must consider how the use of digital technologies can support their value creation activities (propositions, delivery, capture)—the business models—and connect the new sources of value creation and capture to their digital strategy (Bharadwaj et al., 2013). For example, Netflix started its digital transformation in 2000, changing its business from DVD rental and sales to a global streaming service for movies and series over the years (Margiono, 2021). Thus, digital transformation enables companies to create value in novel ways through the revision and extension of products and services, understanding customers' needs better, and increasing collaboration through digital platforms and ecosystems (Vaska et al., 2021). To support companies to succeed in digital transformation, the literature has recommended different strategic approaches and value creation paths (Berman, 2012; Li, 2020; Sebastian et al., 2017), where the digital strategy acts as a guideline. Also, it is noted that in digital transformation predefined paths and outcomes no longer exist; instead, they are frequently shifting, in which case the strategic paths must also be constantly updated (Li, 2020).

For example, Tekic and Koroteev (2019) identified four different digital transformation strategies: disruptive, business model led, technology led, and proud to be analog. These strategies consider two dimensions with high to low levels: the usage of digital technologies and the readiness of a business model for digital operations. These four strategic approaches differ from each other in terms of motivation and goals, management style, required skills, risks and challenges, and consequences of failure. In addition, Sebastian et al. (2017) presented two digital strategy types that managers can utilize to seize new technological opportunities: customer engagement and digitized solutions. The first strategy focuses on building customer loyalty and trust by providing a better customer experience, and the second is to reshape the value proposition by integrating the use of digital technologies into products and services.

Li (2020) suggested that instead of one large-scale and radical digital transformation, companies can use innovating by experimenting, radical transformation through incremental approaches, or dynamic sustainable advantages through an evolving portfolio of temporary advantage approaches. Through innovating by experimenting, companies can try ideas cheaply and then scale them up rapidly. In this approach, managers can use different experiments to re-evaluate the strategy and guide its implementation. Then, if companies choose to make radical changes, they should be planned and executed in a series of incremental steps. In this approach, smaller and more manageable investments are made to reduce risk, and the strategy is frequently developed and recalibrated. Finally, the author pointed out that competitive advantages are often temporary in digital transformation. Companies can achieve a dynamic sustainable advantage through an evolving portfolio, where new temporary advantages are introduced before old ones disappear.

Finally, Margiono (2021) presented two value creation paths for companies in digital transformation: offensive and defensive. The offensive path focuses on aggressively offering new value to new markets through investing in or acquiring start-ups or digitalizing existing businesses by transferring resources from acquired start-ups. The defensive path focuses on the organic growth of new capabilities within the company, thus slowly digitalizing existing products and services in old or new markets or developing new products in existing markets. The author continues that the strategic path a company chooses is related to several factors, such as obstacles, inertia, and financial resources in companies.

As Margiono (2021) noted, changes in value creation activities also require the consideration of other organizational factors. For example, Vaska et al. (2021) revealed through a literature review that digital transformation influences companies' core activities, competencies, capabilities, and roles, which companies should focus on when delivering value to customers. First, the use of digital technologies changes companies' core activities and processes, where digital technologies can provide new digital channels and collaborative platforms to interact with customers and partners (Vaska et al., 2021; Vial, 2019; Warner and Wäger, 2019). In addition, digital technologies enable more automated and smart production processes, data-based decision-making processes, and novel innovation processes (Holotiuk and Beimborn, 2017; Nambisan et al., 2017). Then, these new activities raise the question of developing the competence of existing managers and workers and consider the skills needed for future employees (Vial, 2019). Holotiuk and Beimborn (2017) pointed out the need for new digital competence in companies, such as IT skills, visioning, collaboration, and change management, to implement digital strategy successfully. Consequently, companies must identify the need for training and new talent.

To continue, Konopik et al. (2022) identified seven different themes of organizational capabilities for digital transformation, which were capabilities related to strategy and ecosystem, innovation thinking, digital transformation technologies, data, operations, organizational design, and digital transformation leadership. Also, Nasiri et al. (2020) identified digital-related capabilities, categorizing them into technical, human, innovation, and collaboration capabilities, which collectively propel companies toward digital transformation. Finally, in digital transformation, employees absorb new roles outside their traditional tasks and functions, for example, by participating in technology-focused projects (Vial, 2019). In addition, the creation of new leadership positions has been suggested, such as a chief digital officer, to signal the strategic role of digital transformation, which should have a combination of organizational, strategic, and technological experience (Singh et al., 2020; Vial, 2019).

In summary, as described, digital transformation affects companies' operations and business in multiple ways. To survive, companies should find ways to connect the use of digital technologies to their strategic approach to gain performance effects. These effects are the focus of the next section.

2.2 Digital transformation and the company's performance

Digital transformation internally influences not only companies' operations and business but also the collaboration and competitive landscape, where smaller and more agile companies challenge established players (Leão and da Silva, 2021; Li, 2020). Also, the literature has noted that digital transformation aims to improve performance for different stakeholders by utilizing digital technologies, as well as the organization's resources and capabilities (Gong and Ribiere, 2021; Leão and da Silva, 2021; Vial, 2019). Companies strive to increase their performance year by year, so investments in digital technologies can provide a solution by making products, services, and processes more efficient, inexpensive, and/or convenient (McGrath and McManus, 2020). For example, digital technologies have major implications for innovation processes, shaping how products, services, and processes are created and developed (Nambisan et al., 2017; Tsou and Chen, 2023). In addition, big data and analytics can support and speed up decision-making processes (Korsen and Ingvaldsen, 2022), digital platforms can facilitate collaboration (Reim et al., 2023), and real-time monitoring and control of processes may lead to better operational efficiency (Aheleroff et al., 2021). As stated earlier, the possibilities of digital technology are manifold, so it is important to look at its studied effects on company performance, including, for example, operational efficiency, innovativeness, financial performance, firm growth, reputation, and competitive advantage (Vial, 2019).

The use of digital technologies can potentially improve performance by improving the efficiency of products and services, supporting their continuous development, lowering barriers in and between industries, and supporting cooperation and information sharing in companies (Correani et al., 2020). The study of Leão and da Silva (2021) confirmed the multidimensional effects of digital transformation. They found 52 impacts of digital transformation and mapped them to five strategic domains: customer, competition, data, innovation, and value. In addition, the authors concluded four main impacts on companies' performance: innovation, efficiency, cost reduction, and supporting the implementation of value-adding products and services. On the other hand, speed is an important aspect of achieving a competitive advantage in digital transformation (Bharadwaj et al., 2013). This highlights the organization's ability to recognize and respond to the fast-paced nature of innovation, emphasizing the fast pace of product launches and the obsolescence of previous products (Correani et al., 2020).

Various researchers have also empirically demonstrated the influences of digital transformation on performance (e.g., Singh et al., 2021; Zhai et al., 2022). First, Nwankpa and Roumani (2016) revealed how companies' IT capability has a positive effect on digital transformation and how digital transformation mediates the influence of IT capability and companies' performance. Based on 167 responses from companies across the United States, the study concluded that IT capability is the driving force of digital transformation and achieving better performance. In addition, Singh et al. (2021) identified the antecedents of digital transformation: organization culture, competitive pressure, cognitive readiness, organizational mindfulness, strategic alignment, and IT readiness. They studied the effects of these antecedents on digital transformation and firm performance. Based on the 105 responses from Indian manufacturing companies, they found that competitive pressure, organizational mindfulness, strategic alignment, and IT readiness are significantly related to digital transformation and firm performance. In addition, digital transformation mediates the relationship between these antecedents and firm performance. They concluded that company performance can be developed by antecedents and digital transformation.

To continue, Zhai et al. (2022) studied Chinese companies and found that digital transformation had a positive effect on their financial performance. They observed that the benefits of digital transformation are reflected in better operating efficiency, lower costs, and innovation success, leading to better financial performance. In addition, they noticed that normal digital transformation supports companies' performance in the long term, while excess digital transformation occurs during the first two years, which should be considered in the company's strategic reviews. Finally, Teng et al. (2022) studied the influence of different resources (digital technology, employee digital skills, and digital transformation strategy) on digital transformation and financial performance. The study reveals that digital technology and employees' digital skills positively influence digital transformation. However, the digital transformation strategy had a positive mediating effect on performance, while this was not observed for digital technology and employee digital skills. Considering the results, the authors stated that in some companies the digital transformation is only at the beginning, when the performance effects are not observed; also, the epidemic and the effects of large companies in attracting talent make performance improvements difficult due to the lack of financial resources and talent with digital skills in SMEs.

However, digital strategy and its effects on performance should be examined more deeply as more and more companies are formulating and implementing digital strategies to shape the way they create value and remain competitive. Digital strategy requires companies to examine value creation paths and business models, enabling improved performance brought about by digital technologies (Correani et al., 2020). In addition, the digital strategy considers other factors, such as the technological environment, goals, resources, management capabilities, responsibilities, and roles (Konopik et al., 2022; Matt et al., 2015; Tabrizi et al., 2019; Ukko et al., 2019). Nonetheless, there is contradictory empirical evidence about the influences of digital strategy on performance.

According to Chi et al. (2018), a digital strategy improves company performance through e-collaboration capabilities. Since no direct effect was found related to digital strategy and firm performance, they propose that digital strategy affects operational-level performance first and then company-level performance. Also, the study suggests that a digital strategy prepares companies to build digital capabilities that add value to companies. Then, Ukko et al. (2019) noted that digital strategy in terms of operational and managerial capabilities does not directly affect financial performance but has to connect with the sustainability strategy to gain performance effects. Thus, they concluded that skilled managers foster companies' digital transformation by identifying opportunities and adapting to changes.

According to AlNuami et al. (2022), digital strategy does not moderate the relationship between digital transformational leadership, organizational agility, and digital transformation. They suggested that the reason may be that the participants were not included throughout the organization's strategy development process and digital technologies were only in the experimenting phase in the organization, which led to the fact that the benefits were not concretized. Thus, they concluded that a successful digital strategy requires various supporting elements, such as the alignment of the business model and the strategic evolution of the organization. Kurtz et al. (2021) noted that certain types of digital strategies especially had a positive effect on performance. These strategies focused on the processing of intellectual property and the orchestration of digital business ecosystems.

Finally, Tsou and Chen (2023) studied the relationships between the use of digital technologies, digital transformation strategies, organizational innovation, and their influence on company performance. They found that the direct effect of the use of digital technologies on performance was not significant in financial service firms. However, they concluded that companies can achieve better performance through the use of digital technologies when considering digital transformation strategies and organizational innovation mechanisms, mediating the relationship between digital technology and performance.

Research shows that the effects of digital strategy on performance are not clear-cut, but various other structural factors must be taken into account when achieving performance. In addition, the digital strategy mainly functions as a mediating or moderating actor and does not alone bring performance improvements to the company.

To continue, it is vital for the company to consider the challenges of digital transformation and its negative impacts on performance. It is estimated that even 66–84% of digital transformation projects fail (Libert et al., 2016), and the reward of digital transformation often takes time to materialize (Jardak and Ben Hamad, 2022). In the study by Sigari et al. (2021), only every fifth company managed to generate value through digital investments. However, failure in digital transformation can, on the other hand, threaten the company's ability to compete (Fitzegerald et al., 2014). Thus, complexity and high level of risk push companies to large-scale and radical digital transformation, hoping for the best (Li, 2020; McGrath and McManus, 2020), although often leading to an undesirable outcome.

The literature, such as Sigari et al. (2021), has noted different barriers to digital transformation in companies. For example, two significant barriers to digital transformation are organizational inertia and resistance (Vial, 2019). Also, for many companies, managers can act as obstacles to change, in which case the achievement of digital transformation is not considered important, reflecting a lack of urgency, strategy, and motivation (Fitzegerald et al., 2014). Companies also have challenges in the consistency of digital strategy formulation and implementation (Correani et al., 2020), or they may need new talent and skills to transform digitality (Holotiuk and Beimborn, 2017). If these obstacles are not solved, they can lead to negative performance effects during companies' digital transformation.

Thus, digital transformation can also have negative impacts on companies' performance, such as security and privacy problems (Vial, 2019). According to Kraus et al. (2021), these security threats appear as confidentiality concerns, data breaches, and disclosure of private information. In addition, digital transformation can cause stress and internal tension in the organization and employees due to, for example, its complexity, leading to a negative performance impact (Chen et al., 2016; Leão and da Silva, 2021). Kuhlmann and Heuberger (2023) studied digitalization in German local authorities and found that respondents generally saw digitalization as negative. They concluded that the main negative impacts of digital transformation are constant availability, technical problems, problems with software and service providers, additional processing time per case, the feeling of being controlled, and an increase in workload. Also, there are growing concerns about the issue of whether the use of digital technologies, such as artificial intelligence, will reduce jobs and incomes and thus increase inequality (Aly, 2020), and on the other hand, how the growing use of digital technologies will influence environmental sustainability (Lokuge et al., 2021). Finally, Jardak and Ben Hamad (2022) studied how digital transformation in terms of digital maturity influences a company's financial performance in Sweden and noted its negative effects on return on assets (ROA) and return on equity (ROE) and positive effect on Q of Tobin. The authors summarized that the negative performance effects may be due to the slow materialization of technological investments, poor digital transformation management, and low digital intelligence in companies.

To summarize, digital transformation is not an easy task for companies to handle. Thus, its integration with different management systems should be explored.

2.3 PMM in digital transformation

2.3.1 PMM as part of managing organizations

Performance measurement systems and performance management practices have been recognized as having positive effects on company operations in the form of efficiency and effectiveness (Neely et al., 1995). Performance measurement systems have received a lot of attention among researchers over the years (e.g., Koufteros et al., 2014), being a key element in developing and improving business performance (Najmi and Kehoe, 2001; Sharma et al., 2005) and utilizing different metrics to quantify the efficiency/effectiveness of action (Neely et al., 1995). Performance measurement is described as a process that covers the setting of goals and the collection, analysis, and interpretation of performance data (Melnyk et al., 2014) to assess the efficiency/effectiveness of an action (Bititci et al., 2015). In addition, performance management practices are needed to successfully manage companies by using performance measurement information and focusing on what is most important (Atkinson, 2012). For example, performance management practices include the processes in which the differences between the measured and desired results are evaluated and the critical differences between them are recognized, the various deficiencies are understood, and corrective actions are taken in relation to them, thus monitoring and controlling the development of performance (Melnyk et al., 2014). Thus, together, these two areas form a PMM system.

PMM through a lens of organization and management control

The basis of PMM lies in theories of organization and management control, but the fields have developed parallel (Bititci et al., 2018; Smith and Bititci, 2017). Management control systems are formal, information-based routines and procedures that managers use to maintain, develop, or change organizational practices and behaviors (Otley, 1999; Simons, 1994). The literature states that an organization is a dynamic entity that operates in a constantly changing environment and thus requires the basic structure of any control system: measure, compare, analyze, correct, and prevent (Bititci et al., 2018; Cardinal, 2004; Melnyk et al., 2014; Tessier and Otley, 2012). Considering the above, Bititci et al. (2018) describe PMM as a process of measuring what is important, reporting on those measurements, reviewing performance, and taking action, which together form a closed-loop control system. Furthermore, considering theories of organizational and management control, Simons (1994) identified four different levels of formal control systems that companies use for strategic change:

1. Belief systems used by managers to offer guidance related to values, purpose, and direction
2. Boundary systems used by managers to set clear boundaries and rules that must be followed, including policies, procedures, and codes of conduct
3. Diagnostic systems used by managers for feedback, monitoring, and revision while achieving defined goals
4. Interactive systems used by managers to engage subordinates in decision-making and focus on strategic uncertainties, including focusing attention, dialogue, and learning across the organization.

In addition, Tessier and Otley (2012) studied this framework and noted that managers have two types of central control at their disposal: social and technical controls. Social controls refer to control that appeals to emotional factors in employees, including values, beliefs, norms, and symbols and represents the controllable aspect of an organization's culture (Tessier and Otley, 2012). In addition, social control includes behavioral aspects, such as participation in decision-making, open sharing of information, and collaboration (Bititci et al., 2018). Technical controls, in contrast, are controls that determine how tasks are performed, characterized by a rational and planned approach. These controls encompass aspects such as business planning, goal setting, performance measurement, rules, procedures and policies, and standards (Bititci et al., 2018; Tessier and Otley, 2012). Considering these arguments, Bititci et al. (2018), Nudurupati et al. (2021), and Smith and Bititci (2017) stated that performance measurement can be viewed as a technical control mechanism and performance management as a social control mechanism being separate but complementary concepts. This is evidenced by the emphasis of performance measurement on a rational perspective, which involves setting measures and targets, as well as the systematic gathering, elaboration, analysis, and reporting of data (Atkinson, 2012; Melnyk et al., 2014; Neely et al., 2002). On the other hand, performance management is described as cultural and behavioral routines defining how to use the performance measurement system to manage organizational performance (Bititci, 2015).

Many companies develop and use performance measurement systems to efficiently orchestrate resources and support management (Koufteros et al., 2014). Managers have to make a choice about what kinds of measures and systems they want to use to evaluate their operations. However, it is stated that the performance measurement system must be a balanced and dynamic system that supports decision-making and gives a holistic view of the organization through information (Garengo et al., 2005; Neely et al., 2002; Taticchi et al., 2010). This is also reflected in the fact that the measures should be multidimensional, communicate financial and nonfinancial aspects, change over time if necessary, and focus on development rather than monitoring (Bourne et al., 2003; Folan and Browne, 2005). One of the most popular performance measurement systems is the Balanced Scorecard presented by Kaplan and Norton (1992), where performance is analyzed through four different perspectives: financial, internal business, innovation and learning, and customer. Other well-known measurement systems include the Performance Measurement Matrix, which integrates cost, non-cost, external, and internal perspectives (Keegan et al., 1989). Additionally, the Performance Prism is notable, taking into account perspectives related to stakeholder satisfaction, strategy, processes, capabilities, and stakeholder contribution (Neely et al., 2002).

PMM has also been found to have many consequences and advantages for companies (de Waal and Kourtit, 2013; Franko-Santos et al., 2012; Koufteros et al., 2014). For example, Franko-Santos et al. (2012) examined the consequences and classified them into three categories: people's behavior, organizational capabilities, and performance consequences. De Waal and Kourtit (2013) found that more effective management control enables a stronger process orientation and thus higher operational efficiency. Furthermore, they stated that by combining more effective management control with a strategic focus, it is possible to support the alignment of goals and processes with the strategy and achieve them proactively. However, a systematic use of PMM is needed

(Waal et al., 2009) to support managers in leading people (Ukko et al., 2007) and to achieve increased operational level and financial performance in the long run (Ukko, 2009). To conclude, Nudurupati et al. (2021) noted that companies are moving toward an interactive, open, and inclusive use of performance measures, shifting the purpose of performance measurement from monitoring and control to commitment and development, thus emphasizing the role of interactive and belief systems, i.e., the mechanism of social control. In addition, Guenther and Heinicke (2019) noticed that social control becomes more prominent compared to technical control, especially as company size increases due to complexity.

PMM is highlighted as a social phenomenon that is affected by the feelings and beliefs of individuals, organizations, communities, and society, alongside a technical measurement perspective (Bititci et al., 2012). According to Smith and Bititci (2017), organizations should find an appropriate balance between social and technical mechanisms to improve employee engagement and performance. Finding a balance is also important when responding to ongoing business trends, such as digital transformation (Nudurupati et al., 2021). In summary, PMM should focus on the coexistence and interaction of social and technical perspectives in changing business environments. For this reason, the impact of strategy and digital transformation on PMM should be examined in more detail.

PMM through a strategic lens

PMM research has addressed its contradictory effects on organizational performance (Guenther and Heinicke, 2019). However, it appears that PMM systems do not automatically improve company performance but are influenced by their design, development, and use to achieve performance benefits (Franko-Santos et al., 2012). The performance measurement system represents a set of measures to describe the company's actions and overall performance (Neely et al., 1995), so it has been established that the measures should reflect the company's strategy and its transformation into daily business operations (Endrikat et al., 2020; Franko-Santos et al., 2012; Guenther and Heinicke, 2019; Lucianetti et al., 2019). In addition, PMM can be used in different ways. Considering the strategic perspective and management control theories, the interactive use—performance management practices as a social control—focuses on strategic uncertainties and enables the creation of new strategies (Guenther and Heinicke, 2019; Simons, 1994). In turn, the diagnostic use—performance measurement as technical control—focuses on critical performance measures and helps implement existing strategies (Guenther and Heinicke, 2019; Simons, 1994).

To continue from the strategic perspective, PMM has been found to support *strategy formulation,* enabling assessment of strategy adequacy and thus encouraging managers to understand and praise strategy as a continuous process (Franco-Santos et al., 2012; Guenther and Heinicke, 2019; Yuliansyah et al., 2019). The performance measurement literature has shown that companies should design a more comprehensive PMM system, such as the Balance Scorecard (Kaplan and Norton, 1992) or performance hierarchies (Lynch and Cross, 1991), to gain performance effects (e.g., Franko-Santos et al., 2012;

Hall, 2008; Lucianetti et al., 2019). According to Franko-Santos et al. (2012), a comprehensive PMM system connects the use of financial and nonfinancial performance measures to business strategy in companies, which can support the creation of value for the company’s various stakeholders. Hall (2008) studied a comprehensive performance measurement system and described it as having the following characteristics: (1) it consists of a diverse set of measures, (2) it is linked to the organization’s strategy and goals, and (3) it provides information about the entire value chain across functional boundaries. Lucianetti et al. (2019) stated that a more comprehensive PMM system design clearly visualizes the links between performance measurement perspectives through the strategy maps, emphasizes the integration of strategic goals and performance measures, and targets PMM system design for employees rather than management.

PMM has also been recommended to facilitate *the implementation of a strategy* to improve organizational performance (Franko-Santos et al., 2012; Koufteros et al., 2014; Melnyk et al., 2014; Micheli and Muctor, 2021). PMM can strengthen the strategic focus, develop and clarify the communication of the strategy, and thus commit people to strategic goals through shaping behavior (Endrikat et al., 2020; Franko-Santos et al., 2012; Garengo et al., 2005). Lucianetti et al. (2019) noted that a more comprehensive PMM system design has a positive effect on the organization’s efficiency in relation to the aligning of the business strategy in the organization. Strategy combined with PMM systems provides guidance and supports management decision-making by converting strategy into performance measures (Choi et al., 2012). In addition, strategic PMM has manifold consequences for organizations by influencing behavior, capabilities, and performance (Endrikat et al., 2020; Franko-Santos et al., 2012). For example, PMM enables strategy implementation by facilitating the translation of the strategy into operational terms and supports organizations in aligning their operations with strategic goals.

To continue, PMM is considered an important means of improving performance by supporting strategic alignment, resource management, and feedback (Bourne et al., 2018; Koufteros et al., 2014). It also supports management in envisioning new ways to organize the organization’s resources in pursuit of a competitive advantage (Koufteros et al., 2014). Thus, strategic PMM has been stated to have a positive effect on *strategy alignment, review, and development* processes (Endrikat et al., 2020; Franko-Santos et al., 2012). In addition, strategic PMM influences behavior, such as managers’ cognition and motivation, and thus indirectly affects management performance (Hall, 2008). Finally, according to Melnyk et al. (2014), PMM should align with business strategy, organizational culture, and external environment to be effective. This is reflected in the fact that changes in the external environment should be reflected in the strategies, and accordingly, strategic changes should affect the PMM system. They stated that this is not an easy task, as it takes time to formulate strategic changes into measures, communicate them within the organization, and adapt changes to change behavior. However, a skillfully tailored PMM system plays a significant role in improving the company’s market position by supporting learning and thus the success of companies (Yuliansyah et al., 2019).

Finally, digital transformation changes the external environment of companies, which is reflected in companies' strategies and all the way to companies' PMM systems. Therefore, the impact of digital transformation on PMM should be studied.

2.3.2 PMM undergoing digital transformation

Digital transformation requires companies to critically examine operations and practices beyond their core competencies. PMM has often been studied in stable business environments, and its ability to steer the strategic direction in turbulent environments has been questioned (Melnyk et al., 2014). Companies need controls that enable them to manage uncertainty and support in finding new strategies (Guenther and Heinicke, 2019). In a digital environment, PMM can even be harmful to companies, emphasizing monitoring and control instead of learning (Bourne et al., 2018; Neely and Najjar, 2006). Thus, undergoing digital transformation brings challenges to PMM, as constant change forces it to be more dynamic. The new requirements also require more efficient technological solutions for the implementation of PMM systems. For example, companies must be able to process different varieties and volumes of data to create a competitive advantage (Nudurupati et al., 2016). To apply PMM to complex and uncertain environments, new ways of seeing and understanding its role in companies are needed (Bourne et al., 2018; van Oorschot et al., 2023).

Recent literature on PMM has emphasized the need to step away from control and command toward a more empowering management style, where decision-making power and information are shared, and a culture of trust is cherished (Nudurupati et al., 2021; Robert et al., 2020; Sardi et al., 2019). The development of digital technologies can offer a solution to this by shaping the role of PMM in organizations (Korsen and Ingvaldsen, 2022). According to Nudurapati et al. (2021), companies respond to different business trends by adapting and actively participating in PMM. This adaptation often involves a concentrated emphasis on communication, engagement, reflection, and learning. In addition, Bourne et al. (2018) noted that PMM can be conceptualized as a system of systems, functioning as a metasystem comprising diverse and complex subsystems related to context, geography, technology, operation, and conceptual framework. They suggest that this approach is a viable option for implementing PMM in uncertain and complex environments, as it facilitates learning, adaptation, and navigation toward predefined goals.

Several studies have stated that the use of digital technologies should be connected to existing PMM systems (Korsen and Ingvaldsen, 2022; Ravelomanantsoa et al., 2019; Vallurupati and Bose, 2018). This can be viewed from two perspectives: (1) connecting the use of digital technologies to the company's strategy and goals (Section 2.1) and then monitoring and managing them using PMM and (2) the effects of digital technologies on the more efficient implementation of PMM systems themselves. Digital technologies can support the automation of data collection and analysis, ensuring data reliability, enabling effective visualization, and providing real-time updates. This, in turn, ensures that information is readily accessible throughout the organization (Korsen and Ingvaldsen, 2022; Ravelomanantsoa et al., 2019; Ukko et al., 2022). Thus, advances in digital technology have been noticed, and their effects on PMM systems should be examined more closely.

Examining the adoption of PMM systems through digital technologies, Frank et al. (2019) defined them as base technologies—big data, cloud, IoT, and analytics—which create the basis for the use of front-end technologies and support the development of PMM in companies (Korsen and Ingvaldsen, 2022). In brief, the IoT connects sensors and computers in an internet environment, the cloud enables access to information and virtual representations regardless of time and place, big data can be used to capture a large amount of data, and analytics supports the analysis of this data. Companies do not necessarily know how to integrate these technologies into a PMM system, and, for example, Vallurupati and Bose (2018) proposed a detailed explanation of the implementation of the digitally enabled PMM system covering the six phases: initiation, adoption, adaption, acceptance, routinization, and infusion.

In the context of digitally enabled PMM, IoT technologies can be used to facilitate real-time monitoring and control of a machine, a process, or the entire supply chain, offering the opportunity to develop the organization's agility with fast and intelligent decision-making based on real-time data (Dweekat et al., 2017; Parmar et al., 2020; Zhong et al., 2017). Reinking et al. (2020) studied strategically aligned cloud-based digital dashboards that were used through smartphones, tablets, or laptops and found their impact on managerial and organizational performance. For example, digital dashboards help managers understand the impact of their performance on strategic goals and thus indirectly can influence companies' performance. Sardi et al. (2020a) concluded that the use of big data as part of the PMM system can support the achievement of a competitive advantage; however, strategic use of it is often missing. He continues that companies need systems that can transform diverse and large amounts of data into simple and comprehensive performance measures for monitoring, learning, and strategic decision-making. Finally, digital twins have been studied to support performance improvements through their many features; for example, through data collection and analytics, customer behavior can be studied to achieve a better customer experience (Parmar et al., 2020). Bredmar (2017) noted that with digital development, resources and performance can be monitored in the manner of micro-management, and then unsatisfactory performance can be corrected immediately. They continue that systems based on data analytics can redefine goals as the organization learns and evolves. Therefore, the discussion on the interconnection of PMM and digital technology is timely and appropriate and supports the success of companies in a changing environment (Ravelomanantsoa et al., 2019).

The digitalization of PMM systems has been noted to reinforce empowerment as an organizational culture and management style instead of controlling (Korsen and Ingvaldsen, 2022; Robert et al., 2020; Sardi et al., 2020). Sardi et al. (2019) suggested that a web-based platform can, for example, enable communication between employees, as well as real-time measurement to support participatory performance management. Other studies, such as Robert et al. (2020), have stated the benefits of digital technology in PMM, appearing, for example, as transparent performance measurement information, distribution of responsibility, empowerment, and motivation in the organization leading to the continuous development of a company's performance. With the help of new types of PMM system functionalities, such as real-time and visualization (Holopainen et al., 2021), the challenges of more dynamic and complex operating environments can also be met through the rapid reactive ability of PMM system (Horváth and Szabó, 2019; Ravelomanantsoa et al., 2019). Finally, implementing digital dashboards and integrating them into PMM systems enables interactive management control and operational-level strategy alignment (Reinking et al., 2020). The positive impact of digital technologies and related capabilities on social and technical control mechanisms are also noted (Nasiri et al., 2020; Ukko et al., 2022). Thus, studies have shown the beneficial effects of integrating digital technologies into PMM systems and should therefore be studied more closely in the context of strategic management (Bredmar, 2017).

2.4 Conceptual framework

The use of digital technologies is a main ingredient of digital transformation (Tekic and Koroteev, 2019), where companies are looking for new ways to operate and generate value (Westerman, 2018). As Tabrizi et al. (2019) noted, digital transformation is more than just exploiting as many digital technologies as possible but must be thought of as an integrated way with business at a strategic level (Teubner and Stockhinger, 2020). Thus, companies should consider their strategic readiness to leverage digital technologies in their operations and business, which describes organization-wide preparedness for comprehensive change (Koh et al., 2006; Redding and Catalanello, 1994). In addition, such changes require companies to adopt a digital strategy to address their attitude and ability to exploit these technologies (Bharadwaj et al., 2013; Matt et al., 2015). A digital strategy describes companies' overall vision in digital transformation (Lipsmeier et al., 2020) and defines the technological environment (Konopik et al., 2022; Sousa-Zomer et al., 2020), goals (Li, 2023; Lipsmeier et al., 2020), resources (Hess et al., 2016; Matt et al., 2015), management capabilities (Holotiuk and Beimborn, 2017; Ukko et al., 2019), and roles and responsibilities (Correani et al., 2020; Singh et al., 2020).

To continue, digital transformation means a fundamental change in companies' value creation (Gong and Ribiere, 2020; Vial, 2019), where companies choose between different strategic value creation paths (e.g., Berman, 2012; Margiono, 2021; Tekic and Koroteev, 2019). The changes in value creation activities also require consideration of structural factors (Vaska et al., 2021), providing a basis for the use of digital technologies. On the other hand, barriers, such as inertia and financial resources, affect the company's chosen strategic path (Margiono, 2021; Sigari et al., 2021) and may need to be solved to gain performance effects in digital transformation. Thus, the use of digital technologies can potentially improve companies' performance by improving internal efficiency (Aheleroff et al., 2021; Correani et al., 2020), competitive advantage (Leão and da Silva, 2021; Vial, 2019), customer experience (McGrath and McManus, 2020), innovation (Leão and da Silva, 2021; Zhai et al., 2022), and collaboration (Correani et al., 2020;

Reim et al., 2023), and finally reflecting as an increase in financial performance (Zhai et al., 2022; Teng et al., 2023). To manage the use of digital technologies in digital transformation and achieve strategic goals related to performance, these changes should be connected to the company's PMM systems (Franko-Santos et al., 2012; Guenther and Heinicke, 2019; Lucianetti et al., 2019).

Taking into account the above-mentioned perspectives, the conceptual framework of the study is depicted in Figure 3. It shows the connection between the research concepts and clarifies the understanding of the study results.

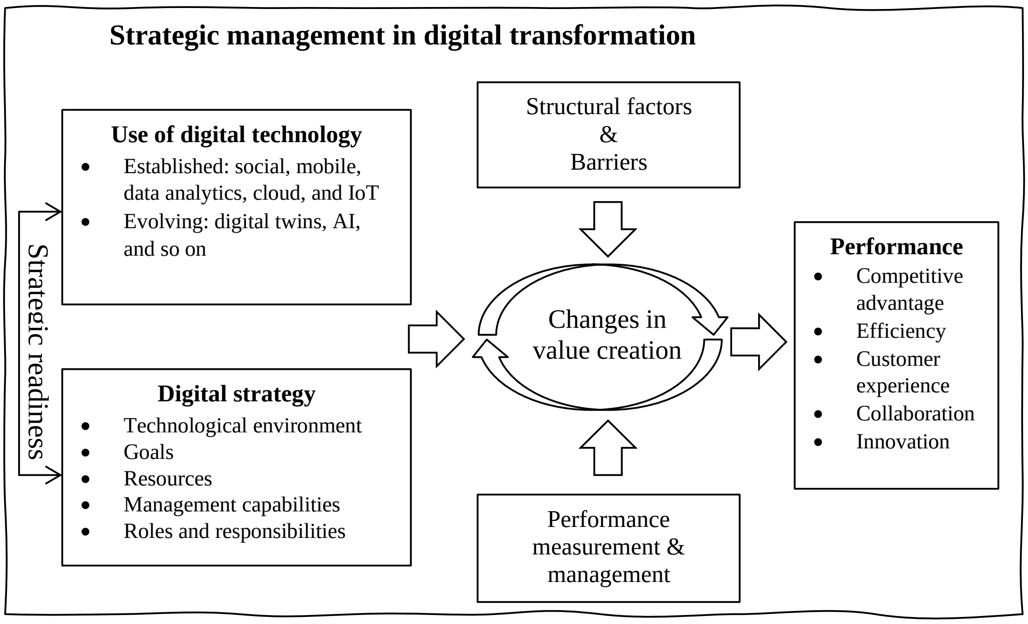

Figure 3. The conceptual framework: how to manage performance in digital transformation.

3 Methodology

3.1 Introduction to the research approach

The research approach describes research plans and procedures, including broad philosophical assumptions, but also detailed data collection, analysis, and interpretation methods, and is based on, for example, the research problem, the addressed issue, and the researcher's personal experiences (Creswell, 2014). To start designing the research, being the overall plan of the research, the philosophical worldview assumptions, i.e., research philosophy, should be considered and identified. Research philosophy is described as a belief and assumptions related to the development of knowledge (Saunders et al., 2015) or the belief that guides action (Guba, 1990), contributing different ways to management research (Saunders et al., 2015). The beliefs and assumptions in research are interconnected with the reality encountered by researchers, human knowledge, and the influence of values on the research process. These are often categorized as ontological, epistemological, and axiological assumptions in research (Saunders et al., 2015).

According to Saunders et al. (2015), research ontology is related to assumptions that consider the nature of reality and shape the way the researcher sees and studies different objects. It concerns questions about the characteristics of existence/reality (Nayak and Singh, 2021). Various ontological positions exist, with examples including objectivism, which asserts that the reality being studied is external and independent of our perceptions, and subjectivism, which posits that reality is constructed through perceptions and shaped by social activities (Saunders et al., 2015). In turn, research epistemology involves assumptions about knowledge—what constitutes rightful and valid knowledge and how it can be communicated to others (Saunders et al., 2015). It forms the foundation for research, addressing questions about what we can know about reality and the methods through which we can acquire that knowledge (Nayak and Singh, 2021). For example, epistemological considerations may involve assumptions about whether knowledge is derived from measurable facts and numbers (objectivism) or individual perspectives and narratives (subjectivism) (Saunders et al., 2015). Therefore, ontology (concerning the nature of reality) and epistemology (related to knowledge about reality) are intertwined (Crotty, 1998). Finally, research axiology refers to the role of values and ethics in the research process, examining how they influence the research (Saunders et al., 2015). Objectivism, for example, posits a value-free role, suggesting that values can introduce bias into the results.

Research design is influenced by mental models or frameworks, which are belief systems that guide research reasoning and observations, and are called paradigms (Nayak and Singh, 2021). To guide the research, Creswell (2014) named four main paradigms related to how the world can be viewed: postpositivist, constructivism, transformative, and pragmatism. On the other hand, Saunders et al. (2015) introduced five major philosophies in the business and management context: positivism, critical realism, interpretivism, postmodernism, and pragmatism. These differ from each other concerning ontological, epistemological, and axiological assumptions but also affect the understanding of the research question, used methods, and interpretation findings. Moreover, research is guided by theory and its approach to theory development, which can be inductive, deductive, or abductive (Saunders et al., 2015). The inductive approach goes from specific to general, reflecting that theory follows the data, the deductive approach is about going from general to specific, where theory is tested using empirical data, and finally, the abductive approach goes back and forth (theory to data and data to theory) combining theory building and theory testing approaches (Ketokivi and Choi, 2014; Nayak and Singh, 2021; Saunders et al., 2015).

To continue designing the research, the research approach must consider the methodology and methods, whose choice is guided by ontological and epistemological assumptions (Nayak and Singh, 2021). The methodology is described as "a research strategy that translates ontological and epistemological principles into guidelines" (Nayak and Singh, 2021, p. 11), as a systematic way to solve a problem (Rajasekar et al., 2013) or theoretical analysis of the methods (Igwenagu, 2016). These guidelines indicate how research should be conducted and the principles, procedures, and practices that guide the research, including different concepts such as paradigm, theoretical model, phases, and quantitative/qualitative techniques (Igwenagu, 2016; Nayak and Singh, 2021). To conclude, the methodology provides a theoretical understanding of the methods used (Igwenagu, 2016), while the methods are related to the techniques used to gather evidence (Nayak and Singh, 2021).

According to Saunders et al. (2015), the first methodological choice is related to which three research designs are followed: qualitative, quantitative, or mixed methods. Creswell (2014) continues that a qualitative research approach is usually used to investigate the meanings given by individuals/groups to a social problem, where data are collected from the participant's environment, data analysis inductively builds from details to general themes, and the researcher makes assumptions about the meaning of the data. The quantitative approach, on the other hand, focuses on testing objective theories by studying the relationships between variables, where numerical data are analyzed using statistical methods, data analysis involves testing theories deductively and building protection against bias, and the researcher must control alternative explanations and generalize and repeat results. Finally, the mixed-methods research approach contains both qualitative and quantitative data collection techniques and analytical methods to provide a comprehensive understanding of the research problem. The way qualitative and quantitative phases are combined can be called, for example, concurrent, sequential exploratory, sequential explanatory, and sequential multi-phase mixed-methods research designs, and they can include inductive, deductive, or abductive approaches to theory development (Saunders et al., 2015). In the next sections, the philosophical and methodological choices of the dissertation, including different data collection and analysis techniques, are described in more detail.

3.2 The chosen research approach

The research approach is coherent if it is ensured that the philosophy of the research underlies the methodological choices, research strategy, data collection, and data analysis methods. This is presented in Table 1. First, the research follows pragmatism assumptions, which are not committed to one system of philosophy and reality, and is suitable for mixed-methods research, where researchers use quantitative and qualitative approaches in their research (Creswell, 2014). According to pragmatism, research begins with a problem to which the aim is to find answers, and concepts are only meaningful when they support action (Saunders et al., 2015).

According to Creswell (2014), this philosophical view is characterized by the fact that it is not tied to a single philosophical system or reality; rather, the research problem is emphasized and there is the freedom to choose the research methods and procedures to meet the research goals. In addition, the world is not seen as an absolute unity in this worldview, and the truth is related to what works at that moment, and not so much whether the truth is formed separately from the mind or in the mind. Finally, the worldview confirms that research happens in social, political, and other contexts. Thus, the author concludes that pragmatism opens up possibilities to use multiple methods, different worldviews and assumptions, and forms of data collection and analysis. Saunders et al. (2015) conclude that ontology, through pragmatic assumptions, is complex, rich, and external and also includes the practical consequences of ideas. On the other hand, the authors continue that epistemology describes that knowledge is what enables successful action, focusing on problems, practices, and relevance. In other words, through pragmatism, truth and knowledge are verified through experience and practice (Creswell, 2014). Finally, axiology is value-driven, where the researcher’s doubts and beliefs initiate and sustain the research (Saunders et al., 2015).

Pragmatism emphasizes the research problem instead of methods, thus underpinning mixed-method research (Creswell, 2014; Saunders et al., 2015). The mixed method approach was utilized because it can be seen that both qualitative and quantitative approaches contain biases and shortcomings that this approach aims to address (Williams, 2007). As described in more detail, the dissertation utilized a concurrent mixed method, which involves separate use of both qualitative and quantitative methods within a single phase of data collection and analysis (Saunders et al., 2015). The approach enables a comprehensive and more versatile answer to the research questions compared to mono-method designs.

To continue, this study utilized an abductive reasoning approach to theory development, moving back and forth from one research activity to another and also between theory and empiricism (Dubois and Gadde, 2002). Abduction is a process that aims to infer something from unobserved causes of events, suggesting a plausible explanation or hypothesis (Sætre and Van de Ven, 2021; Schurz, 2008). In addition, in the context of management research, abduction involves the creation and evaluation of ideas (Ketokivi and Choi, 2014; Sætre and Van de Ven, 2021).

A research strategy describes a plan to answer the research questions (Saunders et al., 2015). The dissertation uses multiple sources of evidence to approach the research problem (Yin, 2018). In more detail, the data were collected through two multiple case studies and one survey, each of which provided a separate set of evidence. Since each method reveals different aspects of empirical reality, using several methods and multiple cases in data collection and analysis provides additional evidence to answer the research problem (Patton, 1999). Finally, the research can be labeled cross-sectional because it studies a certain phenomenon at a certain time (Saunders et al., 2015; Williams, 2007). Next, the implementation of these will be examined more closely.

Table 1. Summary of the research approach.

Philosophical worldview	**Approach to theory development**	**Research design**	**Research strategy**	**Time horizon**
Pragmatism	Abduction	Concurrent mixed method	Multiple case studies and survey	Cross-sectional

Philosophical assumptions		
Ontology	Epistemology	Axiology
Complex and external, multiple perspectives can be chosen that enable the best answer to the research question	*Depending on the research problem/question, both subjective meanings (opinions, narratives) and observable phenomena (facts, numbers) are able to form the knowledge*	*Value plays a main role when interpreting results; the researcher relies on both subjective/objective points of view*

3.3 Data collection and analysis

3.3.1 Case study approach

A case study approach can be considered an empirical study that primarily uses contextual data in limited real-world contexts when investigating a certain phenomenon (Barratt et al., 2011). It is used to study an event, activity, or individual in depth to learn more about a little-understood situation (Williams, 2007). In addition, this approach is usually used to aim theory development or building where mostly qualitative data are collected to develop testable and relevant theories, thus producing, for example, propositions or conceptual frameworks as a final product (Barratt et al., 2011; Eisenhardt, 1989). In the qualitative phase, the dissertation used a multiple case study approach with holistic cases (Yin, 2018) and inductive reasoning (Barratt et al., 2011). The approach was chosen to enable the exploration of differences within and between cases and thus provide a deep and versatile understanding of the research phenomenon in multiple situations (Crowe et al., 2011; Yin, 2018). In addition, multiple case studies were chosen instead of single case studies to create stronger results for theory building (Barratt et al., 2011; Eisenhardt, 1989). Using the case study classification of Ketokivi and Choi (2014), the chosen approach can be classified as a theory-generating case study (instead of theory testing and theory elaboration), in which several cases were exploited to pursue theoretical generalizations by analyzing similarities and differences between cases (Ketokivi and Choi, 2014). Also, features of the theory-elaborating approach can be identified because the findings are shaped by predetermined theoretical frameworks (Ketokivi and Choi, 2014). To continue, the process of building/generating theory from a case study is highly iterative (Eisenhardt, 1989), where a maintaining chain of evidence is a principle to increase the construct validity (Yin, 2018); i.e., researcher questions should reflect the later phases of study, such as data collection and findings. In this approach, data were collected with two different interview protocols as the main sources of evidence. Both interviews were carried out as semi-structured interviews, and their exact structure is presented in Appendices A and C. The next section presents the data collection and analysis phase of both case studies.

Multiple case study 1 related to Publications I and II

The study used a multiple case study approach (Yin, 2018), which aimed to create knowledge concerning managing company performance in digital transformation through empirical analysis (Ketokivi and Choi, 2014). Case companies were selected based on the following inclusion criteria: representing companies of various sizes and operating in different industries, having ongoing digital initiatives, and being able to provide relevant information about them. Additionally, the interviewees were required to possess awareness regarding the utilization of digital technologies in different organizational areas within their respective companies. In addition, companies of varying maturity levels related to digital transformation were deliberately chosen. This selection encompassed firms operating in technologically advanced sectors, as well as more conservative companies in industries such as clothing and furniture. Choosing companies of different sizes and maturity levels as polar-type cases helped in comparative cross-case analyses (Eisenhardt, 1989). In total, six small and medium-sized enterprises (SMEs) and five large companies with 18 interviewees participated in the study. The SMEs met the criteria of having less than 250 employees, a turnover below 50 million euros, and/or a balance sheet total less than 43 million euros. The details of the case companies are presented in Table 2.

Data were collected through open-ended interviews with predefined themes presented in Appendix A. This was the main source of data. The interviews were conducted in August–November 2019 by one researcher, and they lasted between 50 and 90 min. This approach ensured the consistency of the interviews. The interviews were recorded and transcribed to ensure the analysis phase. In addition, in some companies, the company visits and observation ensured information gathering. Additional information was asked by email if clarifications were needed or if some information was missing. Finally, companies' backgrounds were also collected and studied, impacting case selection and research design. Thus, using multiple sources of evidence in a data collection phase—data triangulation—increased confidence that the cases presented the studied phenomenon accurately (Patton, 1999; Yin, 2018).

Table 2. Details of interview 1.

Company	Operating industry	Size	Interviewees
A1	Engineering	Large	Process technology manager Product manager
B1	Welding	Large	Chief digital officer
C1	Engineering	Large	IT manager
D1	Technology	SME	Maintenance director
E1	Chemicals	SME	Production manager Product development chemist
F1	Furniture	SME	CEO Product manager
G1	Plastics	SME	Executive vice president
H1	Construction	SME	Factory manager CEO
I1	Clothing	SME	CEO
J1	Wood processing	Large	Development director Factory manager Project engineer
K1	Technology	Large	Production manager Factory manager

After completing the data collection phase, the study transitioned to the analysis phase. The data were analyzed using content analysis, where built frameworks based on literature serve as a predetermined coding scheme. Considering the dimensions and themes of the frameworks, the data were coded through an iterative process, collecting and filtering information from these subject areas. Traditional word processing tools, Word and Excel, were used to organize the findings by subject area. If interesting perspectives emerged from outside the themes, they were also analyzed. The analysis unit was companies, focusing on the use of digital technologies in their operations and related themes. Establishing a sufficient case study database also supported the implementation of the following analysis steps (Yin, 2018): within-case and cross-case analyses (Eisenhardt, 1989). First, within-case analyses were used to examine how an individual company approaches digital transformation and what kind of strategic mechanisms are involved. Then, with the help of the cross-case analyses, repeated patterns were found between the case companies. The analyses were carried out by one researcher, after which they were discussed and specified with the group of researchers. The discussion enabled different perspectives and developed insights (Eisenhardt, 1989). Consensus on the final findings and propositions of the study was achieved and formulated through the cognitive process at the conclusion of this process.

Multiple case study 2 related to Publication V

The second multiple case study concentrated on the use of digital twins in companies, especially in innovation activities. The case selection followed three criteria: companies have initiatives to develop or implement digital twins, they allow access to relevant information related to digital twins, and interviewees should be aware of the role of digital twins in their companies. In total, six companies with 14 participants were selected for the study, which presented users and providers of digital twin solutions and SMEs and large companies. The selection made it possible to compare and replicate these groups and their features (Eisenhardt, 1989). SMEs met the criteria of having fewer than 250 employees, a turnover below 50 million euros, and/or a balance sheet total less than 43 million euros. In addition, the selection of interviewees from different units and levels allowed multiple views regarding the use and implications of digital twins. The details of the selected cases are presented in Table 3.

Table 3. Details of the case companies related to multiple case study 2.

Company	Operating industry	Size	Interviewees
A2	Technology	SME	CEO
B2	Metal	Large	Chief digital officer Product development manager Product development director
C2	Engineering	Large	Development manager Product development manager Business line manager Director of products, technologies, and R&D
D2	Technology	SME	Chief digital officer Customer project/production manager
E2	Technology	Large	Investigator Software business manager/development direction Data model specialist Research team leader
F2	Technology	SME	Chief digital officer R&D director Business director

The data were collected with open-ended interviews with predefined themes based on the literature. The themes and open questions are presented in Appendix C. The discussion mainly focused on the current use of digital twins and the possibilities for future use. In addition to the themes, a discussion outside of these was also made possible if additional questions or thoughts arose. As a result, the interviews offered diverse views on how digital twins can be utilized in the context of innovation. The interviews were conducted with multiple researchers in 2020. Using multiple researchers as investigators reduced potential bias (Patton, 1999). The interviews lasted from 60 to 90 min. They were also recorded and transcribed to ensure the analysis phase.

As described, the data collection focused on predefined dimensions based on the literature, but analysis of the empirical evidence shaped the findings (Eisenhardt, 1989).

In the analysis phase, similarities and differences between cases were analyzed to pursue theoretical generalizations (Ketokivi and Choi, 2014; Yin, 2018). The unit of the analyses was a company related to its experience with digital twins. Predefined themes (scopes of innovation) helped in the coding of the collected data using Word as a tool. These content analyses were performed by multiple researchers, decreasing the bias (Patton, 1999). This enabled within-case and cross-case analyses (Barratt et al., 2011; Eisenhardt, 1989), which were performed by a single researcher. The researcher had not participated in the former phases (data collection or content analysis), which enabled a more objective examination of the evidence (Eisenhardt, 1989). The within-case analyses concentrated the detailed information on how companies were utilizing digital twins and related innovation mechanisms, allowing unique patterns to arise, and then cross-case analyses identified the repetitive patterns between case companies. After the analyses, a discussion between four researchers was made; thus, using the multiple evaluators of the preliminary results increased the creative potential of the study (Patton, 1999). These different phases produce the final findings and proposals of the study, which guided the building of the study framework (Eisenhardt, 1989).

3.3.2 Survey

The survey is used to give a quantitative description of the opinions, attitudes, or trends of the population by examining a sample taken from it (Creswell, 2014). The survey focused on SMEs operating in Finland. They were randomly selected, and the data were collected from September to October 2021. In detail, the survey was distributed through a linked email sent to the selected companies. After this, three reminders were sent to enable as many companies as possible to respond to the survey; thus, the data collection was carried out in four waves. As a result, 205 responses were received, of which 202 were considered valid. Most of the companies that participated in the research were small companies with a turnover of 2–10 million. The companies operate nearly equally in the service and manufacturing industry, and their main customers are the business-to-business (B2B) sector. In addition, 95.6% of the survey respondents work in a senior management role. The demographic of the respondents is presented in more detail in Table 4.

Table 4. Demographics of the studied companies.

Information categories	Details	Quantity/percentage
Role of respondents	Senior management	197/95.1%
	Middle management	6/2.9%
	Personnel	3/1.5%
	No response	1/0.5%
Operating industry	Manufacturing	97/47.3%
	Service	106/51.7%
	No response	2/1.0%
Customer sector	Business-to-business	172/83.9%
	Business-to-customer	28/13.7%
	No response	5/2.4%
Size of the company (turnover)	Small (under 2 million)	18/8.8%
	Medium (2–10 million)	139/67.8%
	Large (over 10 million)	48/23.4%

The research was related to digital strategy and its influences on PMM and collaboration performance. The study instruments were developed from the literature and are presented in Table 5. In both publications (Publications III and IV), digital strategy was the independent variable with five dimensions. These dimensions consisted of two to three items, and every one of them was assessed with a seven-tier Likert scale, varying from totally disagree to totally agree. The naming of the dimensions varied slightly in different publications: understanding/development, goals/objectives, resources, management/management capabilities, and responsibilities/digital leadership. The description of the items is presented in Appendix B.

The dependent variables were PMM (Publication III) and collaboration performance (Publication IV). The PMM consisted of seven items and was measured with a seven-tier Likert scale. The collaboration performance consisted of only one item and was measured with a 1–4-point scale. In addition, the digitally enabled performance measurement acted as a moderator in Publication IV, consisted of one item, and was measured with a 1–7 Likert scale. Finally, different control variables were used to ensure that different company-specific factors did not significantly affect the results. These were the customer group (B2B/B2C), the industry (service/manufacturing), and the turnover (small/medium/large).

Table 5. Study variables and items including independent and dependent variables, moderator, and different control variables.

Variables	Items (Appendix 2)	Scale
Independent variables		
Digital strategy		1–7 Likert scale
Technological understanding/development	(7) Technological awareness, (8) ongoing projects, (9) achieving competitiveness	
Goals/objectives	(10) Goal setting, (11) monitoring, and	
Resources	(12) the ability to implement	
Management/management capabilities	(13) Financial, (14) time, and (15) knowledge-skills resources	
Responsibilities/digital leadership	(16) Awareness, (17) ability, and (18) enthusiasm	
	(19) Appointment and (20) experience/skills of a responsible person	
Dependent variables		
PMM	(21) Use of PMM, (22) provide information, (23) monitor results related to goals, (24) report information, (25) support decision-making, (26) support development, and (27) impact personnel	1–7 Likert scale
Collaboration performance	(29) Collaboration with external parties	1–4 Likert scale
Moderator		
Digitally enabled performance measurement	(28) performance measurement combined with digital strategy/digital operations	1–7 Likert scale
Control variables		
Operating industry	(2) Service/manufacturing	1/2
Turnover	(3) Actual amount	1/2/3
Customers	(4) B2B/B2C	1/2

To ensure the reliability and validity of the research instruments and to minimize possible bias, various tests were performed. First, a factor analysis ensured that all the constructs of both models were unidimensional. According to the analysis, all item loadings were at a good level and exceeded the set limit (>.50) (Hair et al., 2014). Next, composite reliability (CR) and average variance extracted (AVE) were verified using the calculated values of the loadings. CR was used to measure the internal consistency of the scale items (Netemeyer et al., 2003), and AVE was used to measure the average amount of variance in variables that a construct is capable of explaining. In other words, it assesses whether the measures are intended to capture the same construct and are related to each other (Farrell, 2010). In addition, Cronbach's alpha values were calculated to ensure the internal consistency of the items, in other words, the reliability of the variables (Taber, 2018). When the values were above the undesirable limits (AVE > .50; CR > .70; alpha > .70), the construct reliability and validity were confirmed (Ab Hamid et al., 2017; Fornell and Larcker, 1981; Taber, 2018). The values are presented in more detail in the publications.

After this, the presence of possible bias was assessed. After distributing the survey to respondents in four waves, testing for possible non-response bias was undertaken. It was tested through an analysis of variance (ANOVA) test by first dividing the respondents into two groups (early and late) and then comparing the p-values of the groups. However, the results of this test (p-value $\leq .05$) did not show a significant difference between the two respondent groups, stating that non-response bias occurs. Then, to minimize the potential common method bias, Harman's one-factor test was conducted (Podsakoff and Organ, 1989; Podsakoff et al., 2003). The results did not show the presence of one factor or that the first factor accounted for most of the variance (Podsakoff et al., 2003). However, common method bias was also controlled through the design of the study procedures (Podsakoff et al., 2003). The survey was formulated so that it could be answered anonymously, respondents were also encouraged to give honest answers, the survey questions were kept simple and clear, and the research sample in the data collection phase was chosen randomly. Thus, according to these tests and assessments, research bias did not cause problems.

Finally, correlation matrix and regression analyses were performed, which stated the results of the study. These are presented in more detail per publication and in the Results section.

3.4 Quality of the research design

The concurrent mixed method was utilized, which involves the separate use of both qualitative and quantitative methods within a single phase of data collection and analysis (Saunders et al., 2015). The chosen research approach made it possible to be more confident about the results of the dissertation (Partington, 2002). Therefore, the quality of the research design of these two research strategies will be justified separately.

Quality of the case studies

According to Yin (2018), the quality of the research design of case studies can be judged through four common tests: construct validity, internal validity, external validity, and reliability. Construct validity describes "identifying correct operational measures for concepts being studied" (Yin, 2018, p. 42). To strengthen the construct validity, multiple sources of evidence were used, and various evaluators assessed the preliminary results (Eisenhardt, 1989; Patton, 1999; Yin, 2018). This approach utilized data triangulation and analyst triangulation, contributing to the overall strengthening of the study's validity (Creswell, 2014).

Internal validity refers to the effort to establish causality, whereby certain conditions are believed to lead to other conditions, as distinguished from spuriousness (Yin, 2018). The case study approach has good qualities for understanding causal relationships (Eisenhardt, 1989; Partington, 2002). In this approach, this can be seen in how to access the participant's knowledge and experience and be able to infer meanings from the language used (Saunders et al., 2015). To strengthen the internal validity of the case studies, semi-structured and in-depth interviews were used to enable the participants to express their own views related to the themes. In this, creating a confidential atmosphere was also essential, and if the information was incomplete, clarifications were asked afterward by e-mail. The study evaluated the strength and consistency of the relationships found both within and cross-cases and clearly presented the evidence found and the procedures used (Eisenhardt, 1989). In addition, the formulation of the final results was supported by the entire research group. Lastly, connecting the theory building to the existing literature improved the internal validity of the study (Eisenhardt, 1989).

External validity describes how the findings of a case study can be generalized (Saunders et al., 2015; Yin, 2018). In the case of qualitative research, it can be questioned (Saunders et al., 2015). However, according to Yin (2018), analytic generalizations from the case study can be made, and they may potentially be applied to a variety of situations beyond the original cases. Determining the generality based on a case study is not simple because the study is situation-based, but a sense of generality can be created by confirming and comparing the findings with existing theory (Ketokivi and Choi, 2014). In addition, it is important to note that qualitative research is more about particularity than generalizability, and its value lies more in description and themes developed in a particular context (Creswell, 2014). However, as Yin (2018) argued, some generalizations can be made from the results of the case studies to theory. Thus, to ensure the external validity of the case studies, the research design focused on the formulation of the research questions, reflecting that case studies were used to find answers to the why and how questions (Yin, 2018). In addition, multiple cases were used to enable replication logic between cases and to help guard and reduce observer bias (Eisenhardt, 1989; Yin, 2018). Finally, the research procedures were documented in an appropriate way to ensure replication (Creswell, 2014). The generalizations from case studies are not numeric but argumentative claims (Yin, 2018), and thus the case studies of the dissertation build propositions that were shaped by empirical analyses and were discussed and tied to the existing literature (Eisenhardt, 1989). These can be tested in the future if necessary to ensure generalizations to the theory.

Reliability means that the research, such as its data collection and analysis phases, can be repeated with the same results, thus having a goal to minimize errors and biases (Yin, 2018). However, Yin (2018) argues that in the real world, replicating a case study in the same way is rarely possible. To ensure the replication and thus strengthen the reliability of the case studies, the procedures of the case studies were carefully documented, and databases were created (Creswell, 2014; Yin, 2018). For example, the interviews were recorded and transcribed to reduce errors and bias, and databases helped other researchers review the summary of the interviews without reading all the transcriptions. Subsequently, if needed, more detailed points could be examined from the transcriptions. In addition, to minimize errors and bias, the participation of several researchers and representatives of the studied companies was utilized.

Quality of the survey

In quantitative research, validity is related to the accuracy and trustworthiness of instruments, data, and results (Nayak and Singh, 2021), which can be assessed using measurement validity, external validity, and internal validity (Saunders et al., 2015). However, Partington (2002) states that the different kinds of validity can only be inferred but never really established.

Measurement validity is about a measure actually measuring what is supposed to be measured (Partington, 2002; Saunders et al., 2015). It can be assessed by analyzing content validity, construct validity, concurrent validity, and predictive validity (Partington, 2002; Saunders et al., 2015). Content validity of measurement is related to the extent to which it sufficiently covers the subject under investigation (Emory, 1985) and describes whether items measure the content as they were intended (Creswell, 2014). The content validity of the research was strengthened through an extensive literature review to ensure that the content covered all relevant perspectives (Partington, 2002). Construct validity describes the extent to which a measure actually measures the construct it is intended to measure (Creswell, 2014; Netemeyer et al., 2003). The research ensured construct validity by utilizing the literature review before preparing survey items and the discussion between researchers in formulating and evaluating the survey items. In addition, several items were used to measure one structure, and exploratory factor analyses, correlation analyses, and AVE were performed (Farrell, 2010; Hair et al., 2014; Stehlik-Barry and Babinec, 2017). Concurrent validity and predictive validity are two types of criterion validity, describing whether scores predict a criterion measure (Creswell, 2014). The research did not achieve criterion validity (or concurrent validity) because criterion validity cannot be assessed without existing standards to do so.

External validity is related to the generalization of research findings (Saunders et al., 2015) across persons, settings, and time periods (Emory, 1985). The purpose of quantitative research is to create, strengthen, or validate relationships and develop theory-advancing generalizations (Leedy and Ormrod, 2001). Since the sample was randomly selected to represent the entire population, the answers were sufficient and the sample was large enough; thus, generalizations to the entire population could be made.

Internal validity “addresses the question, can it reasonably be assumed that A causes B” (Partington, 2022, p. 114). The internal validity of the survey may suffer from respondent bias, which reflects the fact that a socially desired response may be given instead of the actual response (Nayak and Singh, 2021). To answer this question, the survey was answered anonymously, and respondents were encouraged to answer honestly. In addition, an ANOVA test was performed between the late and early respondent groups, stating that non-response bias occurred between these groups. Then, to minimize and control the potential common method bias, Harman’s one-factor test was conducted, and attention was paid to the design of study procedures (Podsakoff and Organ, 1989; Podsakoff et al., 2003). Finally, the effects of the control variables were tested.

Reliability describes the ability of measuring instruments to produce the same answer under the same conditions time after time (Partington, 2002), or it concerns estimates of the extent to which a measurement is free from error (Emory, 1985). To enhance reliability, multiple items as measures were used for the majority of variables (Partington, 2002; see Table 5 and Appendix B). Also, Cronbach's alpha values were calculated to ensure internal consistency of scales, in other words, the extent to which items were measuring the same constructs (Partington, 2002; Taber, 2018). The calculated values were over the proposed limit (>.70), and thus, the scales were internally consistent and the reliability of the variables was ensured (Taber, 2018). In addition, CR was calculated to measure the internal consistency of the scale items (Netemeyer et al., 2003).

Thus, in summary, the quality of the study is justified.

4 Results

4.1 Publications and their impact on the research questions

This dissertation consists of five publications, which are presented next. The publications contribute to the research questions in different ways, utilizing different research approaches. The summary of the publication is presented in Table 6, which includes the title, purpose, method, contribution to the research questions, and connections to the research framework. Then, the answers related to the research questions are discussed in the following sections.

Publication I

Holopainen M., Ukko, J., & Saunila, M. (2022). Managing the strategic readiness of industrial companies for digital operations. *Digital Business*, *2*(2), 100039.

The publication investigates how to manage companies' strategic readiness for digital operations. To study the research problem, a research framework is built based on the literature. It presents the dimensions of strategic readiness (management, strategy, organization and culture, supply chain, and customers) and includes processes that are key practices in promoting, strengthening, and measuring digital operations. In addition, the study collected empirical evidence from 11 case companies from different industries. The study findings present four propositions to enable companies' strategic readiness in digital transformation: (1) finding a balance in decision-making, (2) developing managerial capabilities related to technology adoption, strategic development, and culture creation, (3) considering customer responsiveness and thus balancing between companies' own and customers' readiness for digital operations, and (4) increasing collaboration in the use of digital technologies, which enables a simultaneous increase in strategic readiness.

Publication II

Holopainen, M., Saunila, M., & Ukko, J. (2023). Value creation paths of organizations undergoing digital transformation. *Knowledge and Process Management*, *30*(2), 125–136.

The purpose of this publication is to explore the emergence of value creation during digital transformation. The study built a research framework based on the literature that facilitates realizing the potential of digital transformation: changes in value creation, use of technology, structural factors, barriers, and goals. In addition, the research collects empirical evidence from 11 case companies from different industries, addressing mechanisms to outline three different value creation paths. The study findings conclude that in digital transformation (1) to form a value creation mechanism, the related strategic orientation (i.e., digital strategy) must exceed a certain level, (2) value creation paths are driven by changes in the competitive environment, (3) customer pressure also affects value creation mechanisms and depends on the type of the value creation path, and finally (4) value creation is determined by how the company is balancing the existing business and digital transformation.

Publication III

Holopainen, M., Saunila, M., & Ukko, J. (2022). Facilitating performance measurement and management through digital business strategy. *Measuring Business Excellence*, *27*(2), 246–260.

The purpose of this publication is to examine whether digital strategy positively influences PMM. The digital strategy is formed through five dimensions: technological understanding, management, resources, goals, and responsibilities. Their effect on PMM is studied through a survey with 202 respondents. The research findings show that management and goal dimensions related to digital strategy had a positive and significant effect on PMM. The study concludes that these two elements are crucial to facilitating PMM in digital transformation.

Publication IV

Holopainen, M., Saunila, M., & Ukko, J. (2024). The effects of digital business strategy on the collaboration performance of companies: The moderating effect of digitally enabled performance measurement. *International Journal of Industrial Engineering and Operations Management*, *6*(1), 64–81.

The purpose of this publication is to investigate how digital strategy influences the collaboration performance of companies and the role of digitally enabled performance measurement as a moderator in this context. The research identifies different elements of digital strategy through a literature review: development, management capabilities, resources, objectives, and digital leadership. The implications of the elements are then studied through a survey of 202 respondents from different companies and industries to gain empirical evidence. The study findings show that managerial capabilities connected to digital strategy positively affect collaboration performance. In addition, through digitally enabled performance measurement, resources related to digital strategy are better organized, moderating the positive effect on collaboration performance. Contrary to the original assumptions, digitally enabled performance measurement moderated a negative but significant effect on the relationship between digital leadership and collaboration performance and thus may be considered too controlling in companies.

Publication V

Holopainen, M., Saunila, M., Rantala, T., & Ukko, J. (2022). Digital twins' implications for innovation. *Technology Analysis & Strategic Management*, 1–13.

The purpose of this publication is to investigate digital twins and their implications for innovation. To this end, the study gathered empirical evidence from six case companies in different industries that were users and providers of digital twin solutions. The study adds an understanding of digital twins, their characteristics, how they contribute to the innovation processes (i.e., impact), and how they are used in innovation processes (i.e., scope). Through qualitative analysis, the study emphasizes the importance of defining factors, characteristics, scope, and implications of digital twins in an innovation context. It also introduces a framework that supports and can be used to explore the use of digital twins in innovation.

Table 6. Summary of the publications and their impact on research questions.

	Publication I	Publication II	Publication III	Publication IV	Publication V
Title	Managing the strategic readiness of industrial companies for digital operations	Value creation paths of organizations undergoing digital transformation	Facilitating performance measurement and management through digital business strategy	The effects of digital business strategy on the collaboration performance of companies: The moderating effect of digitally enabled performance measurement	Digital twins' implications for innovation
Purpose	To investigate how companies' strategic readiness for digital operations is defined in digital transformation	To investigate what kind of mechanisms determine companies' value creation paths during digital transformation	To investigate whether the digital strategy, considering its five elements, positively influences PMM	To investigate whether the digital strategy positively influences collaboration performance and the role of digitally enabled performance measurement as a moderator	To investigate how digital twins impact and are used in companies' innovation processes
Method	Case study, 11 companies from different industries	Case study, 11 companies from different industries	Survey, 202 respondents from different companies and industries	Survey, 202 respondents from different companies and industries	Case study, 6 companies from different industries
Contribution to research questions	1.1	1.1 and 2.1	1.2	1.2 and 2.2	2.1
The connection to the research framework (see 2.4, Figure 3)	How can companies' strategic readiness (connected to digital strategy) support the use of digital technologies in companies' operations to achieve better performance in digital transformation?	What kind of value creation paths can companies take during digital transformation to achieve better performance?	What is the impact of digital strategy on companies' PMM?	What is the impact of digital strategy on companies` performance (such as collaboration performance), and what is the role of digitally enabled performance measurement in this?	How does the use of digital technologies (such as digital twins) affect companies' performance (innovation processes)?

4.2 How can the use of digital technologies in companies' digital transformation be effectively managed?

4.2.1 Strategic mechanisms

Digital transformation is noted to be a multidimensional entity that creates challenges for managers. Publications I and II focus on studying this phenomenon, facilitating the management of the use of digital technologies in companies. Their results are used to answer research question 1.1: *What kind of strategic mechanisms can be used to manage the use of digital technologies in companies' digital transformation?*

Publication I

The use of digital technologies influences companies across industries, changing their operating methods. The study investigated the mechanisms that facilitate connecting the use of digital technologies to companies' operations. It builds the research framework, which includes dimensions and their factors that tend to exist in companies with high readiness for digital operations. Those dimensions were named as management, strategy, organization, and culture, supply chain and customers, highlighting mechanisms that companies should focus on digital transformation, and they included the following factors:

- Management: their digital skills and capabilities, willingness, and support for change, and data-based decision-making
- Strategy: objectives with measures, investments, and resources
- Organization and culture: willingness to change, learning culture, information sharing, and flexible working
- Supply chain: digital capabilities, supply chain management, and cooperation networks
- Customers: digital information and communication channels, digital capabilities, and customer participation and collaboration.

In addition, the study gathered empirical evidence from 11 case companies operating in different industries to answer the research question. The results proved that the majority of the studied companies face challenges in integrating the use of digital technologies into their operations. Thus, through the analysis of the results, the study proposes that to facilitate strategic readiness for digital operations, (1) companies should focus on a balance between data-based and intuitive decision-making, and (2) consider managerial capabilities related to technology adoption, strategic development, and culture creation. In addition, because the scope of digital transformation extends beyond the boundaries of the company, companies should (3) consider customer responsiveness and thus strike a balance between their own and customers' willingness and readiness to accept digital operations, and (4) increase collaboration beyond boundaries of company in the use of digital technologies, allowing simultaneous upgrading of all partners' strategic readiness to digital operations. In conclusion, companies should first focus on strategic mechanisms related to propositions 1 and 2, after which they should turn their attention to propositions 3 and 4.

Publication II

Companies invest in different digital technologies to change their value creation in digital transformation. For them to succeed in this intention, various structural factors must support the changes, and various obstacles must be solved. The study presents a research framework considering the use of digital technologies, changes in value creation, structural factors, barriers, and goals that companies can use to realize and exploit the potential of digital transformation. It also gathered empirical evidence through multiple case studies including 11 companies in different industries to explore the studied phenomenon in practice. The study focuses on the main mechanisms and determines the companies' different value creation paths in digital transformation.

The results show that in (1) the value creation path, companies were focused on the latest technologies in different functions and their operations, which were driven by a desire to be technology leaders. Along with internal efficiency, the goal was to create a competitive advantage with the help of new digital products and connected services. This requires investments in structural factors, such as management and employee skills, a culture of continuous development, and cooperation networks. On the other hand, the main barrier was noted to be information security hindering the changes. In (2) value creation path, companies' digital transformation was in its infancy, and they were investing in ready-made technological solutions to increase the efficiency of internal operations. For digital project to be successful, employee participation and training were noted to support the change and factors such as change resistance, financial resources, and management ignorance to hinder the change. In (3) value creation path, companies were focused on developing their customer services and sales operations, which emphasized the ability to manage complexity. Structural factors such as digital skills, desire to change and evolve, and cooperation with customers supported the change, whereas too complex a customer interface acted as a barrier in this value creation path. To conclude the experience of the case studies, the value creation path in digital transformation is determined by digital strategy, i.e., what is the company's strategic goal in digital transformation, customer pressure, competitive environment, and employees' digital skills. In addition, the main barriers are related to trust issues, the complexity of the use of digital technologies, and resources. Thus, companies should consider these different strategic mechanisms when using digital technologies to make changes to their value-creation activities.

4.2.2 Role of PMM

The use of digital technologies affects companies' management systems, such as PMM. This connection from different perspectives is studied especially in publications III and IV. The results of the studies are used to answer research question 1.2: *What is the role of PMM in managing the use of digital technologies in companies' digital transformation?*

Publication III

Digital technologies and aligning them with the company's strategic goals also has a significant impact on PMM. The publication identifies five major dimensions of digital strategy, namely technological understanding, management, resources, goals, and responsibilities, and investigates whether digital strategy, through its dimensions, positively affects PMM. The study also summarizes, through a literature review, how these perspectives of digital strategy appear in PMM:

- Understanding: technological understanding, interconnected performances, and sources of higher performance
- Management: driving cultural change, transforming processes and routines, promoting behavior and collaboration, and the potential for decision-making
- Resources: behavioral factors concurrent with technical ones, human involvement, and effects beyond traditional performance dimensions
- Goals: deploying strategy to lower levels, technological developments aligned with organizational strategic objectives, and continuous review of performance measures
- Responsibilities: information sharing, subjects' engagement, need for personalization, and trust between partners.

Then, a survey with 202 respondents from different manufacturing and service companies in different industries was used to analyze the effects. The results demonstrate the positive effects of the goals and management dimensions related to digital strategy on PMM. Considering other dimensions of digital strategy, no direct effects were found. The study states that it is not necessarily the absence of effects of these three dimensions (technological understanding, resources, and responsibilities), but the fact that all dimensions were studied in the same model may have reduced the effect of some dimensions. Or, there is no effect considering these three dimensions without a sufficiently high level of management competence and goal setting related to digital strategy.

However, the study concludes that the higher the management capabilities connected to digital strategy, the more effectively companies use PMM to support the use of digital technologies. These capabilities are connected to how aware managers are of technological opportunities, their own necessary strategic and decision-making capabilities related to digital strategy formulation and implementation, and leading technological projects in a successful manner. They are also reflecting on the effective use of PMM through promoting behavior and collaboration, driving cultural change, and supporting transforming processes and routines in digital transformation. In addition, the study reveals that the use of digital technologies does not add value alone; companies should set, monitor, and try to achieve goals related to digital strategy, and thus through this, they use PMM more effectively to support digital transformation. This effective use of PMM reflects that technological development is aligned with strategic objectives, digital strategy is deployed to lower levels, and performance measurement is continuously reviewed.

Publication IV

Digital technologies shape strategies and forms of collaboration in companies, but they also shape the ways of implementing performance measurement. Thus, the study investigated the role of digitally enabled performance measurement as a moderator between digital strategy and collaboration performance was analyzed. First, the study identified elements of digital strategy through a literature review (development, management capabilities, objectives, resources, and digital leadership). Then, empirical data was gathered through a survey with 202 respondents, and how digitally enabled performance measurement enhances the implementation of digital strategy and ultimately facilitates collaboration performance.

The results show that digitally enabled performance measurement positively moderates the effect of resources related to digital strategy on collaboration performance. On the other hand, contrary to the original assumptions, a negative moderating effect was found between digital leadership, as part of digital strategy, and collaboration the performance. In addition, no effects were found considering other digital strategy elements. Therefore, the study states that digitally enabled performance measurement supports the management of resources related to digital strategy, reflecting positively on collaboration performance. In addition, digitally enabled performance measurement can also have negative effects on collaboration in terms of responsibilities if it is perceived as too controllable or requires the sharing of too detailed data. In addition, in the case of other elements, no effects were found, and thus the benefits do not materialize if, for example, the goals are not set from a collaboration point of view or managers cannot connect the different topics (use of technologies and collaboration) to their performance measurement systems.

4.3 How does the use of digital technologies influence the performance of companies in digital transformation?

4.3.1 Influences on different performances

The dissertation examines how the use of digital technologies influences companies' performance. This connection is explored especially in publications II and V. Publication II focuses on how changes in the company's value creation paths shape the company's performance, and Publication V focuses on how using digital twins shapes the innovation performance of companies. Thus, together, they answer research question 2.1: *How does the use of digital technologies influence the different performances of companies in digital transformation?*

Publication II

The use of digital technologies influences companies' value creation and capture in different industries. The study investigated the emergence of value creation during digital transformation using a multiple case study approach. In total, 11 case companies were selected from different industries, and data were gathered through open-ended interviews. Through this, different value creation paths were identified, presenting how case companies created value through the use of digital technologies. The results show that in (1) the value creation path, companies use digital technologies to develop and sell new digital products and services and thus gain performance effects by increasing sales and competitiveness. In (2) the value creation path, companies were acquiring better systems and digital tools to change their internal processes by increasing, for example, automation and connectivity to improve the efficiency of the operations. In (3) the value creation path, companies used digital technologies to develop their sales and service operations to achieve better customer experience. Thus, to conclude, companies have different goals related to the use of digital technology. Also, these differ based on the objectives and motivation of the digital transformation and are connected to the ways product and services are produced, provided, and/or sold and marketed.

Publication V

The use of digital technologies shapes company processes, and, for example, digital twins can play a major role in generating value and increasing performance in digital transformation. This research specifically investigated how digital twins influence innovation activities, and answers were sought by implementing a qualitative case study approach. Data were gathered through open-ended interviews with six companies that were providers and users of digital twin solutions. The results demonstrate how digital twins impact companies' innovation performance in different scopes, taking into account key characteristics, innovation as a process, innovation as an outcome, and dimensions of impact. The main scopes were identified as product design and development, marketing and sales, maintenance service, collaboration with the customer and within the company, finding new business, and production processes. In the different scopes, the main implications were named as allowing the designing and testing of products virtually, saving time, increasing collaboration, enhancing information availability and sharing for all parties, enhancing decision-making, saving money and time by optimizing maintenance, enabling new types of maintenance service, and increasing knowledge of the customers and their needs. In addition, the characteristics of digital twins affect their implications and are dependent on the understanding of innovation as an outcome or as a process. These characteristics were named exploration, optimization, discovery, guidance, interaction, and experimentation. Thus, the study presents a framework to adopt and use digital twins in innovation to gain better performance in digital transformation.

4.3.2 Digital strategy and its influences on performance

The dissertation seeks to answer how digital strategy affects performance. Publication IV explored this connection, focusing on the effects of digital strategy on collaboration performance. Thus, research question 2.2 is formulated as follows: *What are the influences of the use of digital technologies connected to digital strategy on the performance of companies in digital transformation?*

Publication IV

The use of digital technologies has changed the ways companies operate and has created new collaborative organizational networks. The research focused on how a digital strategy can support the use of digital technologies from a collaborative perspective. The study was carried out as a survey to assess possible effects and was based on the responses of 202 Finnish companies from the industry and service sectors. Through a literature review, the study defines different elements of digital strategy, namely development, management capability, resources, objectives, and digital leadership, and analyzes how they affect collaboration performance. Regression analysis showed that management capability positively affects collaboration, and contrary to original assumptions, the development element was shown to have a negative influence. No other significant effects were found considering the three other elements. Thus, analysis of the study results concludes that managerial capabilities are a crucial element of digital strategy in achieving successful collaboration performance. In addition, if companies are pioneers in the digital development of their industry, it can be reflected as an imbalance in collaboration between partners and thus negatively affects collaboration performance.

4.4 Summary of the result

This dissertation seeks answers from the strategic management and performance management perspectives to two main research questions and uses the results of the five research publications in this effort. Table 7 summarizes the results divided by the research questions. Research question 1 considers how to manage the use of digital technologies in companies and is divided into sub-questions. Research question 1.1 determines what kind of strategic mechanism can be used to manage the use of digital technologies. Research question 1.2, on the other hand, concentrates on the role of PMM in digital transformation. The second main research considers the connection of the use of digital technologies to companies' performance. The sub-research questions are divided in more detail into how the use of digital technologies influences different performances (2.1) and how digital strategy influences performance in companies (2.2).

Table 7. Summary of the results for the research questions.

R1: How can the use of digital technologies in companies' digital transformation be effectively managed?	
R1.1: What kind of strategic mechanisms can be used to manage the use of digital technologies in companies' digital transformation?	*R1.2: What is the role of PMM in managing the use of digital technologies in companies' digital transformation?*
<u>Publication I:</u> The study highlights the mechanism that companies should focus on to manage companies' strategic readiness to use digital technologies in their operations. These mechanisms are related to five dimensions: strategy, management, organization and culture, customers, and supply chain. Furthermore, they exist in companies with high readiness for digital operations. To conclude, the study proposes that companies should focus on balance in decision-making, managerial capabilities, customer readiness, and inter-organizational collaboration to increase their readiness to use digital technologies. <u>Publication II</u> The study highlights the mechanisms for managing changes in value creation and achieving performance in digital transformation. The research framework named five dimensions (use of technology, changes in value creation, structural factors, barriers, and goals) that can be used to realize the potential of digital transformation. They conclude that the value creation in digital transformation is guided by digital strategy (including goals and use of technology) and driven by a competitive environment highlighting cooperation networks, by customer pressure increasing collaboration and participation, and by employees' digital skills. Then, the main barriers were related to trust issues, complexity, and resources. These are the mechanisms that companies should focus on when changing their value creation path in digital transformation.	<u>Publication III</u> Goals and management related to digital strategy have a positive influence on PMM. No other effects were identified. Therefore, companies effectively utilize PMM by focusing on these two dimensions of digital strategy. This is reflected in the promotion of behavior and collaboration, driving cultural change, and supporting the transformation of processes and routines in digital transformation (management). Technological development is aligned with strategic objectives, digital strategy is deploying to lower levels, and performance measurement is continuously reviewed (goals). <u>Publication IV</u> Digitally enabled performance measurement positively moderates the effect of resources related to digital strategy on collaboration performance and negatively affects digital leadership, as part of digital strategy, and collaboration performance. Thus, digitally enabled performance measurement supports the management of digital resources but can be perceived as too controllable or requires the sharing of too detailed data. In addition, in the case of other elements, no effects were found, and thus, the benefits do not materialize if, for example, the goals are not set from a collaboration point of view or managers cannot connect the use of digital technologies from the perspective of collaboration to their performance measurement systems.

R2: How does the use of digital technologies influence the performance of companies in digital transformation?	
R2.1: How does the use of digital technologies influence different performances of companies in digital transformation? <u>Publication II</u> The research shows that companies have different performance goals (internal efficiency, increasing competitiveness and sales, improving customer experience) in digital transformation. They differ based on the motivation for using the technologies and are related to the ways products and services are produced, the types of products and services are provided, and/or the ways in which products and services are sold and marketed. <u>Publication V</u> Digital twins influence innovation in different scopes of the company. The scopes can be product development and design, sales and marketing, maintenance service, cooperation with the customer and within the company, finding new business, and production processes. Implications were identified as allowing virtual design and testing, increasing collaboration, saving time, enhancing information availability and sharing, enhancing decision-making, saving money and time through optimizing, enabling new types of services, and increasing knowledge of customer needs. In addition, when achieving innovation performance, the company must identify the innovation type of the digital twin (innovation as a process/innovation as an outcome) and its characteristics.	R2.2: *What are the influences of the use of digital technologies connected to digital strategy on the performance of companies in digital transformation?* <u>Publication IV</u> Management capability related to digital strategy positively influences collaboration performance; thus, managers should possess the necessary abilities to form and implement a digital strategy. The development element of the digital strategy harms collaboration performance; thus, a digital balance between partners should be considered. No other effects were found.

5 Discussion

Digital transformation disrupts the company's operations and business, collaboration networks, and the competitive environment. It also offers the company the option to look at its operations in a new way, offering multiple opportunities for improving performance. However, digital transformation is a multidimensional entity to manage (Cennamo et al., 2020; Gong and Ribiere, 2021; Tekic and Koroteev, 2019), influencing companies' core activities, competencies, capabilities, and roles (Vaska et al., 2021). The results of the dissertation related to multiple case studies show that most companies experience challenges in using digital technologies to gain business value, which is in line with previous studies (Fitzgerald et al., 2014; Libert et al., 2016; Sigari et al., 2021). Next, the results are discussed from the strategic and performance management aspects to facilitate companies' digital transformation.

The use of digital technologies is the main ingredient of digital transformation (Tekic and Koroteev, 2019), which enables companies to create value in novel ways through the revision and extension of products and services, understanding customers' needs better, and increasing collaboration through digital platforms and ecosystems (Vaska et al., 2021). The studied case companies were using data analytics, IoT, mobile, cloud, and social platforms alongside other modern technologies, such as AI and digital twins, to achieve different goals in digital transformation. The goals were defined as the enhancement of competitiveness/sales, efficiency of operations, and a superior customer experience or were related to innovation. The literature has suggested that to achieve these goals and thus succeed in digital transformation, companies must integrate these technologies into their strategic value creation activities and paths (Correani et al., 2020; Li, 2020; Margiono, 2021). Hence, using digital technology alone does not produce business value; value is created by doing business in a new way (Westerman, 2018). Thus, to identify clear steps in digital transformation, companies should consider redefining their value creation paths. The result of the dissertation describes three different paths for companies considering the use of the technology, the changes in value creation, the structural factors, the barriers, and the goals (Publication II) and presents the use and implications of digital twins on innovation activities (Publication V). The defined frameworks and empirical evidence of the studies support managing the use of digital technologies to achieve performance in digital transformation. In summary, the study proposes the following:

Companies should consider the implications of the use of digital technologies on their value creation paths and activities to facilitate managing performance in digital transformation.

The literature has suggested that companies should integrate the use of digital technologies and changes in value creation in their strategic reviews (Hess et al., 2016; Lipsmeier et al., 2020), having different implications in various areas of companies going beyond existing borders. Due to the transfunctional nature of digital transformation, which spans the entire organization (Bharadwaj et al., 2013), and the emphasis on business-oriented and customer-focused use of digital technologies (Chanias et al., 2019), the leading role should not necessarily be from the IT department. The literature has presented a chief digital officer being responsible for managing the digital transformation of companies (Singh et al., 2020).

However, managing digital transformation requires new capabilities for managers with combinations of organizational and strategic capabilities and technological experience (Singh et al., 2020; Vial, 2019). In addition, the importance of digital skills of managers has been demonstrated, and their absence can be an obstacle to digital transformation, reflecting a lack of urgency, strategy, and motivation (Fitzegerald et al., 2014; Sousa-Zomer et al., 2020). This research is in line with that, and the results state the following. First, Publication I proposes that managerial capabilities facilitate the company's strategic readiness to use digital technologies. Second, Publication III presents that the higher the level of management capabilities connected to digital strategy, the better the companies use PMM to support the use of digital technologies. Third, Publication IV shows that management capabilities are the most important element of the digital strategy that positively affects collaboration performance. Thus, management capabilities can be identified as a cornerstone of the digital transformation of companies. The capabilities are related to managers' awareness of technological opportunities and their adoption, strategic decision-making abilities related to the design and execution of a digital strategy, and the capacity to lead cultural change and successfully implement technology projects. To conclude, the results highlight the crucial role of management capabilities in digital transformation; thus, the dissertation proposes the following:

Companies should develop management capabilities related to the use of digital technologies and digital strategies to facilitate managing performance in digital transformation.

Digital transformation challenges traditional PMM, such as the ability to steer strategic direction in turbulent environments (Melnyk et al., 2014). It forces PMM to be more dynamic and manage uncertainty (Guenther and Heinicke, 2019), to set new goals and measures related to the use of digital technologies (Lipsmeier et al., 2020), and to switch to a more participatory PMM (Nudurupati et al., 2021). In addition, the use of digital technologies enables more efficient technological solutions for the implementation of PMM systems (Vallurupati and Bose, 2018). For example, PMM systems are increasingly visual and real-time and require more efficient data analysis methods in digital transformation (Korsen and Ingvaldsen, 2022; Ravelomanantsoa et al., 2019; Ukko et al., 2022).

Considering PMM in digital transformation, this research proved the benefits of digitally enabled performance measurement-related performance. The results of Publication IV found that through digitally enabled performance measurement, the resources related to digital strategy are managed more efficiently, reflecting better collaboration performance. This aligns with the findings of Reinking et al. (2020) and Sardi et al. (2020a), who studied integrating different digital technologies into PMM systems to gain performance effects. For example, a digitally enabled PMM system can make decision-making more efficient with digital features such as real-time and visualization (Aheleroff et al., 2021; Holopainen et al., 2021). The results of Publication I state that, in digital transformation, companies should find a balance between data-based and intuitive decision-making. While data support efficient decision-making, intuitive decision-making engages humans in the process. This is in line with the idea that PMM systems should be used to support learning and participation in digital transformation instead of just monitoring and control (Bourne et al., 2018; Neely and Najjar, 2006), thus finding a balance between social and technical control mechanisms (Bititci et al., 2018; Smith and Bititci, 2017). In addition, the results of Publication IV support this by stating that digitally enabled performance measurement moderates the negative influences between digital leadership related to digital strategy and collaboration if it is considered too controlling and requires sharing too detailed data.

However, digital transformation necessitates a strategy that integrates business and the use of digital technologies (Li, 2020). This is referred to as a digital strategy, which is then evaluated through success measures (Endrikat et al., 2020), such as PMM. Thus, this dissertation focuses on connecting these two concepts. Publication III studied digital strategy and its influence on PMM. First, it determined that digital strategy consists of technological understanding related to companies' industrial environment (Konopik et al., 2022), as well as goals (Reiking et al., 2020), resources (Matt et al., 2015), management capabilities (Sousa-Zomer et al., 2020), and responsibility (Vial, 2019) related to the use of digital technologies. Then, the study summarizes how these perspectives influence PMM through a literature review. The study concludes that considering the management and goal dimensions of digital strategy, companies use PMM more effectively in digital transformation. This means that, to effectively integrate digital strategy into companies' PMM, companies should consider their management capabilities related to digital strategy in terms of awareness, skills, and activity. This promotes collaboration and behavior, drives cultural change, and supports changing routines and processes in digital transformation. This is in line with previous studies (Korsen and Ingvaldsen, 2022; Robert et al., 2020; Sardi et al., 2020) that noted that the digitalization of PMM systems reinforces empowerment, motivation, and participation as an organizational culture and management style. In addition, the study proposes that companies should set goals for the use of digital technologies and then monitor and evaluate their achievement, which promotes that technological development and strategic goals are aligned, digital strategy is deployed to all levels of the organization, and performance measures are continuously reviewed. This argument is in line with previous research, which noted that connecting the use of digital technologies to PMM enables more transparent performance information (Robert et al., 2020) and strategy alignment (Reinking et al., 2020). Thus, the dissertation proposes the following:

Companies should integrate the use of digital technologies and the perspectives of digital strategy into their PMM systems to facilitate managing performance in digital transformation.

Digital transformation challenges companies, seeing that most related projects fail or often take time to get the rewards (Jardak and Ben Hamad, 2022; Libert et al., 2016). It is difficult for companies to achieve performance effects on their own, and thus, they need suitable partners to succeed in digital transformation (Senyo et al., 2019). In addition, the use of digital technologies is lowering barriers between industries and enables closer collaboration, better information availability, and enhanced communication between partners (Correani et al., 2020; Warner and Wäger, 2019). For example, through digital platforms, the creation and exchange of ideas, information, and experience are shared, providing value to different stakeholders (Kaplan, 2015; Spremic, 2017). These perspectives support the results, as Publication I stated that companies should grow collaboration activities between organizations related to the use of digital technologies and thus make it possible to increase the strategic readiness of different actors for the use of digital technologies in operations simultaneously.

However, companies or customers cannot participate in the digital change if they do not have the willingness or ability to do so, acting as a barrier that hinders the changes. The findings of Publication I show that resistance to changes is lower through collaboration in conservative industries and that SMEs also benefit from this through shared capabilities and resources. In addition, the findings of Publication II noted that cooperation networks could act as a structural factor supporting the changes in value creation in digital transformation.

To continue, it is stated that collaboration considering the use of digital technologies should be integrated into companies' management systems, such as in digital strategy (Holotiuk and Beimborn, 2017) and PMM (Nudurupati et al., 2016). Publication IV is in line with that and noted that increased collaboration in digital transformation should be considered in the company's strategic reflection by defining common goals and metrics for collaboration activities, i.e., extending the performance measurements to a wider network with several stakeholders (Nudurupati et al., 2016). This is in line with Bourne et al. (2018), who noted that PMM can be considered a system of systems in uncertain and complex environments, such as in digital transformation, supporting learning, adaptation, and navigation toward predetermined goals. To conclude, based on the results of the dissertation, it is stated that companies are evolving toward a more interactive, transparent, and inclusive use of digital technologies, and thus the dissertation proposes the following:

Companies should increase collaboration in the use of digital technologies and thus connect it to digital strategy and PMM, which facilitates managing performance in digital transformation.

6 Conclusion

6.1 Contribution to theory

This dissertation contributes to the previous literature on strategic management and performance management in the context of digital transformation. The theoretical base builds on three main concepts: digital strategy, company performance, and PMM. This approach creates and enables an understanding of the engagement of digital technologies with strategy development and measurement to achieve better performance in digital transformation. The research contributes to the existing theory as follows.

First, it combines the theoretical perspectives of the dissertation into a conceptual framework to facilitate managing performance in digital transformation. The framework includes concepts of strategic readiness, the use of digital technologies, digital strategy, changes in value creation, structural factors and barriers, PMM, and performance. Second, the research explores these concepts through the literature and empirical evidence. The results identify the main dimensions and features of strategic readiness and present three different value creation paths considering the use of digital technologies, changes in value creation, structural factors, barriers, and performance goals. In addition, the research identifies the dimensions of digital strategy and studies their influences on PMM and performance.

Third, the dissertation offers four main propositions to facilitate managing performance in digital transformation. As companies face challenges in digital transformation, managers are frustrated by its complexity, and a majority of digital projects fail to improve performance. The research proposes that companies should (1) assess the impact of the use of digital technologies and digital strategy on their value creation paths and activities, (2) cultivate management capabilities associated with them, (3) integrate both perspectives as part of their PMM systems, and (4) increase collaboration in the digital realm to facilitate performance growth.

6.2 Contribution to practice

This dissertation offers various practical perspectives for companies and their managers. Related to the first research question, the dissertation contributes to practice in several ways by highlighting different strategic mechanisms for managing the use of digital technologies in companies. First, it is observed that a company’s strategic readiness for the utilization of digital technologies is associated with five dimensions: strategy, management, organization and culture, customers, and supply chain. The proposal suggests that companies should prioritize achieving a balance in decision-making, managerial capabilities, customer readiness, and inter-organizational collaboration to increase their readiness to use digital technologies. Second, the study suggests that companies should consider the use of digital technologies in their value creation paths and activities to identify clear steps in digital transformation. Thus, the results provide three value creation paths for companies and consider the use of digital technologies in different innovation scopes. Third, the study shows how PMM can support companies in achieving performance in digital transformation. To do so effectively, the research states that companies have to merge the use of digital technologies into their strategic expectations and performance goals and develop their management capabilities related to combinations of organizational and strategic capabilities and technological experience. In addition, the study recommends finding a balance considering data-based and intuitive decision-making, where PMM systems should be used to support learning and participation in digital transformation instead of just monitoring and control.

Answering the second research question, the use of digital technologies influences companies' performance in many ways. The study contributes to practice by first showing the diverse performance goals of companies, which are linked to their motivation and the methods by which products and services are produced, provided, and/or sold and marketed. This supports the identification and therefore the achievement of the company's performance goals in digital transformation. Second, the study outlines how the use of digital technology influences performance, specifically in the innovation context, stating its multiple possibilities and implications. Companies can use these perspectives to develop their activities and operations in different scope areas. Third, the study presents how the dimensions of digital strategy affect companies' collaboration performance, giving managers knowledge about digital strategy and its impact on performance. The dissertation suggests that companies have to concentrate specifically on management capabilities and the ability to integrate their digital strategies and PMM systems to achieve better performance in digital transformation.

6.3 Limitations

The dissertation contains certain limitations that should be acknowledged and are related, for example, to the data collection and analysis. To begin with, the study was geographically limited to companies operating in Finland, although some of the companies also operated internationally, and this can highlight certain features of the results. In addition, the results are based on the subjective opinions of the interviewees and the survey respondents, where the use of objective measures could have revealed different results. Finally, three empirical data sources were used: a survey containing about 200 answers and case studies of 11 companies and 6 companies. Thus, more studies are needed in terms of a larger scope and longitudinal study. For example, the survey was sent to almost 6,000 companies, and the response rate was quite low, which can prevent some results from appearing. In connection with the research items of the survey, collaboration performance was measured using only one item, which is a limitation of the dissertation.

To continue, the boundaries of the research also create certain limitations. The research mainly focused on the experiences of managers; thus, a broader picture of the digital transformation of companies would also be obtained by adding the voice of lower-level employees. The research also focused on different fields and concepts of management, so the results could have been more accurate if the research had been limited to only one field of management, for example, PMM in digital transformation. This is reflected in the fact that the dissertation did not specify the used PMM systems or their special features but looked at them in general. Thus, in the future, more specific and longitudinal studies should be conducted to gather data and detailed evidence of the research topics, such as the utilization of digital strategies and PMM in companies during digital transformation.

6.4 Suggestions for further research

This dissertation offers various possibilities for future research. Publications I and II focus on companies' strategic readiness to use digital technologies and value creation paths in digital transformation through a qualitative approach. In future investigations, quantitative studies should be employed to acquire a comprehensive understanding. For example, exploring the most crucial strategic mechanisms leading to success in digital transformation and their impact on financial performance could be an important avenue of research. It would also be worthwhile to focus more closely on the effects of certain digital technologies related to value creation paths and performance, for example, in the case of artificial intelligence and digital twins.

To continue, considering PMM, it would be interesting to study how PMM influences different performances in digital transformation, for example, through certain digital functionalities, such as real-time and visualization. In addition, the results of the dissertation support the growing idea of increasing collaboration in digital transformation. Future research should focus on gathering empirical evidence through a case study of a collaboration network that simultaneously focuses on developing its digital capabilities and implementing novel digital technologies such as digital platforms. The perspective of PMM could also be added to this context, i.e., how it can support the process.

Digital strategy was an important concept of the dissertation but was quite unknown to companies, although all had some digital initiatives in progress. Thus, further research is needed related to digital strategy formulation and implementation through case studies and the role of PMM in this. In addition, the research focused on the effects of digital strategy on PMM (Publication III) and collaboration (Publication IV) through a quantitative approach. The study noted that the effects of some digital strategy elements were missing, which can be affected by the research setting. In the future, these performance effects should be expanded, and different elements should also be studied independently. Finally, this dissertation proposes that future research should be expanded to an international research area, as the study was limited to one geographical location.

References

Ab Hamid, M. R., Sami, W., & Mohmad Sidek, M. H. (2017). Discriminant validity assessment: Use of Fornell & Larcker criterion versus HTMT criterion. *Journal of Physics: Conference Series*, *890*(1), 12163.

Aguinis, H. (2009). *Performance management*. Upper Saddle River, NJ: Pearson.

Aheleroff, S., Xu, X., Zhong, R. Y., & Lu, Y. (2021). Digital twin as a service (DTaaS) in industry 4.0: An architecture reference model. *Advanced Engineering Informatics*, *47*, 101225.

AlNuaimi, B. K., Singh, S. K., Ren, S., Budhwar, P., & Vorobyev, D. (2022). Mastering digital transformation: The nexus between leadership, agility, and digital strategy. *Journal of Business Research*, *145*, 636–648.

Aly, H. (2020). Digital transformation, development and productivity in developing countries: Is artificial intelligence a curse or a blessing? *Review of Economics and Political Science*, *7*(4), 238–256.

Amaratunga, D., & Baldry, D. (2002). Moving from performance measurement to performance management. *Facilities*, *20*(5/6), 217–223.

Armstrong, M. (2006). *Performance management – Key strategies and practical guidelines* (3rd ed.). London, United Kingdom: Kogan Page Limited.

Atkinson, A. A., Waterhouse, J. H., & Wells, R. B. (1997). A stakeholder approach to strategic performance measurement. *MIT Sloan Management Review*, *38*(3), 25.

Atkinson, M. (2012). Developing and using a performance management framework: A case study. *Measuring Business Excellence*, *16*(3), 47–56.

Atzori, L., Iera, A., & Morabito, G. (2010). The internet of things: A survey. *Computer Networks*, *54*(15), 2787–2805.

Barratt, M., Choi, T. Y., & Li, M. (2011). Qualitative case studies in operations management: Trends, research outcomes, and future research implications. *Journal of Operations Management*, *29*(4), 329–342.

Berman, S. J. (2012). Digital transformation: Opportunities to create new business models. *Strategy and Leadership*, *40*(2), 16–24.

Berman, S. J., Kesterson-Townes, L., Marshall, A., & Srivathsa, R. (2012). How cloud computing enables process and business model innovation. *Strategy & Leadership*, *40*(4), 27–35.

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital business strategy: Toward a next generation of insights. *MIS Quarterly*, *37*(2), 471–482.

Bhimani, A. (2020). Digital data and management accounting: Why we need to rethink research methods. *Journal of Management Control*, *31*(1–2), 9–23.

Bititci, U. S. (2015). *Managing business performance: The science and the art*. Chichester, UK: John Wiley & Sons.

Bititci, U. S., Bourne, M., Cross, J. A. F., Nudurupati, S. S., & Sang, K. (2018). Towards a theoretical foundation for performance measurement and management. *International Journal of Management Reviews*, *20*(3), 653–660.

Bititci, U., Carrie, A. S., & McDevitt, L. (1997). Integrated performance measurement systems: A development guide. *International Journal of Operations and Production Management*, *17*(5), 522–534.

Bititci, U., Garengo, P., Dörfler, V., & Nudurupati, S. (2012). Performance measurement: Challenges for tomorrow. *International Journal of Management Reviews*, *14*(3), 305–327.

Bourne, M., Franco-Santos, M., Micheli, P., & Pavlov, A. (2018). Performance measurement and management: A system of systems perspective. *International Journal of Production Research*, *56*(8), 2788–2799.

Bourne, M., Neely, A., Mills, J., & Platts, K. (2003). Implementing performance measurement systems: A literature review. *International Journal of Business Performance Management*, *5*(1), 1–24.

Bracker, J. (1980). The historical development of the strategic management concept. *Academy of Management Review*, *5(*2), 219–224.

Bredmar, K. (2017). Digitalisation of enterprises brings new opportunities to traditional management control. *Business Systems Research: International Journal of the Society for Advancing Innovation and Research in Economy*, *8*(2), 115–125.

Campbell, J. P., McCloy, R. A., Oppler, S. H., & Sager, C. E. (1993). A theory of performance. *Personnel Selection in Organizations*, *3570*, 35–70.

Cardinal, L. B., Sitkin, S. B., & Long, C. P. (2004). Balancing and rebalancing in the creation and evolution of organizational control. *Organization Science*, *15*(4), 411–431.

Cennamo, C., Dagnino, G. B., Di Minin, A., & Lanzolla, G. (2020). Managing digital transformation: Scope of transformation and modalities of value co-generation and delivery. *California Management Review*, *62*(4), 5–16.

Chandler, A. D. (1962). *Strategy and structure: Chapters in the history of the American industrial enterprise*. New York, NY: Beard Books.

Chanias, S., Myers, M. D., & Hess, T. (2019). Digital transformation strategy making in pre-digital organizations: The case of a financial services provider. *The Journal of Strategic Information Systems, 28*(1), 17–33.

Chen, Y. Y. K., Jaw, Y. L., & Wu, B. L. (2016). Effect of digital transformation on organisational performance of SMEs: Evidence from the Taiwanese textile industry's web portal. *Internet Research, 26*(1), 186–212.

Chenhall, R. H. (2005). Integrative strategic performance measurement systems, strategic alignment of manufacturing, learning and strategic outcomes: An exploratory study. *Accounting, Organizations and Society*, *30*(5), 395–422.

Chi, M., Lu, X., Zhao, J., & Li, Y. (2018). The impacts of digital business strategy on firm performance: The mediation analysis of e-collaboration capability. *International Journal of Information Systems and Change Management*, *10*(2), 123–139.

Correani, A., De Massis, A., Frattini, F., Petruzzelli, A. M., & Natalicchio, A. (2020). Implementing a digital strategy: Learning from the experience of three digital transformation projects. *California Management Review, 62*(4), 37–56.

Creswell, J. W. (2014). *Research design: Qualitative, quatitative, and mixed methods approaches* (4th ed.). Sage Publications.

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Sage Publications.

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., & Sheikh, A. (2011). The case study approach. *BMC Medical Research Methodology, 11*(1), 1–9.

Davenport, T. (2014). *Big data at work: Dispelling the myths, uncovering the opportunities*. Brighton, MI: Harvard Business Review Press.

Davenport, T. H. (2006). Competing on analytics. *Harvard Business Review*, *84*(1), 98.

Dubois, A., & Gadde, L. E. (2002). Systematic combining: An abductive approach to case research. *Journal of Business Research*, *55*(7), 553–560.

Dweekat, A. J., Hwang, G., & Park, J. (2017). A supply chain performance measurement approach using the internet of things. *Industrial Management & Data System*, *117*(2), 267–286.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532–550.

Emory, C. W. (1985). *Business research methods* (3rd ed.). Homewood, IL: Irwin.

Endrikat, J., Guenther, T. W., & Titus, R. (2020). Consequences of strategic performance measurement systems: A meta-analytic review. *Journal of Management Accounting Research*, *32*(1), 103–136.

Farrell, A. M. (2010). Insufficient discriminant validity: A comment on Bove, Pervan, Beatty, and Shiu (2009). *Journal of Business Research*, *63*(3), 324–327.

Feurer, R., Chaharbaghi, K., & Wargin, J. (1995). Analysis of strategy formulation and implementation at Hewlett-Packard. *Management Decision*, *33*(10), 4–16.

Fitzgerald, M., Kruschwitz, N., Bonnet, D., & Welch, M. (2014). Embracing digital technology: A new strategic imperative. *MIT Sloan Management Review*, *55*(2), 1–12.

Folan, P., & Browne, J. (2005). A review of performance measurement: Towards performance management. *Computers in Industry*, *56*(7), 663–680.

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research*, *18*(1), 39–50.

Franco-Santos, M., Kennerley, M., Micheli, P., Martinez, V., Mason, S., Marr, B., ... & Neely, A. (2007). Towards a definition of a business performance measurement system. *International Journal of Operations & Production Management*, *27*(8), 784–801.

Franco-Santos, M., Lucianetti, L., & Bourne, M. (2012). Contemporary performance measurement systems: A review of their consequences and a framework for research. *Management Accounting Research*, *23*(2), 79–119.

Frank, A. G., Dalenogare, L. S., & Ayala, N. F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, *210*, 15–26.

Fuertes, G., Alfaro, M., Vargas, M., Gutierrez, S., Ternero, R., & Sabattin, J. (2020). Conceptual framework for the strategic management: A literature review—descriptive. *Journal of Engineering*, *2020*, 1–21.

Garengo, P., Biazzo, S., & Bititci, U. S. (2005). Performance measurement systems in SMEs: A review for a research agenda. *International Journal of Management Reviews*, *7*(1), 25–47.

Gates, S. (1999). *Aligning strategic performance measures and results*. New York, NY: The Conference Board.

Gong, C., & Ribiere, V. (2021). Developing a unified definition of digital transformation. *Technovation*, *102*, 102217.

Guba, E. G. (1990). *The alternative paradigm dialog*. Newbury Park, CA: Sage.

Guenther, T. W., & Heinicke, A. (2019). Relationships among types of use, levels of sophistication, and organizational outcomes of performance measurement systems: The crucial role of design choices. *Management Accounting Research*, *42*, 1–25.

Gurbaxani, V., & Dunkle, D. (2019). Gearing up for successful digital transformation. *MIS Quarterly Executive*, *18*(3), 1–21.

Haaker, T., Ly, P. T. M., Nguyen-Thanh, N., & Nguyen, H. T. H. (2021). Business model innovation through the application of the Internet-of-Things: A comparative analysis. *Journal of Business Research*, *126*, 126–136.

Hair, J. F., Black, W. C., Babin, B. J., & Anderson, R. E. (2014). *Multivariate data analysis* (7th ed.). London: Pearson New International ed., Pearson Education.

Hall, M. (2008). The effect of comprehensive performance measurement systems on role clarity, psychological empowerment and managerial performance. *Accounting, Organizations and Society*, *33*(2–3), 141–163.

Helfat, C. E., & Lieberman, M. B. (2002). The birth of capabilities: market entry and the importance of pre-history. *Industrial and Corporate Change*, *11*(4), 725–760.

Heredia, J., Castillo-Vergara, M., Geldes, C., Gamarra, F. M. C., Flores, A., & Heredia, W. (2022). How do digital capabilities affect firm performance? The mediating role of technological capabilities in the “new normal”. *Journal of Innovation & Knowledge*, *7*(2), 100171.

Hess, T., Matt, C., Benlian, A., & Wiesböck, F. (2016). Options for formulating a digital transformation strategy. *MIS Quarterly Executive*, *15*(2), 123–139.

Hill, C. W. L., & Jones G. R. (2008). *Essentials of strategic management*. Stamford, CT: Cengage Learning.

Hill, C. W., Jones, G. R., & Schilling, M. A. (2014). *Strategic management: Theory & cases: An integrated approach* (11th ed.). Stamford, CT: Cengage Learning.

Holopainen, M., Ukko, J., Saunila, M., Rantala, T., & Rantanen, H. (2021). The digital twin combined with real-time performance measurement in lean manufacturing. In *Real-time Simulation for sustainable production* (pp. 165–176). Routledge.

Holotiuk, F., & Beimborn, D. (2017). Critical success factors of digital business strategy. In *Proceedings Der 13. Internationalen Tagung Wirtschaftsinformatik (WI 2017)*, St. Gallen, 991–1005.

Horváth, D., & Szabó, R. Z. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change*, *146*, 119–132.

Hunger, J. D., & Wheelen, T. L. (2010). *Essentials of strategic management* (5th ed.). Upper Saddle River, NJ: Prentice Hall.

Igwenagu, C. (2016). *Fundamentals of research methodology and data collection*. Saarbrücken: LAP LAMBET Academic Publishing.

Jardak, M. K., & Ben Hamad, S. (2022). The effect of digital transformation on firm performance: Evidence from Swedish listed companies. *The Journal of Risk Finance*, *23*(4), 329–348.

Jasper, M., & Crossan, F. (2012). What is strategic management? *Journal of Nursing Management*, *20*(7), 838–846.

Johnson, G., Whittington, R., Regnér, P., Angwin, D., & Scholes, K. (2020). *Exploring strategy*. Pearson UK.

Kane, G. C., Palmer, D., Nguyen-Phillips, A., Kiron, D., & Buckley, N. (2017). Achieving digital maturity. *MIT Sloan Management Review*, *59*(1), 1–32.

Kaplan, A. M. (2015). Social media, the digital revolution, and the business of media. *International Journal on Media Management*, *17*(4), 197–199.

Kaplan, R. S., & Norton, D. P. (1992). The balanced scorecard—Measures that drive performance. *Harvard Business Review*, *70*(1), 71–79.

Kazmi, A. (2010). *Strategic management and business policy* (13th ed.). Tata McGraw Hill.

Keegan, D. P., Eiler, R. G., & Jones, C. R. (1989). Are your performance measures obsolete? *Strategic Finance*, *70*(12), 45.

Keong Choong, K. (2013). Understanding the features of performance measurement system: A literature review. *Measuring Business Excellence*, *17*(4), 102–121.

Ketokivi, M., & Choi, T. (2014). Renaissance of case research as a scientific method. *Journal of Operations Management*, *32*(5), 232–240.

Koh, C. E., Prybutok, V. R., Ryan, S., & Ibragimova, B. (2006). The importance of strategic readiness in an emerging e-government environment. *Business Process Management Journal*, *12*(1), 22–33.

Kong, E. (2008). The development of strategic management in the non-profit context: Intellectual capital in social service non-profit organisations. *International Journal of Management Reviews*, *10*(3), 281–299.

Konopik, J., Jahn, C., Schuster, T., Hoßbach, N., & Pflaum, A. (2022). Mastering the digital transformation through organizational capabilities: A conceptual framework. *Digital Business*, *2*(2), 100019.

Korsen, E. B. H., & Ingvaldsen, J. A. (2022). Digitalisation and the performance measurement and management system: Reinforcing empowerment. *International Journal of Productivity and Performance Management*, *71*(4), 1059–1075.

Koufteros, X., Verghese, A. J., & Lucianetti, L. (2014). The effect of performance measurement systems on firm performance: A cross-sectional and a longitudinal study. *Journal of Operations Management*, *32*(6), 313–336.

Kraus, S., Durst, S., Ferreira, J. J., Veiga, P., Kailer, N., & Weinmann, A. (2022). Digital transformation in business and management research: An overview of the current status quo. *International Journal of Information Management*, *63*, 102466.

Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N., & Roig-Tierno, N. (2021). Digital transformation: An overview of the current state of the art of research. *Sage Open*, *11*(3), 21582440211047576.

Kuhlmann, S., & Heuberger, M. (2023). Digital transformation going local: Implementation, impacts and constraints from a German perspective. *Public Money & Management*, *43*(2), 147–155.

Kurtz, H., Hanelt, A., & Firk, S. (2021). Digital business strategy and firm performance: An empirical investigation. In *Innovation through information systems: Volume III: A collection of latest research on management issues* (pp. 606–624). Springer International Publishing.

Leão, P., & da Silva, M. M. (2021). Impacts of digital transformation on firms' competitive advantages: A systematic literature review. *Strategic Change*, *30*(5), 421–441.

Lebas, M. J. (1995). Performance measurement and performance management. *International Journal of Production Economics*, *41*(1–3), 23–35.

Leedy, P., & Ormrod, J. (2001). *Practical research: Planning and design* (7th ed.). Upper Saddle River, NJ: Merrill Prentice Hall.

Legner, C., Eymann, T., Hess, T., Matt, C., Böhmann, T., Drews, P., ... & Ahlemann, F. (2017). Digitalization: Opportunity and challenge for the business and information systems engineering community. *Business & Information Systems Engineering*, *59*(4), 301–308.

Li, F. (2020). Leading digital transformation: Three emerging approaches for managing the transition. *International Journal of Operations & Production Management*, *40*(6), 809–817.

Li, F. (2023). What is digital strategy and does it really matter. In *Research handbook on digital* strategy. Cheltenham, UK: Edward Elgar Publishing.

Libert, B., Beck, M., & Wind, Y. (2016). Questions to ask before your next digital transformation. *Harvard Business Review*, *60*(12), 11–13.

Lipsmeier, A., Kühn, A., Joppen, R., & Dumitrescu, R. (2020). Process for the development of a digital strategy. *Procedia CIRP*, *88*, 173–178.

Loebbecke, C., & Picot, A. (2015). Reflections on societal and business model transformation arising from digitization and big data analytics: A research agenda. *The Journal of Strategic Information Systems*, *24*(3), 149–157.

Lokuge, S., Sedera, D., Cooper, V., & Burstein, F. (2021). Digital transformation: Environmental friend or foe? Panel discussion at the Australasian Conference on Information Systems 2019. *Communications of the Association for Information Systems*, *48*(1), 616–634.

Lucianetti, L., Battista, V., & Koufteros, X. (2019). Comprehensive performance measurement systems design and organizational effectiveness. *International Journal of Operations & Production Management*, *39*(2), 326–356.

Lynch, R., & Cross, K. (1991). *Measure up – The essential guide to measuring business perfomance*. London: Mandarin.

Margiono, A. (2021). Digital transformation: Setting the pace. *Journal of Business Strategy*, *42*(5), 315–322.

Matt, C., Hess, T., & Benlian, A. (2015). Digital transformation strategies. *Business & Information Systems Engineering*, *57*(5), 339–343.

McGrath, R., & McManus, R. (2020). Discovery-driven. *Harvard Business Review*, *98*(3), 124–133.

Melnyk, S. A., Bititci, U., Platts, K., Tobias, J., & Andersen, B. (2014). Is performance measurement and management fit for the future? *Management Accounting Research*, *25*(2), 173–186.

Micheli, P., & Muctor, G. (2021). The roles of performance measurement and management in the development and implementation of business ecosystem strategies. *International Journal of Operations & Production Management*, *41*(11), 1761–1784.

Mintzberg, H. (1987). The strategy concept II: Another look at why organizations need strategies. *California Management Review*, *30*(1), 25–32.

Mithas, S., Tafti, A., & Mitchell, W. (2013). How a firm's competitive environment and digital strategic posture influence digital business strategy. *MIS Quarterly*, *37*(2), 511–536.

Moullin, M. (2002). *Delivering excellence in health and social care*. Buckingham: Open University Press.

Moullin, M. (2007). Performance measurement definitions: Linking performance measurement and organisational excellence. *International Journal of Health Care Quality Assurance*, *20*(3), 181–183.

Mourtzis, D., Angelopoulos, J., & Panopoulos, N. (2021). Smart manufacturing and tactile internet based on 5G in industry 4.0: Challenges, applications and new trends. *Electronics*, *10*(24), 3175.

Nadkarni, S., & Prügl, R. (2021). Digital transformation: A review, synthesis and opportunities for future research. *Management Review Quarterly*, *71*, 233–341.

Nag, R., Hambrick, D. C., & Chen, M. J. (2007). What is strategic management, really? Inductive derivation of a consensus definition of the field. *Strategic Management Journal*, *28*(9), 935–955.

Najmi, M., & F. Kehoe, D. (2001). The role of performance measurement systems in promoting quality development beyond ISO 9000. *International Journal of Operations & Production Management*, *21*(1/2), 159–172.

Nambisan, S., Lyytinen, K., Majchrzak, A., & Song, M. (2017). Digital innovation management. *MIS Quarterly*, *41*(1), 223–238.

Nasiri, M., Ukko, J., Saunila, M., Rantala, T., & Rantanen, H. (2020). Digital-related capabilities and financial performance: The mediating effect of performance measurement systems. *Technology Analysis & Strategic Management*, *32*(12), 1393–1406.

Nayak, J. K., & Singh, P. (2021). *Fundamentals of research methodology problems and prospects*. Delhi, India: SSDN Publishers & Distributors.

Neely, A., & Al Najjar, M. (2006). Management learning not management control: The true role of performance measurement? *California Management Review*, *48*(3), 101–114.

Neely, A., Adams, C., & Kennerley, M. (2002). *The performance prism: The scorecard for measuring and managing stakeholder relationship*. London: Prentice Hall.

Neely, A., Gregory, M., & Platts, K. (1995). Performance measurement system design: A literature review and research agenda. *International Journal of Operations & Production Management*, *15*(4), 80–116.

Netemeyer, R. G., Bearden, W. O., & Sharma, S. (2003). *Scaling procedures: Issues and applications*. California, USA: Sage Publications.

Nudurupati, S. S., Garengo, P., & Bititci, U. S. (2021). Impact of the changing business environment on performance measurement and management practices. *International Journal of Production Economics*, *232*, 107942.

Nudurupati, S. S., Tebboune, S., & Hardman, J. (2016). Contemporary performance measurement and management (PMM) in digital economies. *Production Planning & Control*, *27*(3), 226–235.

Nwankpa, J. K., & Roumani, Y. (2016). IT capability and digital transformation: A firm performance perspective. In *International Conference of Information Systems*, Dublin, Ireland.

Otley, D. (1999). Performance management: A framework for management control systems research. *Management Accounting Research*, *10*(4), 363–382.

Paiola, M., & Gebauer, H. (2020). Internet of things technologies, digital servitization and business model innovation in BtoB manufacturing firms. *Industrial Marketing Management*, *89*, 245–264.

Parmar, R., Leiponen, A., & Thomas, L. D. (2020). Building an organizational digital twin. *Business Horizons*, *63*(6), 725–736.

Partington, D. (2002). *Essential skills for management research*. London: SAGE Publications.

Patton, M. Q. (1999). Enhancing the quality and credibility of qualitative analysis. *Health Services Research*, *34*(5 Pt 2), 1189–1208.

Peppard, J., & Ward, J. (2016). *Strategic management of information systems: Building a digital strategy*. Hoboken, NJ: John Wiley & Sons.

Piccoli, G., Rodriguez, J., & Grover, V. (2022). Digital strategic initiatives and digital resources: Construct definition and future research directions. *Management Information Systems Quarterly*, *46*(4), 2289–2316.

Podsakoff, P. M., & Organ, D. W. (1986). Self-reports in organizational research: Problems and prospects. *Journal of Management, 12*(4), 531–544.

Podsakoff, P. M., MacKenzie, S. B., Lee, J. Y., & Podsakoff, N. P. (2003). Common method biases in behavioral research: A critical review of the literature and recommended remedies. *Journal of Applied Psychology*, *88*(5), 879–903.

Porter, M. E. (1996). What is strategy? *Harvard Business Review*, *74*(6), 61–78.

Rajasekar, S. P., Philominathan, P., & Chinnathambi, V. (2013). *Research methodology*. Tamilnadu, India: Bharathidas University.

Ravelomanantsoa, M. S., Ducq, Y., & Vallespir, B. (2019). A state of the art and comparison of approaches for performance measurement systems definition and design. *International Journal of Production Research*, *57*(15–16), 5026–5046.

Redding, J. C., & Catalanello, R. F. (1994). *Strategic readiness: The making of the learning organization*. San Francisco, CA: Jossey-Bass.

Rêgo, B. S., Jayantilal, S., Ferreira, J. J., & Carayannis, E. G. (2022). Digital transformation and strategic management: A systematic review of the literature. *Journal of the Knowledge Economy*, *13*(4), 3195–3222.

Reim, W., Andersson, E., & Eckerwall, K. (2023). Enabling collaboration on digital platforms: A study of digital twins. *International Journal of Production Research*, *61*(12), 3926–3942.

Reinking, J., Arnold, V., & Sutton, S. G. (2020). Synthesizing enterprise data to strategically align performance: The intentionality of strategy surrogation. *International Journal of Accounting Information Systems*, *36*, 100444.

Robert, M., Giuliani, P., & Gurau, C. (2022). Implementing industry 4.0 real-time performance management systems: The case of Schneider Electric. *Production Planning & Control*, *33*(2–3), 244–260.

Sadler, P. (2003). *Strategic management*. Kogan Page Publishers.

Sætre, A. S., & Van de Ven, A. (2021). Generating theory by abduction. *Academy of Management Review*, *46*(4), 684–701.

Sardi, A., Garengo, P., & Bititci, U. (2019). Measurement and management of competences by enterprise social networking. *International Journal of Productivity and Performance Management*, *68*(1), 109–126.

Sardi, A., Sorano, E., Cantino, V., & Garengo, P. (2020a). Big data and performance measurement research: Trends, evolution and future opportunities. *Measuring Business Excellence*. Advance online publication.

Sardi, A., Sorano, E., Ferraris, A., & Garengo, P. (2020b). Evolutionary paths of performance measurement and management system: The longitudinal case study of a leading SME. *Measuring Business Excellence*, 24(4), 495–510.

Saunders, M., Lewis, P., & Thornhill, A. (2015). *Research methods for business students* (7th ed.). Harlow: Pearson Education.

Schurz, G. (2008). Patterns of abduction. *Synthese*, *164*(2), 201–234.

Schwertner, K. (2017). Digital transformation of business. *Trakia Journal of Sciences*, *15*(1), 388–393.

Sebastian, I., Ross, J., Beath, C., Mocker, M., Moloney, K., & Fonstad, N. (2017). How big old companies navigate digital transformation. *MIS Quarterly Executive*, *16*(3), 197–213.

Senyo, P. K., Liu, K., & Effah, J. (2019). Digital business ecosystem: Literature review and a framework for future research. *International Journal of Information Management*, *47*, 52–64.

Sharma, M. K., Bhagwat, R., & Dangayach, G. S. (2005). Practice of performance measurement: Experience from Indian SMEs. *International Journal of Globalisation and Small Business*, *1*(2), 183–213.

Sigari, S., Altunyurt, A., & Rusu, L. (2021). Barriers in digital transformation: A case study of an IT company in Sweden. *International Journal of Innovation in the Digital Economy*, *12*(4), 1–15.

Simons, R. (1994). How new top managers use control systems as levers of strategic renewal. *Strategic Management Journal*, *15*(3), 169–189.

Singh, A., Klarner, P., & Hess, T. (2020). How do chief digital officers pursue digital transformation activities? The role of organization design parameters. *Long Range Planning*, *53*(3), 101890.

Singh, S., Sharma, M., & Dhir, S. (2021). Modeling the effects of digital transformation in Indian manufacturing industry. *Technology in Society*, *67*, 101763.

Smith, M., & Bititci, U. S. (2017). Interplay between performance measurement and management, employee engagement and performance. *International Journal of Operations & Production Management*, *37*(9), 1207–1228.

Sonnentag, S., & Frese, M. (2002). Performance concepts and performance theory. *Psychological Management of Individual Performance*, *23*(1), 3–25.

Sousa-Zomer, T. T., Neely, A., & Martinez, V. (2020). Digital transforming capability and performance: A microfoundational perspective. *International Journal of Operations & Production Management*, *40*(7/8), 1095–1128.

Spremic, M. (2017). Governing digital technology—how mature IT governance can help in digital transformation? *International Journal of Economics and Management Systems*, *2*, 214–222.

Stehlik-Barry, K., & Babinec, A. J. (2017). *Data analysis with IBM SPSS Statistics: Implementing data modeling, descriptive statistics and ANOVA* (1st ed.). Birmingham, England: Packt.

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, *48*(6), 1273–1296.

Tabrizi, B., Lam, E., Girard, K., & Irvin, V. (2019). Digital transformation is not about technology. *Harvard Business Review*, *13*, 1–6.

Tangen, S. (2004). Performance measurement: From philosophy to practice. *International Journal of Productivity and Performance Management*, *53*(8), 726–737.

Taouab, O., & Issor, Z. (2019). Firm performance: Definition and measurement models. *European Scientific Journal*, *15*(1), 93–106.

Taticchi, P., Tonelli, F., & Cagnazzo, L. (2010). Performance measurement and management: A literature review and a research agenda. *Measuring Business Excellence*, *14*(1), 4–18.

Tekic, Z., & Koroteev, D. (2019). From disruptively digital to proudly analog: A holistic typology of digital transformation strategies. *Business Horizons*, *62*(6), 683–693.

Teng, X., Wu, Z., & Yang, F. (2022). Research on the relationship between digital transformation and performance of SMEs. *Sustainability*, *14*(10), 6012.

Tesch, J. F., Brillinger, A. S., & Bilgeri, D. (2017). Internet of things business model innovation and the stage-gate process: An exploratory analysis. *International Journal of Innovation Management*, *21*(05), 1740002.

Tessier, S., & Otley, D. (2012). A conceptual development of Simons' Levers of Control framework. *Management Accounting Research*, *23*(3), 171–185.

Teubner, R. A., & Stockhinger, J. (2020). Literature review: Understanding information systems strategy in the digital age. *The Journal of Strategic Information Systems*, *29*(4), 101642.

Tsou, H. T., & Chen, J. S. (2023). How does digital technology usage benefit firm performance? Digital transformation strategy and organisational innovation as mediators. *Technology Analysis & Strategic Management*, 35(9), 1114–1127.

Tsvetkov, N., & Chekanov, A. (2021). The data dilemma: How availability can threaten the competitive advantage of data-based firms. *Journal of Business Strategy*, *42*(3), 177–187.

Ukko, J. (2009). How to manage performance by utilising the factors behind successful operative level performance measurement: A framework. In *Performance Management Association Conference 2009,* Otago, 14–17 April, Paper No. 1011,.

Ukko, J., Nasiri, M., Saunila, M., & Rantala, T. (2019). Sustainability strategy as a moderator in the relationship between digital business strategy and financial performance. *Journal of Cleaner Production*, *236*, 117626.

Ukko, J., Saunila, M., Nasiri, M., Rantala, T., & Holopainen, M. (2022). Digital twins' impact on organizational control: Perspectives on formal vs social control. *Information Technology & People*, *35*(8), 253–272.

Ukko, J., Tenhunen, J., & Rantanen, H. (2007). Performance measurement impacts on management and leadership: Perspectives of management and employees. *International Journal of Production Economics*, *110*(1–2), 39–51.

Vallurupalli, V., & Bose, I. (2018). Business intelligence for performance measurement: A case based analysis. *Decision Support Systems*, *111*, 72–85.

van Oorschot, K. E., Akkermans, H. A., Van Wassenhove, L. N., & Wang, Y. (2023). Organizing for permanent beta: Performance measurement before vs performance monitoring after release of digital services. *International Journal of Operations & Production Management*, *43*(3), 520–542.

Vaska, S., Massaro, M., Bagarotto, E. M., & Dal Mas, F. (2021). The digital transformation of business model innovation: A structured literature review. *Frontiers in Psychology*, *11*, 539363.

Venkitachalam, K., & Bosua, R. (2019). Perspectives on effective digital content management in organizations. *Knowledge and Process Management*, *26*(3), 202–209.

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, *122*, 889–901.

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144.

Warner, K. S., & Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. *Long Range Planning*, *52*(3), 326–349.

Westerman, G. (2018). Your company doesn't need a digital strategy. *MIT Sloan Management Review*, *59*(3), 1–5.

Westerman, G., Calméjane, C., Bonnet, D., Ferraris, P., & McAfee, A. (2011). Digital Transformation: A roadmap for billion-dollar organizations. *MIT Center for Digital Business and Capgemini Consulting*, *1*, 1–68.

Wheelen, T. L., Hunger, J. D., Hoffman, A. N., & Bamford, C. E. (2017). *Strategic management and business policy* (Vol. 55). Boston: Pearson.

Williams, C. (2007). Research methods. *Journal of Business & Economics Research*, *5*(3), 65–72.

Yadav, N., Sushil, & Sagar, M. (2014). Revisiting performance measurement and management: Deriving linkages with strategic management theories. *International Journal of Business Performance Management*, *15*(2), 87–105.

Yeow, A., Soh, C., & Hansen, R. (2018). Aligning with new digital strategy: A dynamic capabilities approach. *The Journal of Strategic Information Systems*, *27*(1), 43–58.

Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Thousand Oaks, California: SAGE.

Yoo, Y., Henfridsson, O., & Lyytinen, K. (2010). Research commentary—The new organizing logic of digital innovation: An agenda for information systems research. *Information Systems Research*, *21*(4), 724–735.

Yuliansyah, Y., Khan, A. A., & Fadhilah, A. (2019). Strategic performance measurement system, firm capabilities and customer-focused strategy. *Pacific Accounting Review*, *31*(2), 288–307.

Zairi, M. (1994). *Measuring performance for business results*. London: Chapman & Hall.

Zhai, H., Yang, M., & Chan, K. C. (2022). Does digital transformation enhance a firm's performance? Evidence from China. *Technology in Society*, *68*, 101841.

Zhong, R. Y., Wang, L., & Xu, X. (2017). An IoT-enabled real-time machine status monitoring approach for cloud manufacturing. *Procedia CIRP*, *100*(63), 709–714.

Appendix A: Structure of interview 1

Background information

1. Please briefly name your job title and describe your job description at the company.
2. Please name the department in which you are working.

Digital strategy

3. Please describe how your company has considered digital transformation in its strategic approach, for example, how the use of digital technologies has affected the company's functions, operations, goals, and measures.
4. Please describe how digital technologies have affected company investments, such as how much the company has invested in digital transformation and in which areas the investment has been targeted.
5. Please describe how your company's current resources support digital transformation, such as employees, equipment, and financial resources.

Products and services related to digital

6. Please describe the use of digital technologies in the personalization of products and services.
7. Please describe your company's services related to your products.
8. Please specify the smart products your company offers.
9. Please describe the role of digital technologies in product and service innovations.
10. Please consider how your company uses collaboration networks in digital products and services.

Technology

11. Please define what kind of information systems your company uses.
12. Please describe the role of information security and the different information security practices your company uses.
13. Please consider how aware your company is of new digital technologies and their opportunities and how the company is mapping these opportunities.
14. Please specify the digital technologies and solutions your company uses.
15. Please describe the role of data in the operation of your company.

Digital production and development

16. Please describe the use of digital technologies in production.
17. Please specify how digital technologies support the development of processes.

Organization and culture

18. Please describe your company's approach to digital transformation.
19. Please specify how the information flows in your company, considering how the use of digital technologies can support or is supporting it.
20. Please consider your company's culture of continuous development and the role of digital technology in the development of your company's operations.

21. Please describe different working practices in your company and define the role of digital technology in those.

<u>Management</u>

22. Please picture the management's willingness to digital transformation and how it has been reflected in your company's operations.
23. Please specify the level of management capabilities related to digital strategy, digital technologies, and new digital opportunities.
24. Please describe your company's decision-making processes and the role of data in them.

<u>Employees</u>

25. Please describe the skills of the company's employees in relation to digital technologies.
26. Please consider how employees have adapted to the use of new digital technologies.
27. Please specify the ways in which your company supports the training of digital skills and increasing knowledge related to digitalization.
28. Please consider the opportunities and willingness of employees to participate and influence in relation to digital transformation.

<u>Digital customer experience</u>

29. Please describe what kind of digital channels your company use with the customer, considering information sharing, communication, and interaction.
30. Please define at what level the customers' digital capabilities are.
31. Please describe the role of customers in business, for example, considering testing and developing digital products and services.
32. Please specify how your company utilizes digital technology in different customer processes, such as sales and marketing.
33. Please describe the importance of analytics in processing customer data for your company.

<u>Supply chain</u>

34. Please identify the digital capabilities of your company's supply chain, considering technological know-how, resources, use of digital technologies, and so on.
35. Please specify what kind, how, and in which areas your company uses digital technologies, considering supply chains.
36. Please describe the importance of collaboration networks for your company.

<u>Supporting questions</u>

37. Please describe how your company is performing in relation to your competitors.
38. Please specify the level of digitization in relation to your competitors.
39. Please consider how the use of digital technologies could support your operations in the future.
40. Please summarize how your company wants to increase its digital maturity level in the future.

Appendix B: Survey items

Background information

1. Age of the company
2. Company's main operating industry: service or manufacturing
3. Turnover
4. Company customers: B2B or B2C
5. Number of employees in the company
6. Position of the respondent in the company: top management, middle management, personnel

Digital strategy

Technological development

7. Company recognizes the meaning of digital technology in their industry.
8. Company has continuous digital projects.
9. Company tries to achieve a better performance/competitive advantage through digital technologies.

Goals

10. Company has determined goals related to digital technology.
11. Company follows the realization of determined goals related to digital technologies.
12. Company can use digital technology to achieve the defined goals.

Resources

13. Company has the financial resources to invest in digital projects.
14. Employees have time to work on digital technology projects.
15. Employees have the knowledge to accomplish digital technology projects.

Management

16. Management has noted and followed the changes that digital technology brings to the industry.
17. Management has the capability to design a digital strategy.
18. Management is eagerly looking for new digital opportunities.

Responsibilities

19. Company has appointed a responsible person for digital activities.
20. The responsible persons have the knowledge, skills, and experience to lead digital activities.

PMM in digital transformation

The role of PMM

21. Company uses performance measurement to support management.

22. Company’s performance measurement provides information on different areas of the business.
23. Company uses measures to monitor results related to strategic goals.
24. Company regularly reports on measure information.
25. Performance measurement supports our company’s strategic decisions.
26. Performance measurement is important for the development of our company.
27. Performance measurement has a significant impact on the activities of our company’s personnel.

Performance measurement and digital strategy

28. Company’s performance measurement compounds with digital strategy/digital operations.

Performance indicators

29. Collaboration with external parties

Appendix C: Structure of interview 2

Definition of digital twin

1. Please describe what digital twin refers to you/how the term is defined in your company.

Digital twins: the current state and possible applications

2. Please describe in which functions/operations you currently use digital twins.
3. Please consider in which functions/operations you might use digital twins in the future.
4. Please describe whether your company aims to use digital twins to create a novel business with new customers.
5. Please describe the challenges encountered in selling digital twins to customers.

Use of digital twin

6. Please consider what kind of activities a digital twin can be used for.
7. Please define what kind of requirements, challenges, and effects the use of a digital twin in these activities would bring.

Digital twin and collaboration network

8. Please describe the necessary business cooperation network around the digital twin, and think about the related goals, participants, and roles.
9. Please think about the requirements and challenges related to the cooperation network.
10. Please consider the benefits of the cooperation network for different companies.

Publication I

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Managing the strategic readiness of industrial companies for digital operations

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Managing the strategic readiness of industrial companies for digital operations

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A R T I C L E I N F O

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A B S T R A C T

This study focused on how the strategic readiness of companies for digital operations is managed. The empirical evidence was derived from case studies on 11 industrial companies. The study's findings show that most of the studied companies face challenges in adjusting their digital operations. In response, we propose that to facilitate strategic readiness for digital operations, companies should find a balance between intuitive and data-based decision making; develop leadership capabilities related to strategic development, technology adoption, and culture creation; find a balance between their own and customers' readiness and willingness to accept digital operations; and increase inter-organizational collaboration in the use of digital technologies to allow for simultaneous upgrading of all partners' strategic readiness for digital operations. This study is among the first to examine the strategic readiness of companies for digital operations by attempting to determine how digital operation can be integrated effectively into daily practice.

1. Introduction

Current operations management literature agrees that digital technologies affect or will affect every industry, changing the ways that companies operate (Gölzer & Fritzsche, 2017; Li, 2020; Sebastian et al., 2017; Sousa-Zomer, Neely, & Martinez, 2020). In almost all industries, companies have conducted initiatives related to digital operations to seek ways to develop and digitalize their business operations, exploit their benefits, and respond to the challenges of the competitive environment (Chanias, Myers, & Hess, 2019; Matt, Hess, & Benlian, 2015; Zangiacomi, Oesterle, Fornasiero, Sacco, & Azevedo, 2017). For companies to remain competitive, the flexibility and adaptability of their business operations to economic and technological change are emphasized (Gölzer & Fritzsche, 2017). As a result, the readiness of companies to adjust their operations to the adoption of novel digital technologies has become increasingly important to achieve competitiveness.

Emerging digital technologies enable a new way of formulating company operations (Li, 2020; Olsen & Tomlin, 2020). In this sense, digital operations refer to supporting a company's processes through digital technologies (Boute & Van Mieghem, 2021). These may include analytical, blockchain, cloud, and Internet of Things technologies, along with different types of platforms or three-dimensional printing, autonomous vehicles, mobile applications, and so on (Li, 2020; Olsen & Tomlin, 2020; Vial, 2019; Zangiacomi et al., 2017). The best technology/digital tool or combination of tools for a certain company varies from case to case, since concrete goals are required to underpin implementation (Tabrizi, Lam, Girard, & Irvin, 2019; Ukko, Nasiri, Saunila, & Rantala, 2019). The use of technologies is also influenced by the company's attitude toward new technologies and its ability to take advantage of them (Matt et al., 2015; Vial, 2019). Thus, supporting a company's operations with digital technologies can be regarded as a strategic issue with a significant impact for different business functions and operations, extending even outside company borders and influencing business processes, products, production, supply chains, and sales channels (Horlach, Drews, Schirmer, & Böhmann, 2017; Matt et al., 2015).

Strategic readiness for digital transformation and operations itself is not separately identifiable among company operations because it comprises distinct processes within a company. According to Porter (1996), strategy is a unique and purposeful combination of resources designed for "deliberately choosing a different set of activities to deliver a unique mix of values." Digitalizing company operations necessitates taking into account various structural factors, such as management, people, organizational culture and structure, and industry readiness, needed to support change and achieve value through these initiatives (Galindo-Martín, Castaño-Martínez, & Méndez-Picazo, 2019; Konopik, Jahn,

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Schuster, Hoßbach, & Pflaum, 2022; Sousa-Zomer et al., 2020; Tabrizi et al., 2019). Supply chain and customers are no exception, as digital transformation affects both people and networks as well as their communication and working habits (Agrifoglio, Cannavale, Laurenza, & Metallo, 2017; Büyüközkan & Göçer, 2018; Hausberg, Liere-Netheler, Packmohr, Pakura, & Vogelsang, 2019). Thus, the dimensions of strategic readiness comprise processes that are a crucial practice for fostering, measuring, and strengthening digital operations. The dimensions that comprise digital operations are grouped into five major elements: strategy, management, organization and culture, customers, and supply chain. These dimensions have been built up from the literature on digital transformation to build a theoretical framework that highlights the dimensions through which a strategic level of readiness for digital operations is formed. Thus, the preceding dimensions tend to exist, to some degree, within companies with high strategic readiness for digital operations.

While the influence of digital transformation on companies' operations is widely recognized, its influence on the management of digital operations from strategic perspectives has elicited scant attention. Presumably, digital operations exert a meaningful effect on management activities and their alignment with the strategic objectives of a company. More precisely, the phenomenon of the digital transformation of operations is acknowledged in literature, but little research has been conducted on how operations management from strategic perspectives can assist it. Some strategic issues need to be tackled in order to assist companies in making effective initiatives toward digital operations. Thus, this study investigates how the strategic readiness of companies for digital operations is managed. The study can be classified as a theory-generating case study, as the dimensions of companies' readiness for digital operations are guided by existent theoretical considerations, but the findings are informed and shaped by empirical analysis.

The paper proceeds as follows. The next section provides a literature review of prior research on key concepts and strategic dimensions of digital operations. Different maturity and readiness models, frameworks, and roadmaps in the context of digital transformation are reviewed to determine the dimensions of strategic readiness for digital operations. This study aims to develop a research framework that demonstrates the type of strategic readiness that contributes to the adoption of digital operations in the context of digital transformation. Next, the research methodology is presented to justify the chosen approaches and then empirical evidence is presented based on case studies with 11 companies. For the discussions, the results section is used to create propositions that theorize the contribution of this paper with regard to the role of managing strategic readiness for digital operations. The paper ends with the conclusions and recommended directions for further research.

2. Strategic readiness for digital operations

2.1. Key concepts

2.1.1. Digital transformation

Emerging digital technologies affect strategies and operations through industries (Li, 2020). Digital transformation is the transformation caused by utilization of digital technologies (Hess, Benlian, Matt, & Wiesböck, 2016). It is a multifaceted phenomenon (Tekic & Koroteev, 2019) that enables the development of new or enhanced products and services and creates changes in the company's vision, strategy, business model, organizational structures, processes, capabilities, and culture (Gurbaxani & Dunkle, 2019). It has different aspects and implications for different companies, as the use of novel digital technologies, such as social media, mobile technology, and analytics, can facilitate substantial business improvements, including improving customer experience, increasing operational efficiency, and creating new business models (Fitzgerald, Kruschwitz, Bonnet, & Welch, 2014; Tekic & Koroteev, 2019).

2.1.2. Digital operations

Digital transformation, considered a multidimensional umbrella term, is directly connected to the use of technology, including analytical, blockchain, cloud, and Internet of Things (IoT) technologies, as well as various types of platforms (Vial, 2019), and is increasingly being adopted by companies to facilitate operations. Digital operations are related to operational level action in the corporate realm because they are related to technology that handles digital inputs and outputs; either humans can act as tool users or an organization's core operations can be fully technology-based (Salovaara, Lyytinen, & Penttinen, 2019). Thus, digital operations refer to supporting a company's processes, in part or in full, through digital technologies (Boute & Van Mieghem, 2021), which an organization uses to realign its current environment by modifying its business and operations (Besson & Rowe, 2012; Matt et al., 2015; Vial, 2019). Boute, Gijsbrechts, and Van Mieghem (2022) defined a digital operation as "a process with a digital workflow," which means that all information required to perform functions, such as work instructions and data, is digitized, allowing information transparence and sharing between various actors. Corver and Elkhuizen (2014) noted that by digitizing operations through automation, standardization, and global sourcing, improves companies' agility and responsiveness to changes and provides better opportunities to grow and maintain profitability. Thus, companies reshape their operations through digital operations; digital technology adds value by making products, services, and processes better, faster, cheaper, or more convenient (McGrath & McManus, 2020).

The ability of companies implementing digital operations to adopt novel digital technologies has become increasingly important for achieving competitiveness. Managing digital operations is challenging because of their complexity and uncertainty (Li, 2020; Tabrizi et al., 2019). Leaders believe that digital technology can make business and operations more efficient, but they are also frustrated with the difficulty of achieving results from novel digital technology (Fitzgerald et al., 2014). Digital technology alone does not add much value to a company's operations without a connection to the company's strategic visions and goals (Davenport & Westerman, 2018; Kane, Palmer, Nguyen-Phillips, Kiron, & Buckley, 2017;Matt et al., 2015; Tabrizi et al., 2019). Berman (2012) noted that companies should refocus on the strategic development of customer value propositions and improve their operational models by using digital technologies. In addition, Warner and Wäger (2019) reported that digital transformation often leads to large-scale changes in a company's collaborative approach, which, when properly implemented, will lead to profound changes in organizational culture. To support their business and operating model, culture, and collaborative networks, companies need new kinds of capabilities to facilitate digital operations in digital transformation (Vial, 2019; Warner & Wäger, 2019).

2.1.3. Strategic readiness

Digital transformation and implementing digital operations can be seen as a strategic issue that incorporates the leverage of new digital technologies, creates new digital business models, and enables new ways to generate value (Matt et al., 2015; Tabrizi et al., 2019). In line with previous studies, Tekic and Koroteev (2019) stated that the digital transformation strategy should take into account utilization of digital technologies and readiness of the business model for digital operations. Digital technology often has major implications for various areas of business, extending outside company borders and influencing business processes, products, production, supply chains, and sales and service channels (Horlach et al., 2017; Matt et al., 2015). Such implications and transformations require companies to adopt a strategy that connects their digital technologies and operations (Bharadwaj, El Sawy, Pavlou, & Venkatraman, 2013).

Strategic readiness is a state of permanent, organization-wide preparedness for comprehensive and systemic change (Koh, Prybutok, Ryan, & Ibragimova, 2006; Redding & Catalanello, 1994). As digital technology has significant implications for current and future business, it is important to assess the company's overall readiness to leverage these in the context of the company's business objectives. Thus, this study defined strategic readiness for digital operations as a state of permanent, organization-wide preparedness for comprehensive and systemic change toward implementing digital technologies. However, strategic readiness for digital operations is not separately identifiable among company operations, as it comprises distinct processes within a company. We suggest that strategic readiness dimensions comprise processes that are a crucial practice for fostering, measuring, and strengthening digital operations. These dimensions are introduced next and form the research framework for managing digital operations.

2.2. Research framework for managing digital operations

Facilitating the management of digital operations is an important goal for most modern businesses (Kane et al., 2017); therefore, it is important to determine the type of strategic readiness that contributes to the adoption of digital operations in the context of digital transformation. Through their own activities, companies can promote the use of digital technologies that can result in major improvements in offerings and customer satisfaction, thereby strengthening organizational efficacy (Tortorella, Vergara, Garza-Reyes, & Sawhney, 2020). The management of digital operations from strategic perspectives will support the process of implementing digital technologies to exploit their benefits (Horlach et al., 2017; Li, 2020; Matt et al., 2015; Vial, 2019). Kane et al. (2017) reported that technology has only been one part of the whole, as changes in the capabilities, culture, and organizational structure of a company are needed to achieve business benefits.

With extant operations management studies having paid scant attention to how companies manage strategic readiness for digital operations, a need exists to review empirical studies in other research fields and seek views on the dimensions of companies' strategic readiness for digital operations. Thus, we studied 19 different maturity and readiness models, frameworks, and roadmaps in the context of digital transformation, Industry 4.0, and smart manufacturing to determine the strategic dimensions of industrial companies' digital operations (Appendix 1). Maturity models are generally employed as a tool to conceptualize and measure an organization's maturity or a process in relation to desired goals (Schumacher, Erol, & Sihn, 2016). In this study, digital maturity is the process of adapting company practices in a competitive digital environment (Kane et al., 2017). Using this analysis, five main top-level dimensions were selected: strategy, management, organization and culture, customer, and supply chain. The dimensions were organized such that the first three were interrelated with the last two. This is reflected in the fact that when the first three dimensions, which represent internal readiness, are in order, they serve the last two dimensions, which represent external readiness. These dimensions were used to build a theoretical framework that highlights the mechanisms that companies should focus on to succeed in digital transformation. For companies to effectively leverage digital technologies in their operations, the following dimensions must be considered (Table 1). Thus, the following factors tend to exist, to some degree, within companies with high readiness for digital operations in digital transformation.

2.2.1. Strategy

Integrating digital transformation into a company's strategy is an important success factor in digitalizing operations and adopting digital technologies (Akdil et al., 2018; Chanias et al., 2019; Kane et al., 2017; Pessl et al., 2017). Digital business strategy is not separate but needs to be linked to corporate strategy and other functional and operational strategies (Chanias et al., 2019; Matt et al., 2015). According to Chanias et al. (2019), digital business strategy is a dynamic process that involves learning and doing and is implemented by leveraging digital resources to create a different value. An important part of shaping a digital strategy is setting goals to clarify what is to be achieved and what is less

Table 1
Research framework for managing digital operations.

Dimensions	References	Factors	References
Strategy	Lichtblau et al., 2015; Berghaus & Back, 2016; Schumacher et al., 2016; Klötzer & Pflaum, 2017; Pessl, Sorko, & Mayer, 2017; Akdil, Ustundag, & Cevikcan, 2018; Büyüközkan & Göçer, 2018; Mittal, Romero, & Wuest, 2018; Schumacher, Nemeth, & Sihn, 2019; Williams, Schallmo, Lang, & Boardman, 2019	objectives, measures	Lichtblau et al., 2015; Berghaus & Back, 2016; Schumacher et al., 2016; Jung, Kulvatunyou, Choi, & Brundage, 2016; Klötzer & Pflaum, 2017; Lee, Jun, Chang, & Park, 2017; Pessl et al., 2017; Akdil et al., 2018; Büyüközkan & Göçer, 2018; Schumacher et al., 2019
		Investments	Lichtblau et al., 2015; Mittal, Romero, & Wuest, 2018; Akdil et al., 2018
		Resources	Schumacher et al., 2016; Gökalp, Şener, & Eren, 2017; Pessl et al., 2017; Schuh, Anderl, Gausemeier, Ten Hompel, & Wahlster, 2017; Akdil et al., 2018; Schumacher et al., 2019
Management	Berghaus & Back, 2016; Jung et al., 2016; Schumacher et al., 2016; Gökalp et al., 2017; Lee et al., 2017; Pessl et al., 2017; Akdil et al., 2018; Mittal, Romero, & Wuest, 2018; Schumacher et al., 2019; Williams et al., 2019	Support and willingness to change	Berghaus & Back, 2016; Schumacher et al., 2016; Gökalp et al., 2017; Schumacher et al., 2019
		Digital skills/ capabilities	Schumacher et al., 2016; Gökalp et al., 2017; Pessl et al., 2017
		Data-based decision making	Gökalp et al., 2017; Schuh et al., 2017; Mittal, Romero, & Wuest, 2018; Schumacher et al., 2019
Organization and Culture	Corver & Elkhuizen, 2014; Berghaus & Back, 2016; Geissbauer, Vedso, & Schrauf, 2016; Jung et al., 2016; Schumacher et al., 2016; Gökalp et al., 2017; Klötzer & Pflaum, 2017; Pessl et al., 2017; Schuh et al., 2017; Büyüközkan & Göçer, 2018; Williams et al., 2019	Learning culture and willingness to change	Schumacher et al., 2016; Klötzer & Pflaum, 2017; Pessl et al., 2017; Schuh et al., 2017
		Information sharing	Schumacher et al., 2016; Pessl et al., 2017; Schuh et al., 2017
		Flexible working	Corver & Elkhuizen, 2014; Berghaus & Back, 2016; Pessl et al., 2017; Schuh et al., 2017
Customers	Corver & Elkhuizen, 2014; Berghaus & Back, 2016; Schumacher et al., 2016; Schumacher et al., 2019; Büyüközkan & Göçer, 2018	Digital information and communication channels	Corver & Elkhuizen, 2014; Berghaus & Back, 2016; Akdil et al., 2018
		Digital capabilities	Schumacher et al., 2016; Schumacher et al., 2019 Mittal, Romero, & Wuest, 2018;

(continued on next page)

Table 1 (*continued*)

Dimensions	References	Factors	References
		Customer participation and collaboration	Schumacher et al., 2019
		Willingness to change	Schumacher et al., 2019
Supply chain	Geissbauer et al., 2016; Büyüközkan & Göçer, 2018	Digital capabilities	Geissbauer et al., 2016; Büyüközkan & Göçer, 2018; Schumacher et al., 2019
		Supply chain management	Akdil et al., 2018; Büyüközkan & Göçer, 2018
		Cooperation networks	Corver & Elkhuizen, 2014; Berghaus & Back, 2016; Klötzer & Pflaum, 2017; Schuh et al., 2017; Akdil et al., 2018; Büyüközkan & Göçer, 2018

important (Büyüközkan & Göçer, 2018). Companies also need to define the required capabilities (Geissbauer et al., 2016; Schuh et al., 2017) and measures to monitor changes in the operations (Berghaus & Back, 2016; Pessl et al., 2017; Schuh et al., 2017). Companies of all sizes need to invest in digital-related capabilities to remain competitive (Kane et al., 2017). Therefore, the availability of financial and technical resources is an important factor of digital operations (Mittal, Khan, Romero, & Wuest, 2018).

2.2.2. Management

Ultimate comprehensive digital transformation is hardly possible without the willingness of management to change and play a supporting role (Akdil et al., 2018; Gökalp et al., 2017; Pessl et al., 2017). A positive relationship exists between digital strategy and operations management, as reflected in how management supports digital operations and defines roles, responsibilities, goals, and performance indicators for the implementation process (Berghaus & Back, 2016). Thus, the managers who are operationally responsible for digital strategy should have sufficient strategic capabilities and experience from transformational and technological projects (Matt et al., 2015). In addition to management's willingness to change and the company's digital capabilities, rapid decision making also plays a key role in exploiting technological opportunities (Warner & Wäger, 2019). Data-based decision making can make the decision-making process more efficient by producing faster and better results compared to relying merely on the experiences and intuitions of an individual (Mittal, Romero, & Wuest, 2018; Schuh et al., 2017). Furthermore, fast data-based decision making enables strategic agility, which plays a key role when operating in an environment of uncertainty (Warner & Wäger, 2019). However, Ukko, Saunila, and Rantala (2020) highlighted the role of relational mechanisms in the management context, where management should focus on behavioral factors alongside technical ones. Thus, focus should be on management in terms of design and data analysis but should also engage humans in the process (Ukko et al., 2020).

2.2.3. Organization and culture

The organizational structure and culture of companies must support digital operations and the use of novel digital technologies (Akdil et al., 2018; Pessl et al., 2017; Geissbauer et al., 2016; Mittal, Romero, & Wuest, 2018; Corver & Elkhuizen, 2014: Kane et al., 2017; Warner & Wäger, 2019). Schuh et al. (2017) defined two main dimensions of culture as a key enabler of agility: willingness to change and social collaboration. Büyüközkan and Göçer (2018) noted that if a company's culture opposes change, the result could be a divided organization in which one group is moving toward the future while the other remains in the traditional past, thereby hindering digital operations. Pessl et al. (2017) noted that high maturity levels concerning the desire to learn help create an environment that cultivates and encourages learning, in which digital transformation can be integrated more easily. Digital transformation has revolutionized how companies and individuals share information and collaborate with one another (Berman, 2012; Büyüközkan & Göçer, 2018; Leyer, Richter, & Steinhüser, 2019; Tortorella et al., 2020). Digital technology also changes how employees work, for instance, by enabling flexible working from home or on the move. Through new mobile platforms, employees can work anytime, anywhere, and on any digital device (Berghaus & Back, 2016; Corver & Elkhuizen, 2014). With digital operations, in which information sharing is efficient and more flexible forms of work take place, the company requires a culture of trust that supports the desire to share information openly and allows employees to work independently.

2.2.4. Customers

Digital operations also extend to the customer (Akdil et al., 2018; Corver & Elkhuizen, 2014; Schumacher et al., 2016, 2019). Berman (2012) indicated that companies should focus on two main issues: reshaping customer value propositions and transforming operations through digital technologies for better customer interaction and collaboration. Digital operations enable deeper collaboration between customers and companies in which, for example, customers can offer opinions and suggestions for the development of operations and products through various digital channels (Agrifoglio et al., 2017; Corver & Elkhuizen, 2014). Communication and information sharing with customers are also strengthened through new digital channels (Berman, 2012; Büyüközkan & Göçer, 2018). Schumacher et al. (2016, 2019) mentioned customers' competence related to digital technology and media as one item of the customer dimension and their maturity models. Customers' digital capabilities play an important role in enabling them to take advantage of new digital information and communication channels, including companies' digital products and services. The willingness of customers to change likewise impacts the company's digital operations (Büyüközkan & Göçer, 2018) and is a significant factor of the customer dimension.

2.2.5. Supply chain

In addition to customers, suppliers and partners who are affected by digital transformation must also be integrated during the early stages of the process of implementing digital technologies (Akdil et al., 2018; Büyüközkan & Göçer, 2018; Pessl et al., 2017; Schuh et al., 2017). Companies cannot change their operations alone but need the right suppliers and partners to cope with digital transformation (Moore, 1996; Senyo, Liu, & Effah, 2019). The supply chain needs to focus on enhancing its digital-related capabilities while developing its operations (Büyüközkan & Göçer, 2018). Measuring supply chain performance and managing the digital operations of the supply chain play significant roles in this process (Büyüközkan & Göçer, 2018; Klötzer & Pflaum, 2017). Digital operations enable supply chain partners to cooperate more closely (Corver & Elkhuizen, 2014). Furthermore, the digital supply chain can make a wide range of information available and support collaboration and communication with digital platforms (Büyüközkan & Göçer, 2018; Schuh et al., 2017; Vial, 2019). These digital platforms and collaboration tools allow supply chain employees to efficiently share documents, ideas, contacts, experiences, and information, thereby providing added value (Corver & Elkhuizen, 2014).

3. Methodology

In recent years, digital transformation has become one of the most important issues for changing companies and their operating environments. New emerging technologies and various technological components create new business opportunities that differ from traditional requirements and support a company's existing operations by facilitating the automation of work (Boute & Van Mieghem, 2021; Warner & Wäger, 2019). The present study examines the digital operations of companies through case studies. To assist with the management of digital operations, certain common characteristics should be determined. Thus, this research aims to examine the strategic readiness of companies for digital operations. We pursued the objective of this study through the research question below:

How is the strategic readiness of companies for digital operations managed?

We utilized a qualitative case study approach (Eisenhardt, 1989) to examine the strategic readiness of companies for digital operations. Owing to the nature of this study, the case study approach was deemed appropriate in terms of timeliness and significance of the phenomenon in practice (Yin & Yin, 2018). Our approach emphasized the real-world context in which phenomena occur and offered a review of complicated behavioral processes that cannot be easily exposed by quantitative data (Eisenhardt & Graebner, 2007). In addition, based on Yin and Yin (2018), one criterion for conducting a case study was the researcher's admission to a position that was not available previously in the literature. Specifically, this study can be classified as a theory-generating case study, as it considered that existent theoretical considerations guide the dimensions of companies' readiness for digital operations, but empirical analysis informed and shaped the findings (Ketokivi & Choi, 2014).

3.1. Case selection

Following Yin and Yin (2018), this study examined multiple cases involving small- and medium-sized enterprises (SMEs) and large companies. Multiple cases were used owing to their potential to provide higher external validity compared with single cases (Voss, Tsikriktsis, & Frohlich, 2002). Carefully selected cases were used to link theory and practice and allow comparison and replication within and between cases, providing a broad understanding of the studied phenomenon (Yin & Yin, 2018). Altogether, 11 companies were used as cases for managing digital operations and selected based on the following inclusion criteria:

1) The companies must be involved in concrete initiatives to implement digital operations.
2) The companies must provide access to relevant information concerning their readiness for digital operations.
3) The interviewee/s should be aware of the digital operations of their company in different organizational areas.

All the selected companies operate globally, but they all have their headquarters or a subsidiary based in Finland. The first two criteria were utilized to select the case companies, whereas the final one was used to select proper interviewees. As noted earlier, the study examined the digital operations of companies from a strategic perspective. According to Matt et al. (2015), the digital business strategy covers several operational, functional, and organizational elements. Thus, the third criteria assisted the selection of interviewees in a way that the choice of covering the entire company as the unit of analysis was justified. To obtain a complete picture of the mechanisms through which strategic readiness for digital operations is formed, company representatives from different units, hierarchical levels, and job descriptions were included in the research process. During the research, we allowed more participants from the companies to participate in the interviews to ensure that we obtain the most comprehensive picture of the company's digital capabilities. In some companies, the responsibility for and management of digital operations were mainly handled by one person (e.g., the CEO or the chief digital officer [CDO]), whereas in others it was necessary to select more respondents for the interview to supplement and validate the knowledge of the interviewees regarding the company's strategic readiness for digital operations. Thus, managers from three management levels were interviewed. While their titles may vary, the interviewees were selected in such a way that information regarding their readiness for digital operations at a strategic level could be obtained. Thus, all the interviewees had rich knowledge concerning different areas of digital operations at their respective companies. Overall, 18 people were interviewed across the 11 companies. Details from the case companies and the interviews are presented in Table 2.

3.2. Data collection and analysis

The results of the case study were supported by data triangulation using multiple sources of evidence (Yin & Yin, 2018). Semi-structured interviews were used as the main data source. Background information from companies, such as financial records, was also collected and

Table 2
Description of case companies and interviews.

Companies	Description of company	Size	Number of interviews	Interviewees' roles
Company A	Operating in the engineering industry with a subsidiary supplying systems, equipment, and services to the paper and pulp industry.	Large	2	Process Technology Manager, Product Manager (of Automation Department)
Company B	Operating in the welding industry by designing, manufacturing, and selling welding equipment and related expert services.	Large	1	Chief Digital Officer
Company C	Operating in a technology industry and delivering customized technology solutions and maintenance services.	Large	2	Production Manager, Factory Manager
Company D	Operating in the engineering industry by designing, manufacturing, and selling plywood and veneer-manufacturing equipment.	Large	1	IT Manager
Company E	Operating in a wood-processing industry by producing and processing cut timber.	Large	3	Development Director, Factory Manager, Project Engineer
Company F	Developing and manufacturing industrial chemicals and floor coverings.	SME	2	Production Manager, Product Development Chemist
Company G	Manufacturing and selling joints for concrete structures and composite beams.	SME	2	Factory Manager, CEO
Company H	Developing, designing, and manufacturing robot technology for object-handling systems.	SME	1	Maintenance Director
Company I	Manufacturing chairs, loungers, and sofas for public spaces and ships.	SME	2	CEO, Product Manager
Company J	Designing and manufacturing clothing.	SME	1	CEO
Company K	Manufacturing of printed plastic packaging.	SME	1	Executive Vice President

analyzed, which impacted case selection and the research design. Moreover, company visits and observations were conducted to collect information on the progress of their digital transformation. These data triangulation efforts helped strengthen the construct validity of the case study (Yin & Yin, 2018).

Data from in-depth semi-structured interviews were gathered between August and November 2019. Individual interviews were used to gain insights from interviewees representing distinct areas of company operations. Interviews were conducted using open-ended questions (Appendix 2) that focused on the dimensions of the conceptual framework proposed in Section 2. Following these predefined dimensions and building interview questions based on them helped ensure the reliability of the data (Yin & Yin, 2018). Given that the topic of company readiness for digital operations is evolving, tentative questions were constructed, but the interview protocol allowed for informal discussions and supporting questions from the researcher. Details from the interviews are presented in Table 2. Each interview lasted between 50 and 90 min. One of the researchers was the only interviewer, which enabled the activity performed to be consistent across cases. The interviewees received transcripts of their interviews, and some interviewees were contacted by email when more information was needed. Finally, validity was ensured by utilizing multiple cases and investigators to analyze the data (Yin & Yin, 2018).

The analysis unit for this study was companies, specifically their strategic readiness level for digital operations. All interviews were recorded—with the interviewees' approval—and later transcribed by a professional service provider. Afterward, additional notes and comments regarding the interviewer's observations were included. Interview data were analyzed using content analysis, with the literature framework (Table 1) as a predefined coding scheme. Transcribed data from the interviews were coded using an iterative process that aimed to filter out and gather relevant information (i.e., prior themes from each interview were recognized). The themes were then placed in appropriate dimensions of the research framework and used to reveal mechanisms for managing digital operations. Other dimensions that were not included in the original dimensions were assessed as well.

Next, within-case and cross-case analyses were performed (Barratt, Choi, & Li, 2011; Eisenhardt, 1989; Yin & Yin, 2018). The within-case results clarified how each company is approaching digital operations and identified the related mechanisms. Cross-case analyses were conducted to allow for replication logic to identify repetitive patterns. This process elicited a description of each strategic readiness mechanism at each dimension. Afterward, an open discussion of the case findings between the three researchers was conducted. Final, the results were analyzed during the discussion until consensus was reached, after which propositions were formed.

4. Results

In this study, we attempted to obtain a complete picture of the mechanisms through which a strategic-level readiness for digital operations is formed. The dimensions of companies' readiness for digital operations are guided by existent theoretical considerations (Table 1). The study examined, in more detail, the impact of these five dimensions on a company's readiness to adopt new technologies and practices and guide the development of operations toward becoming more digital. The findings in Table 3 are informed and shaped by empirical analysis of case studies.

4.1. Readiness of companies for digital strategy

First, we found that all case-study companies noticed the impact from digital transformation in their industry and utilized it to develop different business areas and operations. Digital transformation is reflected in the company's internal operations, new digital products and services to customers, more efficient production, and supply chain.

Table 3
Research propositions influenced by highlighted factors and research results.

Propositions	Factors	Description; readiness for digital operations	Value for research
P1 Finding a balance between intuitive and data-based decision making facilitates strategic readiness for digital operations.	Strategy: objectives, and measures; investment Management: data-based decision making, digital capabilities Organization and culture: information sharing	Awareness of the importance of digital transformation has increased. Companies have more digital projects and have considered digital transformation in their strategy or have a digital strategy, along with clear objectives and measures to monitor them. Management can utilize digital transformation to support management (e.g., building competence to form a digital strategy), utilize data to support decision making, and develop operations. When investing and building digital operations, management is data- and information-based, and the company utilizes various information-sharing channels and tools, systematic data collection and documentation, and open access for all information users. Trust-based information sharing is likewise fostered in companies to prevent misuse and ensure effective data-driven decision making.	In digital transformation, data-based decision making can serve as a useful tool for operations management; however, engaging humans in the process allows companies to fully benefit from digital operations. Thus, companies should pay attention to their strategic readiness in terms of digital strategy, management capabilities, and organizational structures and culture to facilitate decision-making in digital transformation.
P2 Managerial capabilities related to strategic development, technology adoption, and culture creation facilitate the strategic readiness for digital operations.	Strategy: objectives, and measures; investment, resources Management: support and willingness to change, digital skills/capabilities Organization and culture: learning culture and willingness to	The company is aware of the need for digital competence in management and the new opportunities brought by digital transformation to develop management. Management has a clear desire for digital	Keeping operations unchanged without regular digital renewal leads to the likely failure of the organization in its operating environment. Thus, digital transformation emphasizes strategic

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Table 3 (*continued*)

Propositions	Factors	Description; readiness for digital operations	Value for research
	change, flexible work	transformation and can utilize digital transformation to support management (e. g., building competence to form a digital strategy), utilize data to support decision making, develop digital operations, and so forth. The company has more digital projects and has considered digital transformation in its strategy and/ or has a digital strategy, along with clear objectives and measures to monitor them. Investments to digital operations are also linked to digital strategy, and resources have been allocated for development projects. This is reflected in the culture, where the company has a desire to try and develop and is looking for solutions to how things could be done better. There is a culture of continuous development and innovation, which supports new ways of working.	readiness of management to adapt and understand new technologies and integrate them into digital strategy, goals, performance indicators, and decision-making. Management leadership and enthusiasm makes it easier for the rest of the organization to embrace cultural changes that facilitate the success of digital operations.
P3 Responsiveness toward customers significantly impacts strategic readiness for digital operations: Companies should strike a balance between their own and customers' readiness for and willingness to accept digital operations.	Customer: digital information and communication channels, digital capabilities, customer participation and collaboration, willingness to change	The company has increased the participation of customers in development projects and is moving to more customer-oriented development, where cooperation with customers is continuous, and the customer is committed to digital operations. Digital information and communication channels are used actively with customers, including social media channels, 24/7 chat, support services, and websites. In addition, the customer has noticed the importance of digital transformation in their operations and wants to be involved in digital operations as well as develop their own skills and functions to be more digital. Customers have begun to develop digital capabilities or have capabilities to use digital products and services as well as digital information and communication channels.	Companies that are strategically adapted to digital transformation and utilize digital operations managed from strategic perspectives (P1 and P2) have the strategic readiness to generate a new type of value for customers. When generating new value through digital operations, customers' participation, capabilities, and willingness toward digital transformation must be assessed and strengthened.
P4 Increased inter-organizational collaboration in the use of digital technologies allows for simultaneous upgrading of all partners' strategic readiness for digital operations.	Supply chain: digital capabilities, supply chain management, cooperation networks	Companies within their supply chains are beginning to develop digital capabilities supporting the development and utilization of digital initiatives or leverage already a variety of digital initiatives/tools to ensure efficient supply chain management, such as automation, real-time monitoring and control, digital information sharing, and documentation. When developing supply chain operations, the company has started to develop cooperation with various actors to discuss, develop, and test new ideas.	In digital transformation, the inclusion of inter-organizational actors, in which the company is viewed as a network of companies with interconnected performances, facilitates the company's strategic readiness to utilize digital operations. For instance, this includes reductions in resistance to change and an increase in capabilities and resources. Considering propositions P1, P2, and P3, the company's strategic readiness develops toward the readiness to utilize inter-organizational collaboration for the introduction of digital operations.

However, even if companies have some technological or digital initiatives, these do not necessarily constitute a digital strategy.

The results indicated that the companies had set different goals related to digital transformation. For example, Company J's goal was to renew the fit of trousers with the help of artificial intelligence through more efficient use of customer data, thereby improving its customer service. Meanwhile, Company C's long-term goal was to shift to paperless production and enhance information flow between partners through digital tools. We also noticed that only a few companies had an existing digital strategy that would guide the development of their operations toward becoming more digital. However, some companies had a strategy in which digital transformation was reflected partially in the goals and measurement activities of each company. Company B's CDO described the company's digital strategy as follows:

> We have long had some level of digitization strategy. When I started this job, of course, I specified it. This is the first CDO job in this company, and our strategy is to understand the customer field and what opportunities are included in digitization in the field. Through that, we will start to produce and modify both the hardware and software services in the direction of how the customer base can be pushed to digitize.

Among the SMEs, only Company J had a digital strategy, even though others had considered the importance of digital transformation in their business operations. The reasons for non-existent digital strategies included the ignorance or strategic incompetence of management, with some managers viewing a digital strategy as unnecessary. Company I described the situation: "*We don't have a strategy. We do these digital purchases when our customers demand them.*"

The third aspect of the strategic dimension noticed was that, particularly at SMEs, it was felt that a lack of resources hindered digital initiatives and projects. Specifically, a lack of financial resources was an obstacle to digital operations, and a lack of human resources in development projects hindered digital operations. Within large companies, the deficits of management or employees in capabilities hindered digital transformation. Fourth, the "acquired as needed or upon stakeholder demand" mindset was also highlighted in relation to the digital investment policies of some companies, while at other companies, investments were linked to strategy mindsets.

4.2. Management readiness for digital operations

First, within more digital companies, the desire to digital transformation starts with management, as reflected in the inclusion of digitalization in their strategy, the provision of money for digital projects and initiatives, and the desire for ideas from employees. Company B describes its management attitude as follows: "*Usually, I don't have a problem pushing new ideas to managers. It's actually the opposite. They want more ideas and implementations than we have the ability to deliver.*" Unlike companies at the start of the digital transformation route, the desire to change often begins elsewhere, such as upon the request of customers or employees. This situation slows down the digital operations of a company when the company's management is not committed to the change. This is how Company F describes the situation: "*The first willingness to change usually doesn't come from management but from elsewhere, such as employees or customers, and the company's management also sees the benefits only after changes are made.*" Thus, management should view digital operations as a positive and a development opportunity, so that it can be used effectively to develop activities.

Second, some companies were increasing data-based decision making while other companies described such decisions as being more intuitive. For example, Company H described how there is a "*clear desire for management to be measure-based management,*" and Company B said its management is constantly seeking new ways to make desired data visible so that these can be used for different needs, such as to support decision making. However, the data must be available, high quality, and in real time to be exploited, thus requiring the necessary systems. Company K said that its large amount of data is often manipulated to advance agendas: "*I have found out that data are utilized for a lot of abuse.*" This situation is reflected in, for instance, how decisions are made first and then specific data are collected to support these decisions. Therefore, information and measures should be transparent within the company to prevent misuse.

The third management element noticed was that all companies described how the digital capabilities of management need to be developed and vary widely among companies. The inability of management to lead a company's digital strategy can be viewed as an obstacle to the company's digital operations. Management must be able to utilize digital transformation to develop the business, possessing the competence to form a digital strategy, define goals and measures, and utilize novel digital tools and data to support management activities and decision making. Management should also be aware of new opportunities and technologies and lead the implementation of a digital strategy.

4.3. Organizational and cultural readiness for digital operations

First, we noticed that companies ready for digital operations have the desire to try and evolve and are looking for solutions to how things could be done better. Company B said, "*We cherish the culture of innovation; we encourage employees to always think about how things could be done better and in a new way.*" However, within younger companies, changes tend to be delayed and often made only when necessary. As Company F describes it, "*We're always trying to prolong change, only moving forward out of compulsion, but that culture is changing so that we're a little more receptive to new technology*." Second, we also found that other factors, such as industry, economic situation, and management, influence the culture of change and openness of a company. Some of the companies described themselves and their industries as conservative, with no emphasis on openness and willingness to change, making it difficult to move toward digital operations, as reflected, for example, during the implementation of new digital tools. Unlike companies within technology industries, such as Company H, whose business is to develop, design, and manufacture robot technology for object-handling systems, there is an inherent interest in technology and so new technologies are being received at a lower level. In two SMEs, a change in ownership positively or negatively impacted an organization's openness to digital operations. For example, Company G set out to develop its competitiveness by leveraging new technologies and practices while Company K took some steps backward due to the attitudes of management toward digital operations. Company K noted that its culture has become more conservative due to economic woes.

Third, we studied the information-sharing practices of companies and noticed problems with information sharing among almost all companies. To make information sharing more efficient, companies introduced new digital tools alongside traditional ones. A common digital tool was information screens that displayed information for employees, and others were the Intranet and Microsoft Teams. Company J described utilizing an application that included a "learning environment" for employees within a year, with a work-related information and discussion platform available in one place. Some companies also have increased documentation and transparency of information so that the necessary information is available to employees: "*With these tools, we take care that everything is documented, and others can see it from there if necessary.*" The importance of real-time information was also emphasized: "*The intention is to add measures in the future that are visible in real time and may be linked to reward systems.*"

We also examined how companies' organizations and cultures support new ways of working. The aspect we noticed was that more digital companies have cultures that were more supportive of remote working. In particular, remote work was encouraged on the expert side. Other forms of work were also common among mature companies, such as desk sharing, home offices, and remote meetings. Company B described its culture as follows:

> Today, remote working is business as usual. In my team, employees keep a remote day at least once a week, as it calms things down when there are fewer interruptions. Then it's time to delve deeper into the job itself. The systems can be accessed at home on a computer and also on most mobile devices.

However, among companies other than the two specified, the culture maintained the attitude that "work is done at work" even if their systems could accommodate working from home. Additionally, few case companies defined general remote work principles.

4.4. Customer readiness for digital operations

First, our research showed that customers with weaker digital capabilities hindered the digital operations of companies. As Company K noted, "*Our customers' digital capabilities vary greatly; for example, we still have 120 customers who do not have e-mail in use.*" There were obstacles to companies' digital operations if customers did not have the ability to participate in the change. The wide variation in customers' digital capabilities also elicited problems when trying to make operations and services more digital:

> One of our challenges is that the digital capabilities of our customers (are) highly polarized to these uber users and non-capability users, so the challenge is how to create a system equally for both customer groups without doing extra work (Executive Vice President, Company K).

Second, the willingness of customers to adjust to digital transformation also impacts companies' digital operations. If customers are not willing to take advantage of the digital products and services or information and communication channels that the company offers, then it would be more difficult for the company to leverage these operations. Company K described the situation: *"Our current ERP allows the customer to place an order directly in that system, but our customers may not be ready for it yet."* The company's use of digital initiatives must meet customers' needs, and even if a company has the know-how and necessary technology but the customer's digital desire is lacking, it would be difficult for the company to take advantage of these digital initiatives. Third, we noticed that customers' willingness to change was influenced by the industry in which they were operating. For example, the construction industry was perceived as a conservative sector. As Company H noted, *"We have customers in so many different industries that they also need to be treated differently. It must also be taken into account in our digital strategy."*

Fourth, we noticed that some companies made more active use of digital information and communication channels than did other companies. For example, Company B, a digitally developed company, stated that social media channels are important to create a corporate image and information access, and Company C, accustomed to digital operations, thought that an online support channel makes information sharing and conversations with customers more efficient. However, customers require access to these channels to use them effectively. Fifth, our study found that customers should be involved in and collaborate with the company's digital operations. They should be able to engage with change, such as by developing digital channels, products, and services together in a customer-oriented way. As Company E noted:

> Increasingly, we want to understand our customers' earnings logic and business environment. It opens up a whole different world and the opportunity to understand different business concepts for the benefit of the customer. For example, our company's digital store is made with customers to make it a success.

4.5. Supply chain readiness for digital operations

First, we noticed how the supply chain was viewed as having many opportunities for digital development. For example, Company E was developing its supply chain by designing an application that seeks to increase the utilization of empty trucks. Looking to the future, companies saw that there was much room for digital initiatives in supply chains. To develop the supply chain, companies need the cooperation of different parties. Second, we found that digital operations of the supply chain emphasized the use of collaborative networks. Company B described this finding as follows: *"Our supply chain's digital operations require partner networks, and the deeper we go into the digitality, the more services we need to complement our expertise, such as data analytics."* Digital operations of SMEs' supply chains are hindered by a lack of cooperation networks that would support the development of operations with novel digital initiatives. The companies' culture must also support collaboration to enable this kind of development.

Third, we found that within large companies, the digital capabilities of supply chains were greater than those of SMEs. Fourth, we found that some companies ready to implement the digital operations of supply chain used technology more efficiently than did other companies for supply chain management. For example, the technology was utilized in supply chain automation, real-time monitoring and control, digital order placement, and information sharing. Company D described its supply chain automation as follows:

> We have a variety of automations involved in the supply chain. For example, buyers can see what delivery dates have been set by suppliers to monitor their fulfillment, production can be tracked for individual pieces, and we also have automatic alert lists in case of any delay in schedules at some point in the process.

Moreover, at the end of the supply chain, companies took advantage of digital initiatives. Company A described how it used real-time tracking of deliveries to monitor the routes that ships and trucks take before they reach customers.

5. Discussion

Next, the theoretical and managerial implications of the case findings were discussed. In this matter, the four propositions shown in Table 3 relating to how companies' strategic readiness for digital operations is managed are discussed. The findings show that most studied companies face challenges in adjusting their operations to a more digital one, responding differently to this challenge. Companies have conducted initiatives related to digital operations to seek the ways to develop and digitalize their business operations and exploit their benefits. To succeed in digital transformation and implementing digital operations, digitally developed companies increased their data-based decision making to facilitate the integration of activities into their strategic goals. Schuh et al. (2017) stated that the benefits of digital technology include better information availability and access, which enable more efficient decision making; as well as the transparency of their consequences and alignment with the company's strategic objectives. In addition, Warner and Wäger (2019) reported that when operating in conditions of deep uncertainty, fast decision making is key to seizing technological opportunities and achieving strategic agility. Thus, data-based decision making can serve as a useful tool for operations management in turbulent environment because digital transformation has enabled managers to access data faster than ever (Gölzer & Fritzsche, 2017). The current study supports this perspective on data-based operations management, as it was viewed as providing accurate and timely information for company management. However, the results show that data cannot be trusted blindly, and that some data interpretation is needed. Therefore, a culture of trust-based information sharing should be embedded within a company to support the use of data so that no misuse occurs (Sarka, Heisig, Caldwell, Maier, & Ipsen, 2019).

Thus, an intuitive perspective on the management of digital operations should be considered in conjunction with the technical perspective. This notion corresponds with prior research that concluded that in facilitating the management of digital operations, focus should not only be on management in terms of design and data analysis but should also engage humans in the process to fully benefit from digital operations (Tortorella et al., 2020; Ukko et al., 2020). Based on the findings of the present study, some companies rely more on intuitive decision making through lack of planning and systematic actions to manage digital operations, leading to digital initiatives being implemented only when needed or upon stakeholder demand and not as data-driven strategy activities. However, the operating environment is more complex, and there are other influential factors that cannot be controlled; companies cannot cope with intuitive decision making alone. Both intuitive and data-based decision-making approaches were found to have certain benefits and limitations, and neither was enough individually to manage a company's strategic readiness for digital operations.

Digital technologies enable data collection and communication, which allow individuals, teams, and organizations to benefit from such support to exchange information and make decisions more effectively (Gölzer & Fritzsche, 2017; Tortorella et al., 2020). Based on this study's results, the concurrent utilization of intuitive and data-based decision making is highlighted in the strategic readiness for digital operations management (cf. Schuh et al., 2017; Tortorella et al., 2020; Ukko et al., 2020; Warner & Wäger, 2019). Thus, on the basis of this study's findings, we propose the following:

P1. Finding a balance between intuitive and data-based decision making facilitates strategic readiness for digital operations.

The findings highlighted the role of managers in managing digital operations in various aspects, such as strategic development, technology adoption, and creation of proactive culture. Our study is line with Li (2020) and Sousa-Zomer et al. (2020), who stated that management of the transition to new technologies, new strategies, and operation models requires new leadership skills. Managers' capabilities to create a digital strategy were viewed as essential, and the lack of a digital strategy may lead to market failure (e.g., Besson & Rowe, 2012; Matt et al., 2015). The current study shows that the initiatives for digital operations must originate from inside the company, not only from customers or other stakeholders, because a late reaction can make it difficult to succeed in the market. Furthermore, maintaining operations as they are without regular digital renewal leads to the likely failure of the organization in its operating environment (Li, 2020). The findings indicate that a lack of digital strategy may be due to managers' ignorance or incompetence, in which the incompetence regarding novel technologies may lead to a lack of motivation that may hinder movement toward the proactive culture as well as strategy and technological development (cf. Mittal, Khan, et al., 2018; Sousa-Zomer et al., 2020). All these can hinder adapting companies' operations in a competitive digital environment.

The notions above led to the discussion around the capabilities of managers to adapt and understand novel technologies as well as connect them to digital strategy, goals and performance measures, and decision making (cf. Berghaus & Back, 2016; Büyüközkan & Göçer, 2018; Pessl et al., 2017; Schuh et al., 2017; Warner & Wäger, 2019). Understanding technological development is emphasized within those who operate with a lack of financial and human resources (Mittal, Khan, et al., 2018). SME managers need to understand industrial development to invest in the most appropriate technologies without being overheated. To avoid misdirected and oversized investments, managers need to understand both the industry and technology. They also need to be aware of existing digital tools, or at least be aware of how and where necessary skills and competencies can be acquired. Thus, managers should be able to evaluate and manage their companies' digital operations to strike a balance between the readiness of industry, internal and external pressure, technologies, and available resources (cf. Büyüközkan & Göçer, 2018; Kane et al., 2017; Mittal, Khan, et al., 2018; Ukko et al., 2020; Warner & Wäger, 2019).

Implementing digital operations is also a cultural issue (Kane et al., 2017; Warner & Wäger, 2019). The results of this study showed that managers contributed to change in terms of incorporating digital transformation into strategy, allocating money for digital projects and initiatives, and employees' willingness to offer ideas. In addition, when managers want to evolve, they seek out ideas, implementation, and solutions from employees to understand how things could be done better (Li, 2020; Tabrizi et al., 2019). Such a proactive culture requires new digital tools to make information sharing more efficient and create a proactive learning environment (Büyüközkan & Göçer, 2018; Pessl et al., 2017). However, it also is important to consider that in digital operations, people need to play by the rules because culture is affected by history, environment, and the current situation, which is slow and difficult to change. Managers determine how an organization operates, and with management enthusiasm, it is easier for the rest of the organization to embrace cultural changes that facilitate strategic readiness for digital operations (cf. Chanias et al., 2019). Thus, based on the above, we propose:

P2. Managerial capabilities related to strategic development, technology adoption, and culture creation facilitate strategic readiness for digital operations.

The findings of this study demonstrated the importance of customers' role in enabling digital operations. With help from digital technologies, companies could refocus on developing customer value proposition (Berman, 2012) and customer experience (Büyüközkan & Göçer, 2018), leading to better customer interactions and collaboration in digital transformation. The management of digital operations likewise fosters the adoption of digital technology in companies, resulting in major improvements in product and service offerings as well as customer satisfaction (Tortorella et al., 2020). Corresponding with this, and in line with Chanias et al. (2019), the present study revealed that the digital strategy must be formed in a customer-oriented manner, taking into account the capabilities and willingness of customers to accept digital operations. It also showed that companies should be strategically aligned toward digital operations to succeed in complex competitive environments rather than making changes based on customer demands. Digital operations management from strategic perspectives will support the management of the process of adapting companies' practices in a competitive digital environment (Horlach et al., 2017; Kane et al., 2017; Li, 2020; Matt et al., 2015; Vial, 2019).

The findings of this study revealed that barriers to companies' digital operations exist if customers lack the ability and/or desire to participate in the change of operations. In this case, the company must have the capacity to help customers adapt to digital operations and support the development of their digital skills. However, customers should not be forced into using digital operations if they are not ready for it. Corver and Elkhuizen (2014) stated that digital operations enable deeper collaboration between customers and companies. Our study found that customers should be involved in as well as collaborate with the company's digital operations. Customers should be committed to digital transformation; for example, they should have the opportunity to provide feedback and suggestions through digital channels to help develop products and services together with the company in a customer-oriented way, promoting operations management (Agrifoglio et al., 2017; Tabrizi et al., 2019). Thus, customer commitment and cooperation with the company support the management of digital operations. For this reason, the third proposition of this study is as follows:

P3. Responsiveness toward customers significantly impacts strategic readiness for digital operations: Companies should strike a balance between their own and customers' readiness for and willingness to accept digital operations.

The findings indicated that digitally developed companies were more active in extending the use of digital technologies with both the customers and the multi-tier supply chain. Digital information and communication channels are emphasized with customers while supply chain automation, real-time monitoring and management, digital ordering, and information sharing are emphasized in multi-tier supply chains. This development was possible when both customers and the supply chain were involved in collaboration, considering the design and implementation of digital technologies for mutual benefits. These findings strongly supported prior statements that management research on digital technologies focuses on the inclusion of inter-organizational actors in the process, in which the company is not viewed as one company but rather as a network of companies with interconnected performances (Senyo et al., 2019). The findings also showed that collaboration with the supply chain and customers positively influences reductions in resistance to change in conservative industries as well as the capabilities and resources in SMEs. This may have been realized via the enhancement of relational mechanisms, such as inter-organizational trust and know-how development, which facilitate the relationships governed by social interactions that drive inter-organizational management in digital operations (Ukko et al., 2020).

The results emphasized that companies use digital technologies, such as information and communication channels, in a variety of ways together with customers and suppliers. This understanding will enable the purposeful and strategic use of digital operations, in which both the multi-tier supply chain and customers are asked to evaluate the organization and its operations, often using social media and other information technology-enabled platforms (Agrifoglio et al., 2017; Büyüközkan & Göçer, 2018). Thus, the findings supported the notion that digital transformation of the entire supply chain helps make a wide range of information available, supports collaboration and communication with digital platforms (Büyüközkan & Göçer, 2018; Schuh et al., 2017), and allows for the evaluation of experiences (Corver & Elkhuizen, 2014). The study shows that companies purposefully are moving toward a more interactive, open, and participatory use of digital technologies to engage the multi-tier supply chain and customers in a conversation about the operations performance and management of collaborative partners (cf. Agrifoglio et al., 2017; Büyüközkan & Göçer, 2018). Co-evolution in inter-organizational collaboration and digital technologies seems to facilitate the ability to move collectively to more digital-enabled operations (cf. Moore, 1996; Senyo et al., 2019). This means that all partners react and adapt to digital operations simultaneously. Based on this, the following proposition is presented:

P4. Increased inter-organizational collaboration in the use of digital technologies allows for the simultaneous upgrading of all partners' strategic readiness for digital operations.

6. Conclusions and future research

This study contributes to existing operations management literature in the context of digital transformation. First, the research determines the strategic dimensions and their factors for managing digital operations, namely, strategy, management, organization and culture, customer, and supply chain. These dimensions are suggested to facilitate the readiness of companies for digital operations. Second, identifying the strategic dimensions and factors comprises a contribution to operations management research and helps develop a framework to determine the type of strategic readiness that contributes to the adoption of digital operations in the context of digital transformation. Third, four propositions are presented that relate to how companies' strategic readiness for digital operation is managed.

The findings of this study show that most studied companies face challenges in adjusting their operations in the digital transformation, but they respond to such challenges differently. The main contributions regarding the companies' readiness for digital operations are as follows. Regarding the first proposition, the study contributes to the literature by highlighting the importance of finding a balance between intuitive and data-based decision making. Intuitive and data-based decision making should be utilized concurrently to facilitate digital operations. Thus, the study contributes to previous research related to digital transformation, which over-emphasizes data-based decision making, by arguing that a suitable balance should be found between intuitive and data-based decision making. Regarding the second proposition, the study contributes by highlighting the role of managers in digital operations in various aspects, such as strategic development, technology adoption, and creation of a proactive culture. The capabilities of managers in adapting and understanding novel technologies and connecting them to digital strategy, goals and performance measures, and decision making are critical in managing digital operations. Thus, the study contributes to the existing literature by highlighting the expanding role of managers in digital transformation.

Transformation into digital operation does not just happen within a company, but instead, the company needs to consider its customers and other stakeholders and partners. Regarding the third proposition, the study states that companies should strike a balance between their own and customers' readiness and willingness to embrace digital transformation. Responsiveness to customers significantly furthers digital operations, and customers' commitment and cooperation with a company support digital operations. Thus, the study contributes to previous research by emphasizing the importance of helping and engaging customers in utilizing digital operations rather than forcing them to implement digital operations. Regarding the fourth proposition, our study contributes by stating that companies should increase inter-organizational collaboration in the use of digital technologies, as it allows for simultaneous upgrading of the maturity of all partners' digital operation. Companies should purposefully move toward a more interactive, open, and participatory use of both digital technologies to engage the multi-tiered supply chain and customers in a conversation about the performance of collaborative partners. Thus, the study contributes to previous research by emphasizing the importance of cooperation to realizing a simultaneous digital leap between partners. If both partners and customers have similar capabilities, the strategic readiness to utilize digital operations will also be at a higher level.

The results of this study are relevant for management practice as well because they highlight the key issues taken into account with digital operations. Furthermore, the study provides suggestions on the determinants of the effective adoption of digital operation (i.e., the dimensions of strategic readiness). Managers need to be aware of existing digital tools, or at least be aware of how and where such skills and competencies can be acquired. Thus, they need to be able to evaluate and manage companies' digital operations to strike a balance between an industry's maturity, internal and external pressures, technologies, and available resources. There can be barriers to the digital operation of companies if customers (or partners) do not have the capabilities or willingness to participate in the process. In this case, the company must have the capacity to help customers adapt to digital transformation and support the development of digital skills without forcing them to change.

The limitations of this study depend on findings from 11 companies, but considering that the research focused on extending existing theory on companies' digital transformation and operation, an in-depth analysis of the limited number of cases was viewed as a suitable approach. It can also be considered as a limitation of the study that only the interview data were used in the in-depth analysis, but other collected data were used to develop a background understanding. Further research could focus on specific industries or multi-tiered relationships to gain deeper insights relating to how strategic readiness for digital operations is managed. More research is also needed on the connection between a specific focus of digital operation (e.g., digital products and services, internal processes, or sales and marketing) and its effect on managing digital operation.

In addition, the study provides broad opportunities for quantitative future research. First, future research could investigate the readiness of customers and partners for digital operations and its connection to financial success. The starting point of initial hypothesis would be that the higher readiness they have, the better the company's financial performance. Another interesting line of research would be to study the mix of data-based and intuitive decision making, and what is the appropriate balance between these to maximizing success in a company. Finally, managerial capabilities and their effects on different strategic dimensions could be studied: what kinds of paths can be formed from these capabilities to develop an organization's strategic readiness for digital operations?

Declaration of Competing Interest

There is no conflict of interest in the manuscript.

Appendix 1. Digitalization-related maturity models

Research paper	Dimensions	Study perspective
Corver & Elkhuizen, 2014	Products, processes and systems, organization, customer	A framework for digital business transformation
Lichtblau et al., 2015 "IMPULS Industrie 4.0 readiness"	Strategy and organization, smart factory, smart operations, smart products, data-driven services, employees	Readiness model that classifies six levels of Industry 4.0 readiness
Schumacher et al., 2016 "Industry 4.0 maturity model"	Nine dimensions and 62 items Dimensions: strategy; leadership; customers; products; operations; culture; people; governance; technology	A maturity model for assessing Industry 4.0 readiness and the manufacturing enterprise's maturity
Geissbauer et al., 2016 "PwC maturity model for Industry 4.0″	Digital business models and customer access; digitization of product and service offerings; digitization and integration of vertical and horizontal value chains; data and analytics as core capabilities; agile IT architecture; compliance, security, legal issues, and taxes; organization, employees, and digital culture.	A maturity model for Industry 4.0 capabilities development
Jung et al., 2016 "Smart manufacturing system readiness assessment, SMSRL"	Organizational, IT, performance management, information connectivity	Evaluating smart manufacturing readiness for SMEs and MNEs.
Berghaus & Back, 2016 "Digital Maturity Model, DMM"	Nine dimensions: customer experience; product innovation; strategy; organization; process digitization; collaboration; information technology; culture and expertise; transformation management	Digital maturity model
Schuh et al., 2017 "Industrie 4.0 Maturity Index"	Structural areas: resources; information systems; culture; organizational structure Functional areas: development; production; logistics; services; marketing; and sales	Industry 4.0 maturity index for managing digital transformation
Gökalp et al., 2017 "Industry 4.0-MM"	Asset management, data governance, application management, process transformation, organizational alignment	Industry 4.0 maturity model
Lee et al., 2017 "A Smartness Assessment Framework for Smart Factories"	Four criteria, 10 sub-criteria, 46 items: Criteria: leadership; process; system and automation; performance assessment	An assessment framework to evaluate smartness for factories
Pessl et al., 2017 "Roadmap Industry 4.0"	Acceptance and application of new technologies and media, professional competence, learning competence, corporate strategy, human resources development strategy, organization and democratization, flexible working models, health and safety, information and communication, employer branding, change management, process orientation, knowledge management	A maturity model capable of evaluating the different areas of development in the field of human resources
Klötzer & Pflaum, 2017 "Digital Transformation Maturity Model for Supply Chain"	Strategic development, offerings to customers, smart factory, complementary IT systems, cooperation, structural organization, process organization, competencies, innovation culture	Maturity model for the manufacturing industry's supply chain
Akdil et al., 2018 "Industry 4.0 Maturity Model"	Smart products and services; smart business processes, strategy, and organization	Industry 4.0 maturity model
Büyüközkan & Göçer, 2018 "Digital Supply Chain Framework"	Digitalization: digitalization strategy; digital organization and culture; digital operations; digital products and services; digital customer experience Technology implementation: project management; human and technology relationship; formation of technology infrastructure; technology enablers Supply chain management: integration; automation; reconfiguration; analytics; process	Digital supply chain development framework
Mittal, Romero, & Wuest, 2018 "SM^{3}E Maturity Model"	Five dimensions: finance; people; strategy; process; product Seven toolboxes: manufacturing/fabrication; design and simulation; robotics and automation; sensors and connectivity; cloud/storage; data analytics; and business management	Smart manufacturing maturity model for SMEs
Schumacher et al., 2019 "Industry 4.0 realization model"	Eight maturity dimensions and 65 maturity items Dimensions: technology; products; customers and partners; value-creation processes; data and information; corporate standards; employees; strategy and leadership	Industry 4.0 maturity model and 10-step roadmap for manufacturing enterprises
Williams et al., 2019 "Digital Maturity Models for Small and Medium-size Enterprises"	Strategy, products/services, people and culture, management, processes	Digital maturity model for SMEs.

Appendix 2. Structure for interview questions

This interview structure clarifies the questions asked during the interviews. The interview structure was designed to concentrate on five strategic dimensions: digital strategy; management; organization and culture; customer; and supply chain. In addition, general questions were asked.

General questions:

1. Please briefly describe your job title and job description at the company.
2. Please identify the department in which you operate and the department's size (if it is a large company).

Questions about the company's strategic readiness for digital transformation:

3. Please describe how your company has taken digitalization into account in its strategy (goals, effects, measures, actions) (digital strategy).
4. Please specify how much and in what areas your company has invested in digital transformation (digital strategy).
5. Please indicate whether your company's current resources support digital transformation (digital strategy).
6. Please describe management's willingness to engage in more digital operations at your company (management).
7. Please describe management's competence in digital strategy, technologies, and opportunities at your company (management).
8. Please outline how the company leverages data in its decision-making processes (management).
9. Please describe how the company views digital change (organization and culture).
10. Please describe how information flows within your company, and specify what kinds of technological tools for information sharing the company uses (organization and culture).
11. Please describe continuous improvement processes and culture at your company, and how digital technologies are part of it (organization and culture).
12. Please describe working practices at the company (flexible work, remote work) and analyze how digital technology is part of it (organization and culture).
13. Please specify what kinds of digital channels your company uses to communicate and share information with customers (customer).
14. Please analyze your customers' digital capabilities (customer).
15. Please explain how the company utilizes customers in business, e.g., to test and develop digital products and services (customer).
16. Please describe how the company leverages digital technology in service processes, sales, and marketing (customer).
17. Please describe how the company leverages customer data through analytics (customer).
18. Please analyze your supply chain's digital capabilities (supply chain).
19. Please describe how the company leverages digital technology in your supply chain (supply chain).
20. Please describe what kind of cooperation you have in your supply chain (supply chain).

References

Agrifoglio, R., Cannavale, C., Laurenza, E., & Metallo, C. (2017). How emerging digital technologies affect operations management through co-creation. Empirical evidence from the maritime industry. *Production Planning and Control, 28*(16), 1298–1306.

Akdil, K. Y., Ustundag, A., & Cevikcan, E. (2018). Maturity and readiness model for industry 4.0 strategy. In *Industry 4.0: managing the digital transformation* (pp. 61–94). Cham: Springer.

Barratt, M., Choi, T. Y., & Li, M. (2011). Qualitative case studies in operations management: Trends, research outcomes, and future research implications. *Journal of Operations Management, 29*(4), 329–342.

Berghaus, S., & Back, A. (2016, September). Stages in digital business transformation: Results of an empirical maturity study. In *MCIS* (p. 22).

Berman, S. J. (2012). Digital transformation: Opportunities to create new business models. *Strategy & Leadership, 40*(2), 16–24.

Besson, P., & Rowe, F. (2012). Strategizing information systems-enabled organizational transformation: A transdisciplinary review and new directions. *The Journal of Strategic Information Systems, 21*(2), 103–124.

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital business strategy: Toward a next generation of insights. *MIS Quarterly*, 471–482.

Boute, R. N., Gijsbrechts, J., & Van Mieghem, J. A. (2022). Digital lean operations: Smart automation and artificial intelligence in financial services. In *Innovative technology at the interface of finance and operations* (pp. 175–188). Cham: Springer.

Boute, R. N., & Van Mieghem, J. A. (2021). Digital operations: Autonomous automation and the smart execution of work. *Management and Business Review, 1*(1).

Büyüközkan, G., & Göçer, F. (2018). Digital supply chain: Literature review and a proposed framework for future research. *Computers in Industry, 97*, 157–177.

Chanias, S., Myers, M. D., & Hess, T. (2019). Digital transformation strategy making in pre-digital organizations: The case of a financial services provider. *The Journal of Strategic Information Systems, 28*(1), 17–33.

Corver, Q., & Elkhuizen, G. (2014). *A framework for digital business transformation*. Cognizant Business Consulting Benelux.

Davenport, T. H., & Westerman, G. (2018). Why so many high-profile digital transformations fail. *Harvard Business Review, 9*, 15.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review, 14*(4), 532–550.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal, 50*(1), 25–32.

Fitzgerald, M., Kruschwitz, N., Bonnet, D., & Welch, M. (2014). Embracing digital technology: A new strategic imperative. *MIT Sloan Management Review, 55*(2), 1.

Galindo-Martín, M.Á., Castaño-Martínez, M. S., & Méndez-Picazo, M. T. (2019). Digital transformation, digital dividends and entrepreneurship: A quantitative analysis. *Journal of Business Research, 101*, 522–527.

Geissbauer, R., Vedso, J., & Schrauf, S. (2016). Industry 4.0: Building the digital enterprise. Retrieved from PwC Website. https://www.pwc.com/gx/en/industries/industries-4.0/landing-page/industry-4.0-building-your-digital-enterprise-april-2016.pdf.

Gökalp, E., Şener, U., & Eren, P. E. (2017, October). Development of an assessment model for industry 4.0: Industry 4.0-MM. In *International conference on software process improvement and capability determination* (pp. 128–142). Cham: Springer.

Gölzer, P., & Fritzsche, A. (2017). Data-driven operations management: Organisational implications of the digital transformation in industrial practice. *Production Planning and Control, 28*(16), 1332–1343.

Gurbaxani, V., & Dunkle, D. (2019). Gearing up for successful digital transformation. *MIS Quarterly Executive, 18*(3).

Hausberg, J. P., Liere-Netheler, K., Packmohr, S., Pakura, S., & Vogelsang, K. (2019). Research streams on digital transformation from a holistic business perspective: A systematic literature review and citation network analysis. *Journal of Business Economics, 89*(8), 931–963.

Hess, T., Benlian, A., Matt, C., & Wiesböck, F. (2016). Options for formulating a digital transformation strategy. *MIS Quarterly Executive, 15*(2), 103–119.

Horlach, B., Drews, P., Schirmer, I., & Böhmann, T. (2017). Increasing the agility of IT delivery: Five types of bimodal IT organization. In *Proceedings of the 50th Hawaii international conference on system sciences*.

Jung, K., Kulvatunyou, B., Choi, S., & Brundage, M. P. (2016, September). An overview of a smart manufacturing system readiness assessment. In *IFIP International conference on advances in production management systems* (pp. 705–712). Cham: Springer.

Kane, G. C., Palmer, D., Nguyen-Phillips, A., Kiron, D., & Buckley, N. (2017). Achieving digital maturity. *MIT Sloan Management Review, 59*(1).

Ketokivi, M., & Choi, T. (2014). Renaissance of case research as a scientific method. *Journal of Operations Management, 32*(5), 232–240.

Klötzer, C., & Pflaum, A. (2017). *Toward the development of a maturity model for digitalization within the manufacturing industry's supply chain*.

Koh, C. E., Prybutok, V. R., Ryan, S., & Ibragimova, B. (2006). The importance of strategic readiness in an emerging e-government environment. *Business Process Management Journal, 12*(1), 22–33.

Konopik, J., Jahn, C., Schuster, T., Hoßbach, N., & Pflaum, A. (2022). Mastering the digital transformation through organizational capabilities: A conceptual framework. *Digital Business, 2*(2), Article 100019.

Lee, J., Jun, S., Chang, T. W., & Park, J. (2017). A smartness assessment framework for smart factories using analytic network process. *Sustainability, 9*(5), 794.

Leyer, M., Richter, A., & Steinhüser, M. (2019). Power to the workers: Empowering shop floor workers with worker-centric digital designs. *International Journal of Operations & Production Management, 39*(1), 24–42.

Li, F. (2020). Leading digital transformation: Three emerging approaches for managing the transition. *International Journal of Operations & Production Management, 40*(6), 809–817.

Lichtblau, K., Stich, V., Bertenrath, R., Blum, M., Bleider, M., Millack, A., … Schröter, M. (2015). *IMPULS-industrie 4.0-readiness. Impuls-Stiftung des VDMA, Aachen-Köln*.

Matt, C., Hess, T., & Benlian, A. (2015). Digital transformation strategies. *Business & Information Systems Engineering, 57*(5), 339–343.

McGrath, R., & McManus, R. (2020). Discovery-driven digital transformation. *Harvard Business Review, 98*(3), 124–133.

Mittal, S., Khan, M. A., Romero, D., & Wuest, T. (2018). A critical review of smart manufacturing & industry 4.0 maturity models: Implications for small and medium-sized enterprises (SMEs). *Journal of Manufacturing Systems, 49*, 194–214.

Mittal, S., Romero, D., & Wuest, T. (2018, August). Towards a smart manufacturing maturity model for SMEs (SM 3 E). In *IFIP international conference on advances in production management systems* (pp. 155–163). Cham: Springer.

Moore, J. F. (1996). *The death of competition: Leadership and strategy in the age of business ecosystems*. New York: Harper Business.

Olsen, T. L., & Tomlin, B. (2020). Industry 4.0: Opportunities and challenges for operations management. *Manufacturing & Service Operations Management, 22*(1), 113–122.

Pessl, E., Sorko, S. R., & Mayer, B. (2017). Roadmap industry 4.0–implementation guideline for enterprises. *International Journal of Science, Technology and Society, 5* (6), 193–202.

Porter, M. E. (1996). What is strategy? Harvard business review. *Harvard Business Review, 74*(6), 61–78.

Redding, J. C., & Catalanello, R. F. (1994). *Strategic readiness: The making of the learning organization*. San Francisco, CA: Jossey-Bass.

Salovaara, A., Lyytinen, K., & Penttinen, E. (2019). High reliability in digital organizing: Mindlessness, the frame problem, and digital operations. *MIS Quarterly, 43*(2), 555–578.

Sarka, P., Heisig, P., Caldwell, N. H. M., Maier, A. M., & Ipsen, C. (2019). Future research on information technology in knowledge management. *Knowledge and Process Management, 26*(3), 277–296.

Schuh, G., Anderl, R., Gausemeier, J., Ten Hompel, M., & Wahlster, W. (Eds.). (2017). *Industrie 4.0 maturity index: Managing the digital transformation of companies. Utz, Herbert*.

Schumacher, A., Erol, S., & Sihn, W. (2016). A maturity model for assessing industry 4.0 readiness and maturity of manufacturing enterprises. *Procedia Cirp, 52*(1), 161–166.

Schumacher, A., Nemeth, T., & Sihn, W. (2019). Roadmapping towards industrial digitalization based on an industry 4.0 maturity model for manufacturing enterprises. *Procedia Cirp, 79*, 409–414.

Sebastian, I. M., Moloney, K. G., Ross, J. W., Fonstad, N. O., Beath, C., & Mocker, M. (2017). How big old companies navigate digital transformation. *MIS Quarterly Executive, 16*(3), 197–213.

Senyo, P. K., Liu, K., & Effah, J. (2019). Digital business ecosystem: Literature review and a framework for future research. *International Journal of Information Management, 47*, 52–64.

Sousa-Zomer, T. T., Neely, A., & Martinez, V. (2020). Digital transforming capability and performance: A microfoundational perspective. *International Journal of Operations & Production Management, 40*(7/8), 1095–1128.

Tabrizi, B., Lam, E., Girard, K., & Irvin, V. (2019). Digital transformation is not about technology. *Harvard Business Review, 13*, 1–6.

Tekic, Z., & Koroteev, D. (2019). From disruptively digital to proudly analog: A holistic typology of digital transformation strategies. *Business Horizons, 62*(6), 683–693.

Tortorella, G. L., Vergara, A. M. C., Garza-Reyes, J. A., & Sawhney, R. (2020). Organizational learning paths based upon industry 4.0 adoption: An empirical study with Brazilian manufacturers. *International Journal of Production Economics, 219*, 284–294.

Ukko, J., Nasiri, M., Saunila, M., & Rantala, T. (2019). Sustainability strategy as a moderator in the relationship between digital business strategy and financial performance. *Journal of Cleaner Production, 236*, Article 117626.

Ukko, J., Saunila, M., & Rantala, T. (2020). Connecting relational mechanisms to performance measurement in a digital service supply chain. *Production Planning and Control, 31*(2–3), 233–244.

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems, 28*(2), 118–144.

Voss, C., Tsikriktsis, N., & Frohlich, M. (2002). Case research in operations management. *International Journal of Operations & Production Management, 22*(2), 195–219.

Warner, K. S., & Wäger, M. (2019). Building dynamic capabilities for digital transformation: An ongoing process of strategic renewal. *Long Range Planning, 52*(3), 326–349.

Williams, C., Schallmo, D., Lang, K., & Boardman, L. (2019). Digital maturity models for small and medium-sized enterprises: A systematic literature review. In *ISPIM Conference Proceedings* (pp. 1–15). The International Society for Professional Innovation Management (ISPIM).

Yin, R. K., & Yin, R. K. (2018). *Case study research and applications: Design and methods* (6th ed.). Los Angeles: SAGE.

Zangiacomi, A., Oesterle, J., Fornasiero, R., Sacco, M., & Azevedo, A. (2017). The implementation of digital technologies for operations management: A case study for manufacturing apps. *Production Planning and Control, 28*(16), 1318–1331.

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Value creation paths of organizations undergoing digital transformation

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Abstract

This study examined the emergence of value creation during digital transformation. We used case studies to gather empirical evidence of the phenomenon from an organizational perspective. The study tried to closely link theory and practice by identifying the mechanisms that determined the paths of value creation in 11 companies that had taken concrete steps toward digital transformation. It contributed to knowledge management research by building a research framework according to previous literature and outlining three different value creation paths based on the objectives and motivations of the organizations. The conclusions of the study were that (1) the strategic orientation of transformation must exceed a certain level to constitute an actual value creation mechanism; (2) digital transformation paths are driven by changes in the competitive environment; (3) pressure from customers impacts the value creation mechanism in digital transformation, but depends on the value creation path essence; as well as (4) value creation in digital transformation is determined by the extent to which a company manages to balance the existing business with digital transformation. The results also had managerial implications because they assisted managers in considering the key mechanisms of digital transformation.

1 | INTRODUCTION

Recently, there has been increasing interest in research related to knowledge management (KM) and digital technology (Ikeda et al., 2021; Sarka et al., 2019; Venkitachalam & Bosua, 2019). For example, Ikeda et al. (2021) studied the relationships between the Internet of Things (IoT) and KM when creating smart ecosystems and new business models and stated that technology can support management by transforming data into information and knowledge. Sarka et al. (2019) studied KM and information technologies and considered them a crucial part of knowledge creation, sharing, and capture. Directly connected to digital technology being a multifaceted phenomenon (Tekic & Koroteev, 2019), digital transformation is changing the past practices concerning value creation and capture of companies in different industries (Tekic & Koroteev, 2019). At the organizational level, companies seek new ways to operate and generate data-based value by leveraging digital technology (Davenport & Westerman, 2018; Matarazzo et al., 2021; Matt et al., 2015). To achieve a new type of value, knowledge managers must have the necessary skills for understanding and capitalizing on the potential of these technologies (Sarka et al., 2019).

Investments in novel technologies support organizational change and are the main ingredients benefiting digital transformation (Ikeda et al., 2021; Venkitachalam & Bosua, 2019). However, digital transformation does not merely involve technology; it is an ongoing change process requiring investments in skills, projects, infrastructure, and IT systems (Davenport & Westerman, 2018; Van Veldhoven & Vanthienen, 2021). Additionally, various structural factors, such as management, organizational culture, and industry readiness, need to support change to achieve value through these investments (Galindo-Martín et al., 2019; Sarka et al., 2019; Tabrizi

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et al., 2019). Unfortunately, new technologies often fail to achieve the desired results due to deficiencies in organizational practices and people's willingness to change (Tabrizi et al., 2019; Venkitachalam & Bosua, 2019). Accordingly, companies first need to manage knowledge in order to facilitate digital transformation and generate value through novel technologies.

KM experts have considered the effects of adopting digital technology on an organization's openness, information, and knowledge sharing as well as on the organization's culture (Sarka et al., 2019). For example, the resistance to change, from individuals either inside or outside companies, can hamper their digital transformation processes. Managing digital transformation is difficult, requiring constant information and process monitoring and effective decision-making to achieve the desired results (Davenport & Westerman, 2018; Venkitachalam & Bosua, 2019). To transform their business and operating model, culture, and collaborative networks, companies need new kinds of capabilities and tools to facilitate such transformations (Nasiri et al., 2020; Tomé et al., 2022). For example, big data, machine learning, and social media were seen as key technologies to enable future knowledge-based innovations in organizations (Sarka et al., 2019). However, there was a need for empirical evidence on how companies reshape their processes with digital technology to obtain a variety of benefits (e.g., Margiono, 2020). Based on the research gap, the research goal was to analyze the companies' changes in their value creation paths using novel technologies in the digital transformation context. When changing their operations and processes, organizations experience various obstacles, so the factors that support and hinder change were also examined. We consequently built our research framework based on the literature and researched 11 case studies corresponding to the research question: *What mechanisms determine organizations' value creation paths during digital transformation?*

The article is structured like this: The first section presents the literature background regarding the dimensions and functions of organizations' digital transformations and describes the research framework. The next section explains the case study approach used to address the chosen research subject. The results section presents the empirical evidence from the 11 case studies and then discusses the evidence supporting our study contributions. Finally, the paper reveals the implications of our research.

2 | LITERATURE BACKGROUND

2.1 | Organizations' functions in light of digital transformation

According to Ritter and Pedersen (2020), digitalization relates to the utilization of digital technology that is causing transformations in businesses and markets. In that sense, digital transformation intended to introduce and exploit digital technologies affects various functions of companies and causes changes in their value creation paths (Matarazzo et al., 2021; Vial, 2019). Horlach et al. (2017) considered digital transformation a strategic and tactical business movement that triggers data-driven reforms, creates new digitalized business models, and enables novel means to generate value with the help of data-based knowledge. Referring to Matt et al. (2015), who considered digital transformation a strategic issue, digital technology often has major implications for different areas of business, extending even outside company borders and influencing business processes, products, production, supply chains, and sales channels. Horlach et al. (2017) propose that digital transformation involves the digitalization of communication channels, sales, as well as product and service offerings of the companies to replace or enhance physical functions; hence, digitalization has a wide range of impacts on organizations' functions, including knowledge sharing, productivity or sales growth, innovation in value creation, and new ways of customer collaboration (Matt et al., 2015).

Because of the notions above, digital technologies can be considered a critical component of businesses that affects their business operations (El Sawy et al., 2016; Sia et al., 2016; Ukko et al., 2019). However, value creation paths change depending on the organizational function, the extent to which digitization is implemented, and the selected technology; for example, technology that requires minor changes can often be integrated into an existing system, but technology that requires major changes involves significant business change (Margiono, 2020; Matt et al., 2015). If the introduction of a novel technology requires structural changes (changes in the skills, knowledge, processes, organizational structures, and culture required to make use of the new technology; Hess et al., 2016), the extent of the change is also relevant in terms of its cost-effectiveness and value creation paths (Vial, 2019). Major changes in individual activities and changes in cross-border activities necessitate reviewing the effects of changes on different value creation paths. The greater the change, the more consideration must be given to the impact of organizational dimensions, such as technology usage, structural factors, and barriers, on various value creation paths.

2.2 | Digital transformation: Organizational dimensions

2.2.1 | The use of technologies

In this study, digital transformation is directly connected to the usage of technology to create specific types of value and make changes to companies' past practices. Investment in novel technologies is the main ingredient enabling contemporary knowledge and resources to benefit customer value creation in a digital economy (Ikeda et al., 2021; Matt et al., 2015; Verhoef et al., 2021). In addition, it is important to understand the requirements of technical expertise, knowledge, and skills when investing in new technology in order for its implementation to succeed in its implementation (Afolayan & de la Harpe, 2020). Managers often feel confused about the choices they have to make when investing in digital tools for the purpose of creating novel value (Venkitachalam & Bosua, 2019).

Digital technologies, rather than replacing existing artifacts, transform them to build links with the surrounding environment and

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opportunities for collaboration (Tekic & Koroteev, 2019). Digital technologies may include analytic, blockchain, cloud, and IoT technologies along with different types of platforms (Vial, 2019). In the field of KM, big data, machine learning, and social media were seen as key technologies for enabling future organizational data-based innovations (Sarka et al., 2019). The best tool or combination of tools for a certain company varies from case to case because concrete goals are required to underpin implementation (Tabrizi et al., 2019; Ukko et al., 2019). In fact, Matt et al. (2015) considered digital transformation to be strategic. Companies need to determine whether they seek market leadership by creating their own technological norms or making use of established norms. In the latter scenario, technology is seen as a way to enhance business operations and processes (Matt et al., 2015).

Tabrizi et al. (2019) concluded that digital technologies not only determine the success of digital transformation, but also offer opportunities for increased effectiveness and the meeting of customer needs through data-based innovations. Without the willingness to change organizational operations, digital transformation is likely to fail. Thus, companies should focus not only on technological aspects but also on human-based factors and the relationships between them (Sarka et al., 2019).

2.2.2 | Structural factors

Structural factors determine whether companies have the capability to provide a sound basis for new digital operations (Holopainen et al., 2022; Matt et al., 2015), meaning that digital transformation usually requires changes in both the structures and cultures of companies (Sarka et al., 2019; Tabrizi et al., 2019; Vial, 2019). Thus, firms need to be able to question their past practices and choices to change their value creation paths. Organizational setups need to be changed based on the extent of change, since in the case of limited transformation, new operations may be purposefully integrated into existing structures, but more significant transformation may require the formation of a separate subsidiary within a company (Matt et al., 2015). In this, transformational leaders support employees in adopting a common vision; this sharing of ideas and knowledge helps them achieve common goals (Lee & Seol, 2021).

Regarding cultural change, companies need to tolerate uncertainty because transformation needs to be implemented progressively, requires fast decision-making and KM, and depends on people from different parts of the company becoming engaged in the process (Sarka et al., 2019; Tabrizi et al., 2019). This requires company personnel to adopt a positive mindset (Tabrizi et al., 2019) and strong digital and analytical skills (Verhoef et al., 2021). Although company employees' insider knowledge cannot be neglected (Lee & Seol, 2021; Tabrizi et al., 2019), the capability to match different users and find new partners to work with is essential for facilitating digital operations (Verhoef et al., 2021). Thus, companies can benefit from technology cooperation as they change their business models and look for new ways to create value in order to gain a competitive advantage.

2.2.3 | Barriers

Despite the benefits, resistance to change can hamper digital transformation (Tabrizi et al., 2019; Tomé et al., 2022; Vial, 2019) and may be either internal or external to a company. Companies can be entrenched in their existing customer and supplier collaborations and highly optimized production processes (Andriole, 2017). These collaborations can be very rigid, causing resistance to digital transformation. Additionally, personnel may feel threatened if novel technologies are introduced in an organization (Vial, 2019) and, intentionally or unintentionally, oppose the changes (Tabrizi et al., 2019). Employees' inertia can manifest as a lack of appreciation for the call to form collaborations with outside parties (Tekic & Koroteev, 2019). According to Tekic and Koroteev (2019), this can create barriers if companies are unable to identify which knowledge is valuable and necessary and which is not, or if businesses are using single technologies to solve separate problems.

2.2.4 | Changes in value creation paths

Digital transformation usually means transformations in value creation (e.g., Matt et al., 2015). Technologies make it possible to form novel value propositions based on service offerings (Barrett et al., 2015), but also facilitate changes in companies' distribution and sales (Vial, 2019), among other functions. For example, Mavri (2015) demonstrated how 3D printing technology, which simplifies processes formerly requiring many steps, is reshaping the production chain. This type of novel value creation is realized in parallel with distinct technological and product-related capabilities. Digital transformation may allow or require distinct types of monetization or changes to the scope of companies' businesses (Matt et al., 2015). Different paths of value creation thus require further research.

2.3 | Research framework

Prior research has proposed that, to successfully realize and exploit its potential, digital transformation should be reviewed from the following perspectives: use of technologies, organizational barriers, structural changes, and value creation changes (e.g., Matt et al., 2015; Van Veldhoven & Vanthienen, 2021; Vial, 2019). The use of technologies involves companies' approaches toward novel technologies and their capabilities to take advantage of these technologies (Matt et al., 2015). To exploit such technologies, companies must consider the structural factors and prevailing organizational barriers that can hamper their transformation success (Vial, 2019). By considering the three mentioned dimensions, companies can implement different value creation paths to meet customer needs. Tekic and Koroteev (2019) found that digital transformation paths differ based on the motivation for and objective of the transformation. They found that paths may differ based on the rate of supremacy of technologies, as well as the rate of business model preparedness for digitalization of operations. Thus, it is essential to assess the mechanisms of digital transformation based

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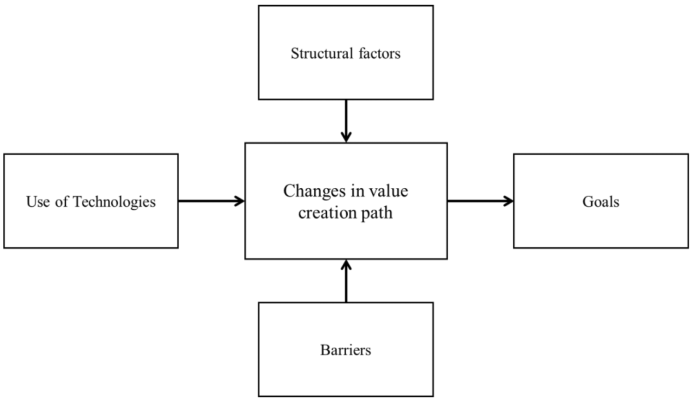

FIGURE 1 Research framework: the use of technologies to change value creation paths.

on their target. The target may relate to the ways in which products and services are generated, the types of products and services provided, or the ways in which products and services are sold and marketed (Bharadwaj et al., 2013; Brynjolfsson & Kahin, 2000). In the current research, the use of technologies, structural factors, and organizational barriers were considered essential dimensions for determining value creation paths for digital products/services, digital production and processes, as well as digital sales and service processes. In line with the framework shown in Figure 1, this study aimed to examine the mechanisms that determine the paths of organizations' value creation during digital transformation.

3 | CASE STUDY APPROACH

Companies use digital technology to develop and transform their operations and processes. Recent studies have examined digital transformation as a process in which technologies determine value creation to a great extent (Vial, 2019). We studied the phenomenon of digital transformation from a company point of view and examined how the case companies used digital technology to change their value creation paths. Concerning the management of the value creation process, certain common factors were considered, that is, the characteristics of digital technology that supported or prevented changes in value creation. Based on theory, we collected empirical evidence from 11 case studies to achieve the objective of determining different paths for companies to succeed in digital transformation. We pursued this objective through the following research question: *What mechanisms determine organizations' value creation paths during digital transformation?*

3.1 | Case selection

We used case studies to investigate the phenomenon of digital transformation from an organizational perspective (Eisenhardt, 1989). The case study approach enables a deep and versatile understanding of the studied phenomenon in its natural context (Crowe et al., 2011). It intensively focuses on a single unit to understand a larger set of units, with a unit connoting a spatially bounded phenomenon (Gerring, 2004). Due to the essence of the research, a case study approach seemed to be the most suitable method for examining the research phenomenon in practice and answering the research question, which was firmly based on existing theory. Our study approach emphasized the real-world context in which phenomena occur and offered a review of complicated behavioral processes that cannot be easily exposed by quantitative data (Eisenhardt & Graebner, 2007).

Our study used multiple case studies, which is appropriate when the same phenomenon is believed to occur in multiple situations (Yin, 1981). Several case studies were used to provide a more comprehensive picture of the phenomena being studied and help us identify different paths and analyze the similarities and differences between them. A total of 11 case companies and 18 interviewees were carefully selected for the study to enable comparison and replication of the collected data (Yin, 2003). The companies had different goals regarding digital transformation, such as developing new digital products, enhancing production through new digital technologies, and improving communication with various stakeholders. Through these cases, we aimed to link theory and practice more closely. The selection criteria for the case companies were as follows:

1. The companies should represent different industries and sizes.
2. The companies' goals must relate to digital transformation.
3. The companies must have taken initiatives to achieve these goals.
4. The interviewee(s) should be aware of the digital transformation of their company in different organizational areas.

The first three selection criteria helped in choosing suitable companies for the study, and the final criterion guided the selection of suitable interviewees. We selected companies from different industries to gain a comprehensive view of the level of the companies'

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TABLE 1 Details of the case companies.

Company	Size of company	Industry	Number of interviews	Interviewees' role	Objective of value creation
Company A	Large	Operating in the engineering industry	2	Process technology manager, product manager (in the Automation Department)	Digital products/services
Company B	Large	Operating in the welding industry	1	Chief digital officer	Digital products/services
Company C	Large	Operating in the engineering industry	1	IT manager	Digital products/services
Company D	SME	Operating in the technology industry	1	Maintenance director	Digital products/services
Company E	SME	Operating in the chemicals industry	2	Production manager, product development chemist	Internal processes and production
Company F	SME	Operating in the furniture industry	2	CEO, Product manager	Internal processes and production
Company G	SME	Operating in the plastics industry		Executive vice president	Internal processes and production
Company H	SME	Operating in the construction industry	2	Factory manager, CEO	Internal processes and production
Company I	SME	Operating in the clothing industry	1	CEO	Sales and service
Company J	Large	Operating in the wood-processing industry	3	Development director, factory manager, Project Engineer	Sales and service
Company K	Large	Operating in the technology industry	2	Production manager, factory manager	Sales and service

digitalization and analyze prevailing practices across contexts (Yin, 2003). The selected companies included SMEs as well as large multinational companies with headquarters or a subsidiary based in Finland. Details of the case companies are shown in Table 1. When choosing companies, it was also crucial that they had goals relating to digital transformation in different organizational areas and had striven to achieve these with digital initiatives. Finally, the interviewees were chosen from different organizational areas, based on their knowledge of digital transformation. To supplement and validate the interviewees' knowledge, we invited more participants from the companies to participate in the interviews.

3.2 | Case studies data collection and analysis

The data were gathered between August and November 2019 through semi-structured in-depth interviews. Eighteen focal informants were interviewed, each possessing information about the case companies' digital transformations in different organizational areas. The informants had a general conception of the organization's overall digital state, as well as specific information about the digital development projects in their working areas. We used open-ended questions (available from the authors on request) for the interviews. The questions were constructed using the theoretical framework outlined in Section 2. Each case study interview was conducted independently by one researcher and lasted between 50 and 90 min. This allowed for consistency across all interviews. As each interview progressed, additional questions were asked, and further information was requested afterwards by email. This provided the basis for the empirical analysis.

Interviews were used to capture relevant information about the study phenomenon. All interviews were recorded and transcribed by an external service provider. After the data collection, cross-case and within-case analyses were utilized to achieve the research objective. The specific analyses were unique to the case-oriented process and were used to identify and describe the mechanisms that determined the paths of the organizations' value creation during their digital transformations (Eisenhardt, 1989). Within-case analysis revealed the main goals of the case companies' digital transformations and the means by which they tried to accomplish these goals. Cross-case analyses were conducted by considering the main changes in companies' value creation paths (i.e., digital products and services, internal processes, and sales and services). The analysis focused on the three common value creation paths for companies to create value through digital technology, aiming to identify which factors supported or hindered the change process.

4 | FINDINGS

In the findings section, we outline three different paths through which the case companies created value through digital

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TABLE 2 Recap of the value creation paths.

	Value creation path		
	Digital products and connected services	**Digital production and internal processes**	**Digital sales and service processes**
Use of technologies	Artificial intelligence Automation Data usage Digital twin IoT Machine vision Mobile applications Scanner technology Sensors	Automation and connection CRM Engineering and design programs ERP Mobile tools and applications Robotics Sensors	Artificial intelligence Data usage Digital channels (online store, digital ordering, online support, chat, digital marketing) Digital platform Mobile applications
Structural factors	Cooperation networks Continuous development Digital skills	Employee participation and training during change	Cooperation with customers Desire to change and evolve Digital skills
Barriers	Customers' concerns regarding information security	Change resistance Financial factors Technology ignorance	Complex user interface
Goals	Increase of sales and competitiveness	Improvement of internal operations	Better customer experience

technology. When defining paths, we focused on the companies' main goals for creating new value and on the factors that supported or hindered digital change. Table 2 presents a recap of the findings.

4.1 | Path 1: Digital products and connected services

Four case companies were creating value through digital technology by developing and selling new digital products/services to their customers. The value creation path is described in Figure 1. The main goal of the companies was to increase sales with new digital products and services and increase their competitiveness. Alongside this, the companies were also constantly developing their internal processes with digital technologies. Here are a few sentences describing how companies implemented their digital transformation strategies and achieved their goals:

> A digital strategy is a couple of different things for us: on the one hand, it involves, of course, a traditional kind of IT, where we think about how we work in-house, and on the other hand, it involves digital services relating to traditional products for our customers (IT manager, Company C).

> For us, IoT is a tool to sell better equipment and services (Maintenance director, Company D).

> The goal is that our digital services should increase our machine sales and increase our competitiveness in relation to our competitors (Chief digital officer, Company B).

The companies were united by a desire to be pioneers in digital change in their industries. Other supporting factors for digital change included the skills of employees and cooperation networks. The continuous development of both factors alongside digital products and services was seen as important support for change. A need for new types of future cooperation and expertise was recognized in some companies:

> When the digital project has progressed a long way in the next few years and we are able to provide envisioned services to customers, we will need new types of experts who will be capable of working with data (Maintenance director, Company D).

A factor seen as potentially slowing down the change was customers' concerns about information security, which could prevent the utilization of new digital products and services. This barrier could be avoided by developing the most secure products and services possible and by communicating the security measures openly to customers.

> Due to security issues, we have a customer who doesn't want to use the Internet for products, even if it makes more sense and is cheaper for everyone, is easier to repair, or helps the customer remotely more effectively than sending someone to the scene to watch (Maintenance director, Company D).

> Security is highlighted because we understand the risks involved; for example, when building remote connections. We have invested a lot in it, and we can show the customer how information security is organized and how it is managed (Process technology manager, Company A).

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The companies used a variety of digital technologies and tools to develop their products by adding new features and services. Company A, for example, utilized intelligent algorithms, automation, machine vision, and scanner technology to optimize customer processes. Company C, on the other hand, utilized sensor technology and IoT to measure and monitor customer products and process quality, quantity, temperature, humidity, and speed, and had developed a digital twin of its main product to allow customers to experiment with product control virtually. Finally, Company D had an IoT project underway that sought to improve the use of customer data and provide additional product-related services for customers.

4.2 | Path 2: Development of internal operations

Four companies had begun their digital transformations in recent years. The changes began with a focus on streamlining internal operations and production with digital technologies. The companies started digital transformation by acquiring better systems (enterprise resource planning [ERP] or customer relationship management [CRM]), more efficient production equipment, and design and engineering software, as well as by increasing production automation and Internet connectivity. The value creation path is described in Figure 2. For these companies, digital transformation in other business areas was in its infancy; for example, the companies had acquired websites but did not yet have digital services or products. Here are a few examples of how companies described streamlining their operations:

> We will streamline production with these new machines and equipment. They speed up the production process and various work steps, as well as increase accuracy, which then shortens the manufacturing lead time. This, in turn, frees up resources elsewhere (the CEO, Company F).

> Consider, for example, our federal beam production. Last summer, it was discovered that there was a bottleneck in the plasma phase of the production process. Now we have acquired a new plasma [machine], and that bottleneck has shifted to design. Currently, we are acquiring more design resources and leveraging digital technology by building design automation. We have made these types of changes to streamline internal processes (the CEO, Company H).

Factors supporting the transformation of companies included training employees to use new equipment, machines, hardware, and software. This ensured that the new acquisitions were used as efficiently as possible. Employee participation in the change process was also seen as a supporting factor, allowing employees' voices to be heard in connection with their own process-related tasks: "We train our staff annually in connection with, for example, our systems. It means that the use of the systems is already doing quite well and not having constant problems" (Factory manager, Company H).

Barriers to the success of change in the companies were change resistance, financial resources, and ignorance of technology. Opposition to change was evident at various levels of the organization, both at the employee and management levels, which negatively impacted the benefits received. The industry and the digital transformation of the industry also affected companies' willingness to change. In some cases, digital change was met with ignorance, and the potential benefits it brought were unknown, which also slowed down the companies' digital transformation:

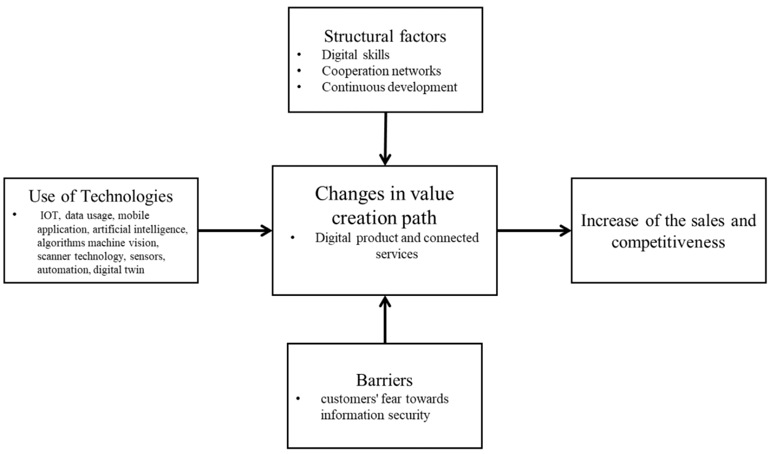

FIGURE 2 Value creation path 1: digital product and connected services.

When thinking about changes in relation to digitalization, such as updating websites, the initial willingness does not come from the management but from customers or employees, for example, and the other parties only see the benefits of the changes once they have been implemented. (Production manager, Company E).

The economic situation must also support change. In situations where company finances were poor, change took place slowly, and change resistance was greater:

For 15 to 20 years, we have been in such a bad financial situation that we have had to look for price solutions. It has slowed down the organizational change and caused a conservative attitude and culture toward many things; for example, the implementation of a new ERP was a complex and cumbersome project (Executive vice president, Company G).

4.3 | Path 3: Digital sales and service processes

Three case companies focused specifically on developing their sales and service operations using digital technology. The main goal of the digital initiatives was a better customer experience. Figure 3 presents the value creation path of these companies, showing how they created new value using different technologies. Technology acted as a tool, opening up new possibilities for customer service:

Increasingly, we want to understand our customers' "earnings logic" and their business environment. It opens up a whole different world and the opportunity to understand different business concepts that benefit the customer. That thinking doesn't end when the goods leave here and the invoice comes … For example, our digital store was designed together with our three largest Central European customers (Development director, Company J).

We have the best customer service in the market that we are talking about, so to deliver on that promise of service, we're working shoulder to shoulder, and digitalization really plays a major role in that. Because we can't put employees physically at every customer's site to help and provide information, we need digital tools to deliver on our promise (Factory manager, Company K).

The companies used a variety of digital technologies and tools to improve their customers' experiences. Company I was developing its customer service using artificial intelligence and customer data. They collected their customers' trouser-fitting data and thus strove to streamline their trouser fitting and sales processes by finding the best trouser design for the customer using technology. Simultaneously, they developed new and existing digital service channels such as websites, online chat facilities, and mobile applications that customers could take advantage of. Company K also developed its customer service through digital channels to enable customers to place orders easily, obtain online support, and view order information in real time in one place. Company J had a new collaborative project underway that supported the utilization of empty log trucks using a digital platform. Additionally, Company J had a project that aimed to provide a track-and-trace service in the future to allow customers to track their products, and the company was developing a lifecycle service whereby

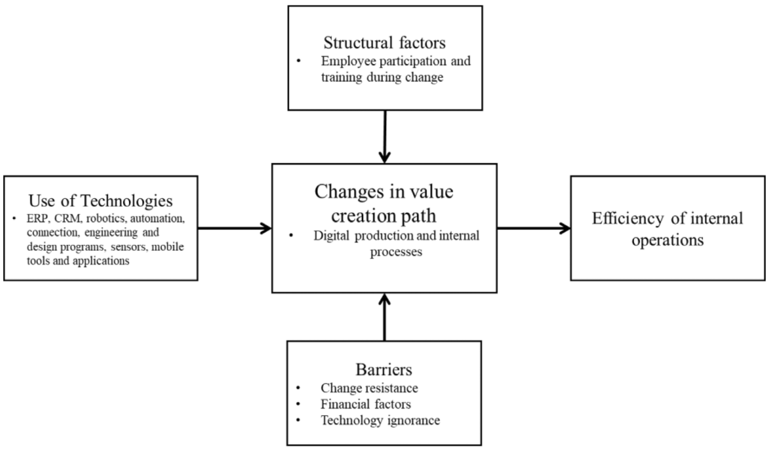

FIGURE 3 Value creation path 2: digital production and internal processes.

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smart tags would tell customers about a product's lifespan, location, and recycling point. These development projects were supported by companies' desires to change and develop and to meet customer needs: "Information systems have been a matter of interest to me personally, which has contributed to our company's strong focus on digitalization. The digital strategy and its significance has emerged here, as stated over the last ten years" (the CEO, Company I).

Also, know-how regarding digitalization was increasingly emphasized as digital projects progressed to enable digital initiatives to be successful and used effectively. Indeed, some companies recruited people with new types of expertise to ensure the effective implementation and use of digital tools:

> We are in a good position because we have an expert inside the organization who can make a system tailored for us on a common software platform (the CEO, Company I).

> We hired a person to handle our digital marketing, where the key tools are social media, websites, and email signatures (Factory manager, Company K).

The factor that slowed the change was the complex user interface. The complexity of the systems and the difficult user interface weakened the customers' service experience, meaning that the benefits of the new tools were not realized or only partially realized. Company I aimed to meet this challenge by developing its digital services to fulfill the requirements of different types of customers (Figure 4):

> Systems are too complicated for customers at the moment, and it's really annoying for them. If they fail to use the digital tool in a few seconds, the tool is abandoned. We also have a wide range of customers, so we need to be able to develop the digital service tool so that everyone can use it (the CEO, Company I).

5 | DISCUSSION

This study investigated the mechanisms that determined organizations' value creation paths during digital transformation. The study contributes to KM research by proposing a research framework based on the literature and outlining three different value creation paths for companies in the digital transformation frame. Next, the case findings' theoretical and managerial implications are discussed, focusing on the main mechanisms (use of technology, structural factors, barriers, and changes in value creation and goals) and their differences across different pathways.

The findings highlighted that the case companies had different goals relating to digital transformation when creating new value through the use of technology. Those goals differed based on the motivation for and objectives of transformation (Tekic & Koroteev, 2019). The objectives could be the ways in which products and services were produced, the types of products and services provided, or the ways products and services were sold and marketed (Bharadwaj et al., 2013; Brynjolfsson & Kahin, 2000). At the present research, the goals of the companies were to increase sales and competitiveness using novel digitalized products as well as connected services, improve the efficiency of internal operations through digital production processes, and provide better customer service through digital sales and service processes.

First, four case companies focused on the digital technology usage to develop and sell novel digitalized products with connected services to their customers. The main goal was to increase the sales of

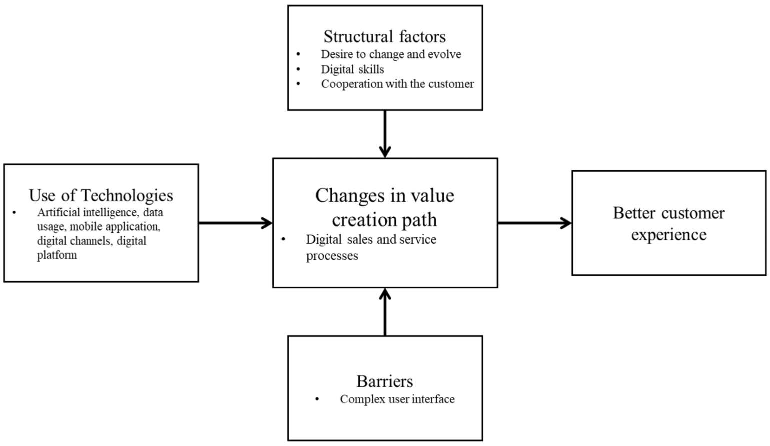

FIGURE 4 Value creation path 3: digital sales and service processes.

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new digital products and services and increase their competitiveness. The characteristics of this group of companies were that they focused on the latest technologies and their utilization for completely new uses that best served their customers; thus, the initiatives were not driven by customers but resulted from the companies' own desire to be technology leaders. This was perceived as the best way to serve customers in situations where it might be difficult for them to be aware of the latest technology trends. Managing such strong technology leadership requires companies to invest in a variety of structural factors (Matt et al., 2015; Tabrizi et al., 2019; Vial, 2019). For example, in order to achieve a new type of value, attention should be paid to management and human-based factors; managers must have the necessary skills to understand and utilize the potential of these technologies and to support employees in adopting a common vision and achieving common goals (Lee & Seol, 2021; Sarka et al., 2019). The present study is in line with previous ones stating that, from the standpoint of continuous development, a systematic approach was needed to simultaneously update and maintain the skills of both management and employees.

This was necessary because, in this group of companies, design, coding, and even turnkey solutions were implemented in-house, although naturally some solutions were sourced from partners. In these companies, internal production and processes usually operated at a high level and did not only utilize ready-made solutions from external suppliers, unlike many early-stage companies. With in-house expertise, the companies knew when they needed a partner, and this expertise also assisted them in choosing the best partners. The above notions were in tune with Tabrizi et al. (2019) and Verhoef et al. (2021), who proposed that company personnel are required to adopt a positive mindset and strong digital and analytical skills to tolerate, for example, uncertainty and collaboration with essential new partners. Consensus among managers and employees, together with in-house expertise, also helped the companies identify mechanisms for mapping and learning the latest and upcoming technologies. It seemed that the value creation mechanisms of more advanced companies were clearer and focused on the generation of new digitalized products as well as service processes based on their own expertise. In the most advanced companies, the common knowledge, desire, and skills of both employees and management were crucial and enabled the reduction of resistance to change. Hence, somewhat surprisingly, resistance to change was not considered a barrier in more advanced companies, where the only clear barrier was customers' concerns about information security. It has been noted in the literature that the introduction of digital technologies has had positive and negative effects on organizations' openness and information and knowledge sharing, as well as on their culture (Holopainen et al., 2022; Sarka et al., 2019). Our research asserts that by developing management's knowledge and skills and involving employees in the change process, resistance to change can be reduced. This is a topical issue in society and requires a great deal of further research using different methods in the context of this research.

Second, four case companies operating in the chemical, furniture, construction, and plastics industries had begun their digital transformations in recent years by focusing on streamlining internal operations and production through digital technologies. The results showed that these companies' digital transformation in other business areas was in its infancy. According to the results, the drivers of change were mostly customers or other stakeholders rather than the strategic decisions of the management. This was due to the technological incapability or ignorance of the management, which led these companies to be content with ready-made technological solutions rather than developing them internally. The present study is in line with that of Venkitachalam and Bosua (2019), who noted that managers often feel confused about the choices they have to make when investing in digital technologies for the purpose of creating novel value. To assist the management of the value creation process and the success of the transformations, these changes were supported by the companies' ability to manage financial factors and change resistance internally and externally. According to Tabrizi et al. (2019), company employees' insider knowledge should not be neglected, which was reflected in the study in that digital projects were more successful if employees were committed and participated in the change. This is in agreement with a study by Lee and Seol (2021), who show that learning and knowledge sharing through direct interaction between people are crucial for increasing employees' skills and encouraging them to discover new ways to solve problems.

Third, three case companies focused specifically on developing their sales and service operations using digital technology to create a better customer experience. Building on the context of digital transformation, investment in novel technologies is the main ingredient for benefiting from contemporary knowledge and resources for customer value creation (Ikeda et al., 2021; Matt et al., 2015; Verhoef et al., 2021). The findings showed that, to enable companies to achieve this goal, they emphasized their ability to manage complexity. This required company personnel to have strong digital and analytical skills (Verhoef et al., 2021). The results also showed that these companies had a desire to serve customers more effectively, as opposed to putting digital change pressure on customers, emphasizing trustful relationships with customers. This concurs with Holopainen et al. (2022), who proposed that companies should find a balance between their own and customers' readiness and willingness to adopt digital operations. In addition, Tabrizi et al. (2019) concluded that digital technologies alone do not determine the success of digital transformation. According to the case studies, companies need closer cooperation with customers to develop technological solutions to meet their customers' needs. Therefore, when developing cooperation with the customer, companies can view KM as a learning process in the production of continuous knowledge implemented with the help of various feedback mechanisms (Ikeda et al., 2021).

6 | CONCLUSION

This study has explained the emergence of value creation during digital transformation. It has addressed the mechanisms that determine value creation paths by investigating 11 companies that were taking

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concrete steps toward digital transformation. The emergence of value creation paths was examined from three perspectives: the use of technologies, structural factors, and barriers. Based on the cases, digital transformation paths are determined by digital business strategies, the competitive environment, customer pressure, and the digital skills of employees. The main barriers relate to managing trust issues, the complexity of technology solutions, and resource constraints. Hence, the result highlights the need for companies to manage knowledge in order to facilitate digital transformation and generate value through novel technologies.

The following conclusions can be drawn: First, the strategic orientation of digital transformation needs to exceed a certain level to be an actual value creation mechanism. Companies whose transformations are guided by digital business strategies consider digital technologies only as tools to accomplish their strategic goals, and technologies are an integral part of the strategic approach. Second, digital transformation paths are driven by changes in the competitive environment. The need for and goals of digital transformation must be assessed in relation to competitors and industry averages, which was the push for digital transformation for the studied companies. Further, the influence of the competitive environment on value creation paths is indirect via a second route, since it offers a driver for forming cooperative networks. The more advanced the technological solution is, the less likely it is that a single company can provide it alone, which, in turn, subsequently affects the formation of value creation paths. Third, pressure from customers impacts the value creation mechanisms during digital transformation, depending on the nature of the value creation path. The more advanced the technology solution, the more it will be driven by a real desire to get to know customers and serve them more effectively. Fourth, digital transformation driven value creation is determined by the extent to which a company manages to balance its existing business and digital transformation. This balance can be facilitated by building trust in technology and managing the complexity of technological solutions.

The results have relevant managerial implications, since they can assist managers in considering the key mechanisms of digital transformation. The study's limitation is that it relied on data from 11 companies, and further studies are required to validate the findings with other datasets and in other regions. Further research should focus on specific technologies to explore the value creation mechanisms and also examine the connection between the features of value creation with technologies as well as multiple dimensions of company performance.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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REFERENCES

Afolayan, A. O., & de la Harpe, A. C. (2020). The role of evaluation in SMMEs' strategic decision-making on new technology adoption. *Technology Analysis & Strategic Management*, *32*(6), 697–710.

Andriole, S. J. (2017). Five myths about digital transformation. *MIT Sloan Management Review*, *58*(3), 19–22.

Barrett, M., Davidson, E., Prabhu, J., & Vargo, S. L. (2015). Service innovation in the digital age: Key contributions and future directions. *MIS Quarterly*, *39*, 135–154.

Bharadwaj, A., El Sawy, O. A., Pavlou, P. A., & Venkatraman, N. (2013). Digital business strategy: Toward a next generation of insights. *MIS Quarterly*, *37*(2), 471–482.

Brynjolfsson, E., & Kahin, B. (2000). *Understanding the digital economy: Data, tools, and research*. The MIT Press.

Crowe, S., Cresswell, K., Robertson, A., Huby, G., Avery, A., & Sheikh, A. (2011). The case study approach. *BMC Medical Research Methodology*, *11*(1), 1–9.

Davenport, T. H., & Westerman, G. (2018). Why so many high-profile digital transformations fail. *Harvard Business Review*, *9*, 15.

Eisenhardt, K. M. (1989). Building theories from case study research. *Academy of Management Review*, *14*(4), 532–550.

Eisenhardt, K. M., & Graebner, M. E. (2007). Theory building from cases: Opportunities and challenges. *Academy of Management Journal*, *50*(1), 25–32.

El Sawy, O. A., Kræmmergaard, P., Amsinck, H., & Vinther, A. L. (2016). How LEGO built the foundations and enterprise capabilities for digital leadership. *MIS Quarterly Executive*, *15*(2), 141–166.

Galindo-Martín, M. Á., Castaño-Martínez, M. S., & Méndez-Picazo, M. T. (2019). Digital transformation, digital dividends and entrepreneurship: A quantitative analysis. *Journal of Business Research*, *101*, 522–527.

Gerring, J. (2004). What is a case study and what is it good for? *American Political Science Review*, *98*, 341–354.

Hess, T., Matt, C., Benlian, A., & Wiesböck, F. (2016). Options for formulating a digital transformation strategy. *MIS Quarterly Executive*, *15*(2), 123–139.

Holopainen, M., Ukko, J., & Saunila, M. (2022). Managing the strategic readiness of industrial companies for digital operations. *Digital Business*, *2*(2), 100039.

Horlach, B., Drews, P., Schirmer, I., & Böhmann, T. (2017). Increasing the agility of IT delivery: Five types of bimodal IT organization. In *Proceedings of the 50th Hawaii international conference on system sciences*. Hawaii International Conference on System Sciences. 5420–5429.

Ikeda, E. K., da Silva, L. F., Penha, R., de Oliveira, P., & Gonçalves, S. (2021). The relationship between the internet of things and knowledge management in smart ecosystem development. *Knowledge and Process Management*, *28*(2), 181–194.

Lee, J., & Seol, H. D. (2021). An inquiry into transformational leadership, knowledge management strategies, and employee creativity. *Knowledge and Process Management*, *28*(4), 364–376.

Margiono, A. (2020). Digital transformation: Setting the pace. *Journal of Business Strategy*, *42*(5), 315–322.

Matarazzo, M., Penco, L., Profumo, G., & Quaglia, R. (2021). Digital transformation and customer value creation in made in Italy SMEs: A dynamic capabilities perspective. *Journal of Business Research*, *123*, 642–656.

Matt, C., Hess, T., & Benlian, A. (2015). Digital transformation strategies. *Business & Information Systems Engineering*, *57*(5), 339–343.

Mavri, M. (2015). Redesigning a production chain based on 3D printing technology. *Knowledge and Process Management*, *22*(3), 141–147.

Nasiri, M., Ukko, J., Saunila, M., Rantala, T., & Rantanen, H. (2020). Digital-related capabilities and financial performance: The mediating effect of performance measurement systems. *Technology Analysis & Strategic Management*, *32*(12), 1393–1406.

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Ritter, T., & Pedersen, C. L. (2020). Digitization capability and the digitalization of business models in business-to-business firms: Past, present, and future. *Industrial Marketing Management*, *86*, 180–190.

Sarka, P., Heisig, P., Caldwell, N. H. M., Maier, A. M., & Ipsen, C. (2019). Future research on information technology in knowledge management. *Knowledge and Process Management*, *26*(3), 277–296.

Sia, S. K., Soh, C., & Weill, P. (2016). How DBS Bank pursued a digital business strategy. *MIS Quarterly Executive*, *15*(2), 105–121.

Tabrizi, B., Lam, E., Girard, K., & Irvin, V. (2019). Digital transformation is not about technology. *Harvard Business Review*, *13*, 1–6.

Tekic, Z., & Koroteev, D. (2019). From disruptively digital to proudly analog: A holistic typology of digital transformation strategies. *Business Horizons*, *62*(6), 683–693.

Tomé, E., Gromova, E., & Hatch, A. (2022). Knowledge management and COVID-19: Technology, people and processes. *Knowledge and Process Management*, *29*(1), 70–78.

Ukko, J., Nasiri, M., Saunila, M., & Rantala, T. (2019). Sustainability strategy as a moderator in the relationship between digital business strategy and financial performance. *Journal of Cleaner Production*, *236*, 117626.

Van Veldhoven, Z., & Vanthienen, J. (2021). Digital transformation as an interaction-driven perspective between business, society, and technology. *Electronic Markets*, *32*(2), 629–644.

Venkitachalam, K., & Bosua, R. (2019). Perspectives on effective digital content management in organizations. *Knowledge and Process Management*, *26*(3), 202–209.

Verhoef, P. C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J. Q., Fabian, N., & Haenlein, M. (2021). Digital transformation: A multidisciplinary reflection and research agenda. *Journal of Business Research*, *122*, 889–901.

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144.

Yin, R. K. (1981). The case study as a serious research strategy. *Knowledge*, *3*(1), 97–114.

Yin, R. K. (2003). Case study research. In *Design and methods* (3rd ed.). Sage Publications.

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Publication III

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Facilitating performance measurement and management through digital business strategy

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Facilitating performance measurement and management through digital business strategy

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Abstract

Purpose – *This study aims to focus on the connection between digital business strategy and performance measurement and management (PMM).*

Design/methodology/approach – *The implications of digital business strategy and its dimensions with regard to PMM were investigated through a survey. The survey questionnaire provided 202 valid cases with a focus on senior management of small- and medium-sized enterprises. Strategic dimensions were identified from the literature on management in the context of digitalization to build a theoretical framework that highlights the mechanisms that companies should focus on when managing and implementing digital technologies successfully.*

Findings – *The aspects that comprise digital business strategy are grouped into five major dimensions: technological understanding, goals, resources, management and responsibilities. The study reveals a direct and positive relationship between goals and management related to digital business strategy and PMM.*

Research limitations/implications – *The study contributes to the existing PMM literature in the context of digitalization.*

Practical implications – *The results indicate that if a company has excellent goals and management with regard to its digital business strategy, it uses PMM in a more successful and effective way.*

Originality/value – *To the best of the authors' knowledge, this study is among the first to examine PMM in terms of managing digital business strategy by trying to determine the extent to which the elements of digital business strategy can be integrated effectively into PMM.*

Keywords *Performance management, Performance measurement, PMM, Digital, Business strategy*

Paper type *Research paper*

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1. Introduction

Performance measurement and management (PMM) has been impacted by ongoing digitalization and the changes it has forced in the management of companies' operations (Nudurupati *et al.*, 2020). In the context of digitalization, PMM can be viewed as a system of systems (Bourne *et al.*, 2013; Sardi *et al.*, 2020) that "need to interrelate complex subsystems, different in technology, context, operation, geography, and conceptual frame" (Sardi *et al.*, 2020), thereby affecting the use of PMM in complex and turbulent environments (Bourne *et al.*, 2013). Digitalization built on the utilization of digital technologies is consequently affecting PMM. Digital technologies can cause transformations resulting in improvements in companies' offerings and customer satisfaction (Tortorella *et al.*, 2020). Such major transformations require companies to adopt a strategy that connects their technologies and businesses (Bharadwaj *et al.*, 2013). This type of digital business strategy and its management require companies to implement success metrics, that is, PMM (Bharadwaj *et al.*, 2013; Nasiri *et al.*, 2020). Such PMM is challenged by the turbulence of the external environment (Nudurupati *et al.*, 2016) and, therefore, requires the capability to gather information that is highly volatile and fast-changing.

Despite the abundant literature on PMM practices, little research has been conducted on how the current highly volatile, uncertain and ambiguous digital environment has been affecting how organizations measure and manage performance (Nasiri *et al.*, 2020; Nudurupati *et al.*, 2020). Specifically, while digital transformation's influence on companies' strategies is widely recognized, its influence on PMM has elicited scant attention. Presumably, digital transformation and its alignment with a company's strategic objectives exert a meaningful effect on PMM. The phenomenon – digitalization's influence on PMM – is acknowledged in the literature, but little research has been conducted on the specific factors that influence PMM. If the company's strategic goal is to digitalize its operations, for example by moving to e-commerce, they must find the most suitable possible solution in terms of costs, quality and goals. It is assumed that the better a company manages the various aspects of a digital business strategy, such as understanding technology, the various costs of investment and maintenance and the goals set for it, the better they will be able to link digital investment goals to company-wide strategic goals and decision-making in their PMM. This in turn positively contributes to the efficient use of PMM.

Thus, the aim of the study is to answer the question of whether digital business strategy positively influences PMM. The aspects that comprise digital business strategy are grouped into five major dimensions: technological understanding, goals, resources, management and responsibilities. The research is based on an analysis of survey results from 202 respondents. The research contributes to recent literature and practices as follows. First, it reveals the influence of the specific dimensions of digital business strategy on PMM. The results explain which digital business strategy dimensions are more effective in this sense. According to the results, goals and management related to digital business strategy should be considered with regard to supporting PMM in digital transformation. Second, this study offers a holistic framework for indicative research on digital business strategy's influence on PMM. A better understanding of the dimensions of digital business strategy related to PMM will assist the development of a comprehensive picture of performance management in line with digital business strategy.

The paper proceeds as follows. In the literature review, prior research on PMM in the context of digitalization is reviewed. Then, in Section 2, hypotheses are developed, and a research model is presented. After this, the methodology and results of the study are outlined in Sections 3 and 4, respectively. Finally, the research results are discussed in Section 5, and a conclusion is presented in Section 6.

2. Theoretical model and hypotheses

2.1 Theoretical underpinnings

2.1.1 Performance measurement and management. Despite the abundant literature on PMM practices, little research has been conducted on how the current highly volatile, uncertain and ambiguous operating environment has been affecting how organizations measure and manage performance (Nudurupati *et al.*, 2020). Similarly, limited effort has been made to construct a theoretical framework to understand the interplay between performance measurement and performance management, or their impact on employee engagement and performance (Bourne *et al.*, 2013; Smith and Bititci, 2017). To understand the differences between the studied concepts, the key ideas must be defined. Ittner *et al.* (2003) touted a performance measurement system as a system that "provides financial and nonfinancial information that allows the firm to identify the strategies offering the highest potential for achieving the firm's objectives, and aligns management processes, such as target setting, decision-making, and performance evaluation with the achievement of the chosen strategic objectives." Hall (2008) defined a performance measurement system as one that "translates business strategies into deliverable results by combining financial, strategic, and operating business measures to gauge how well a company meets its targets." From an organizational control perspective, PMM can be examined through technical control and social control mechanisms (Child, 1973; Cardinal *et al.*, 2004; Smith and Bititci, 2017). As a technical control, performance measurement refers to a process (or processes) of setting goals, developing a set of performance measures and collecting, analyzing, reporting, interpreting, reviewing and acting on performance data (Neely *et al.*, 1995; Smith and Bititci, 2017). Performance management, in turn, refers to social controls that are conceptualized as cultural and behavioral routines that define how we use a performance measurement system to manage an organization's performance (Bititci, 2015; Smith and Bititci, 2017). Summing up, it is suggested that the research around PMM could focus more on the co-existence and interplay between the technical and social control aspects of PMM in changing business environments.

PMM systems have also been demonstrated to be complex, adaptive systems that are evolving and constantly adjusting to transformations within an internal company environment (Okwir *et al.*, 2018). Koufteros *et al.* (2014) suggested that in changing business environments, organizations can use these systems as orchestration mechanisms, not only to control and evaluate internal organizational behavior, but also to adapt to the needs of organizational renewal activities. For example, companies experience internal and external pressures to implement digital transformation, which forces them to retool their functions and operations. Renewal activities are strongly related to PMM's social control aspect with regard to, for example, people's behavior and organizational capabilities. Franco-Santos *et al.* (2012) noted that people's behavior refers to consequences related to employees' actions or reactions (e.g. motivation, participation) and their underlying cognitive mechanisms (e.g. perceptions). They also suggested that organizational capabilities refer to consequences associated with specific processes, activities, or competencies that enable an organization to perform and gain competitive advantages (e.g. strategic alignment, organizational learning). Nudurupati *et al.* (2020) also highlighted the use of more subjective, perception-based evaluation measures, in which both the multi-tier supply chain and customers are asked to evaluate an organization, often using social media and other information technology-enabled platforms. Similarly, Nasiri *et al.*'s (2020) findings showed that when companies digitize their operations and functions, social controls (digital-related human and collaboration capabilities) positively affect technical controls (i.e. performance measurement systems) and, further, financial performance. This indicates that changes in people's behavior and organizational capabilities (social controls) influence PMM (technical controls) and vice versa. The discussion above indicates the need for parallel assessments in terms of both the social and technical control mechanisms of PMM, as well as the need to consider in which case (e.g. social controls) the notion of performance evaluation, rather than measurement, would be a viable alternative (cf. Bititci *et al.*, 2012). Therefore, PMM is, all in all, an essential means of handling digital transformation.

2.1.2 Performance management and digital business strategy. To survive the intensifying competition, companies need a digital business strategy that reflects a fusion between technologies and business (Bharadwaj *et al.*, 2013). Bharadwaj *et al.* (2013) defined digital business strategy as "organizational strategy formulated and executed by leveraging digital resources to create differential value". Mithas *et al.* (2013) concluded that "digital business strategy is not solely a matter of optimizing firm operations internally or of responding to one or two focal competitors, but also arises strikingly from awareness and responsiveness to the digital business competitive environment". The successful implementation of such a digital business strategy certainly causes some changes to PMM as well (Bharadwaj *et al.*, 2013; Nasiri *et al.*, 2020).

Comprehensive PMM facilitates the interplay between company operations and strategy (Chenhall, 2005). Digital technologies foster transformations that can result in major improvements in offerings and customer satisfaction (Tortorella *et al.*, 2020), thereby requiring a strategy that reflects a fusion between technologies and the business (Bharadwaj *et al.*, 2013). This type of strategy is called a digital business strategy. To manage such a strategy, companies need success metrics, that is, PMM (Bharadwaj *et al.*, 2013; Nasiri *et al.*, 2020). A challenge associated with this is coping with turbulence from the external environment (Nudurupati *et al.*, 2016). Thus, PMM should possess the capability to gather information that is highly volatile and fast-changing. In response, contemporary research has defined PMM in the digital context as a system of systems (Bourne *et al.*, 2013; Sardi *et al.*, 2020). Consequently, it "need(s) to interrelate complex subsystems, different in technology, context, operation, geography, and conceptual frame" (Sardi *et al.*, 2020), thereby facilitating the use of PMM in complex and turbulent environments (Bourne *et al.*, 2013).

According to this perspective, novel directions for the utilization of PMM to foster digital business strategy are evident. These are summarized in Table 2 and described next. Contemporary PMM puts greater emphasis on evaluation, rather than on traditional measurement (Nudurupati *et al.*, 2016; Ukko *et al.*, 2020). This requires deep understanding about the entire process directing digital business strategy. Ravelomanantsoa *et al.* (2019) suggested that prior technological changes have led to the view that a company is not understood as one company, but rather as a network of companies with interconnected performances. According to them, this view elicits major changes in how PMM is constructed. Further, PMM success strongly depends on different technological capabilities, as they facilitate process transformations and promote decision-making (Vallurupalli and Bose, 2018).

The importance of goal alignment in PMM has been highlighted in prior studies (Reinking *et al.*, 2020; Sardi *et al.*, 2020). Nudurupati *et al.* (2016) concluded that companies should integrate technological developments into their strategic and performance expectations. Further, PMM is a powerful tool that can translate strategy to the lower levels of a company and assess performance against strategy. Strategic alignment is also critical to the utilization of specific PMM tools, such as dashboards. Reinking *et al.* (2020) studied dashboards as a tool to align company performance with strategy and found that the strategic alignment of digital dashboards enhances performance (Reinking *et al.*, 2020). In addition to individual PMM tools, Sardi *et al.* (2020) highlighted the importance of defining and managing the entire PMM process in relation to utilizing digital technologies and resources in line with a company's strategic goals. In digital transformation, PMM requires continuous updates, as the tools implemented need to keep up with changes in the external environment (Kamble *et al.*, 2020; Chanias *et al.*, 2019).

Targeting different types of resources is also indicated as being crucial in PMM. Nudurupati *et al.* (2016) stated that PMM, in the digital era, is characterized by a balance between traditional measures, with an emphasis on financial aspects and the evaluation of behavioral metrics. Kamble *et al.* (2020) reported similar findings in their study of smart manufacturing systems' PMM. They concluded that PMM should incorporate effects beyond traditional performance dimensions, such as cost, quality and productivity. Thus, in addition to financial aspects, human resources should be targeted to facilitate digital business strategy. Further, Ukko *et al.* (2020) studied PMM in the context of digital services and highlighted the role of relational mechanisms in such a system. They stated that behavioral factors, along with technical ones, should be considered in contemporary PMM. Thus, it should not focus merely on design and data analysis, but also engage humans in the process (Ukko *et al.*, 2020). This makes human resources crucial.

Digital transformation has elicited a greater emphasis on management facilitating PMM processes (Kamble *et al.*, 2020; Nasiri *et al.*, 2020). According to Nudurupati *et al.* (2016), contemporary PMM should aim to enhance and support different skills and capabilities, as it is the way forward for affecting behavior and further driving cultural change. Similarly, Seele (2016) stated that the implementation of digitally unified measurement changes company processes and routines. Further, different types of management capabilities are required to manage these changes. Nasiri *et al.* (2020) found that companies can improve their financial performance with the assistance of PMM-facilitated human and collaboration capabilities. PMM is also an important tool for facilitating decision-making. Sahlin and Angelis (2019) studied the opportunities for the digitalization of real-time PMM and found that it can serve as a useful tool for decision-making in turbulent environments, as digitalization has facilitated much faster data access for managers.

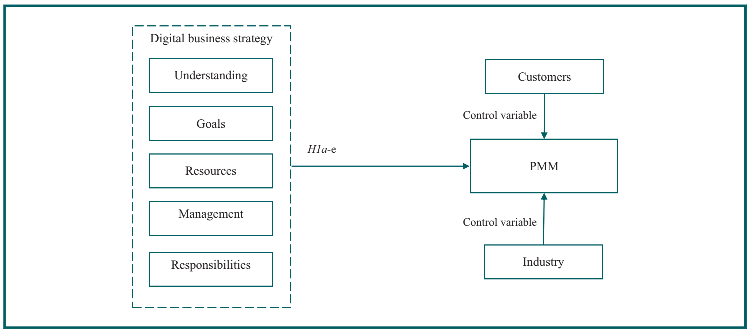
Finally, balancing and defining different responsibilities is crucial in PMM. Ukko *et al.* (2020) demonstrated that inter-organizational trust and know-how development via knowledge sharing act as relational mechanisms that facilitate the relationships governed by social interactions that drive PMM. Their study, within the digital service context, classified the criticality and personalization of services to guide exploited relational mechanisms (Ukko *et al.*, 2020). Engaging with different parties via performance-based collaboration also facilitates innovation (Nudurupati *et al.*, 2016). Other benefits from involving actors in PMM include enhanced trust and a willingness to share information and knowledge (Ukko *et al.*, 2020).

The above evidence indicates that PMM is influenced by different perspectives of digital business strategy. Digital business strategy is an essential motivator of actions and also acts as a determinant for firms to transform their processes and routines to manage performance. Next, hypotheses are developed by examining how PMM is driven by digital business strategy.

2.2 Hypothesis development

The objective of this study was to examine the effect of digital business strategy on PMM. A digital business strategy is a multidimensional entity that requires the consideration of various factors. In our study, digital business strategy consists of the subdimensions of technological understanding, goals, resources, management and responsibilities, which are identified from previous literature on management in the context of digitalization. Figure 1 shows the conceptual model and hypotheses guiding our research. The model suggests that digital business strategy offers the potential to influence PMM. Thus, in the digital business environment, a firm lacking strong emphasis on the five dimensions of digital business strategy is not necessarily capable of improving its PMM. In addition, control

Figure 1 Research model



variables are added to the research model. We propose the following hypothesis and five sub-hypotheses that are explained in more detail in the following section:

H1. Digital business strategy positively influences PMM.

Technological understanding in relation to digital business strategy describes whether a firm strives to gain a competitive edge through digital technology by recognizing the importance of such technology and by implementing projects based on it. McAdam *et al.* (2017) stated that transformations in technology challenge the connection between operations and strategy. They continued by recognizing that avoiding such misalignment requires developing dynamic capabilities built on PMM. These capabilities assist in balancing business strategy, technological strategy and technological practices (McAdam *et al.*, 2017). This is likely to transform PMM as well. Nudurupati *et al.* (2016) suggested that adopting PMM in digital economies requires firms to understand the potential of technologies in terms of creating competitive advantage via strategy. Technological developments lead to greater amounts of data, and therefore, the adoption of new easy-to-use methods facilitates decision-makers (Nudurupati *et al.*, 2016), which affects PMM. Accordingly, we hypothesize the following:

H1a. Technological understanding related to digital business strategy positively influences PMM.

Goals related to digital business strategy refer to the objectives pursued by the new strategic technologies. The importance of goal alignment that also includes the ambitions of the new PMM technologies has been highlighted in prior studies (Reinking *et al.*, 2020; Sardi *et al.*, 2020). Nudurupati *et al.* (2016) emphasized how companies need to integrate technological development expectations into their strategic and performance goals. Kamble *et al.* (2020) studied the interplay between PMM and smart manufacturing systems and found that aligning manufacturing goals with performance targets guides the adoption of new technologies. Sardi *et al.* (2020), in turn, emphasized the importance of defining and managing the entire PMM process for utilizing digital technologies and resources in line with a company's strategic goals. Thus, in line with the considerations above, the following hypothesis is proposed:

H1b. Goals related to digital business strategy positively influence PMM.

With regard to digital business strategy, resources refer to financial resources as well as the time and skills that employees need to implement digital technologies in line with the objectives. Nasiri *et al.* (2020) showed that human capabilities significantly contribute to PMM. Also, Nudurupati *et al.* (2016) found that the workforce is crucial in the digital era in terms of managing recurring inter-organizational business turbulence and related PMM transformations. Similarly, Beer and Micheli (2018) recognized that PMM should cover both the objects (e.g. cost or quality) being measured and the mechanisms that are created and used by the subjects involved in the process. Based on these, the following hypothesis is proposed:

H1c. Resources related to digital business strategy positively influence PMM.

The management of digital business strategy is considered as crucial and refers to managers' strategic capabilities, decision-making capabilities and willingness to implement changes, in addition to their experience and skills developed through technology projects (Matt *et al.*, 2015). Managerial capabilities have been highlighted as one of the main dimensions of a digital business strategy, along with launching new technologies (El Sawy *et al.*, 2016; Li *et al.*, 2018). Managerial capabilities also benefit PMM (Horváth and Szabó, 2019; Frederico *et al.*, 2020). For example, Nasiri *et al.* (2020) showed how personal capabilities, such as adaptable mind-sets and skill sets, together with digital know-how (El Sawy *et al.*, 2016), have been linked to the better utilization of PMM. This new way of using PMM enables diagnoses of digitalized processes with real-time information and reveals opportunities for improving financial performance. Horváth and Szabó (2019) suggested that an increased managerial emphasis on PMM enables increased control and permits real-time performance measurement, which in turn, promote the adoption of new technologies. Based on the notions above, managerial capabilities related to digital business strategy can influence both the adaption of new technologies and PMM by changing the culture and enabling real-time performance measurement. Thus, the following hypothesis is put forward:

H1d. Management-related aspects of digital business strategy positively influence PMM.

Responsibilities related to digital business strategy include the implementation of digital strategy functions and involve having sufficient experience in managing digital technology projects. These may require the development of joint platforms to share pertinent resources and skills to encourage shared continuous improvement activity via PMM (Nudurupati *et al.*, 2016). The way responsibilities and roles are divided between individuals and groups has a significant impact on how a company operates (Tardieu *et al.*, 2020). As distributing responsibilities in a meaningful way affects company performance, it will require changes in PMM as well. Thus, the following hypothesis is proposed:

H1e. Responsibilities related to digital business strategy positively influence PMM.

3. Research methodology

3.1 Sample and data collection

This research focuses on the connection between digital business strategy and PMM. The implications of strategic dimensions for PMM were investigated through a survey. The survey was conducted in September–October 2021. The questionnaire was sent to 5,665 companies by e-mail and was answered by 205 representatives. The responses were received in four waves. One week after the first mailing of the link, reminder messages were sent. The last two reminders were circulated a week after the previous reminder. Of the responses, 202 were considered to be valid cases, which provided a sufficient sample size. The research was limited to Finland with a focus on small and medium-sized enterprises. In total, 95.6% of the respondents were senior management, and the rest were middle management or lower-level employees. After the data collection, statistical analyses were conducted using SPSS and Excel software to test the hypotheses.

3.2 Survey measures and their validity and reliability

All the study scales were developed based on previous studies. The dependent variable was PMM. A scale was informed by previous research to reflect the impact of PMM on company operations (Child, 1973; Cardinal *et al.*, 2004; Smith and Bititci, 2017; Neely *et al.*, 1995; Bititci, 2015). It included a total of seven items, each of which was assessed with a seven-tier Likert scale (with the responses varying from totally disagree to totally agree) to find out how companies use PMM to support their businesses and operations (Chenhall, 2005). The seven items that constituted the PMM scale are presented in Table 2.

Digital business strategy, as the independent variable, was divided into five different dimensions: technological understanding, goals, resources, management and responsibilities (Table 1). All five dimensions consisted of two or three items based on recent studies (see Section 2.1.2). Technological understanding was composed of three items: the technological development of the industry, the existence of digital projects and the achievement of a competitive advantage through digital technology. The goals dimension included a company's ability to define goals related to the use of digital technologies, to monitor the achievement of such goals and to use digital technology to achieve the defined goals. The items in the resource dimension focused on dealing with

Table 1 Summary of contemporary perspectives on PMM related to digital business strategy

Perspective	*References*	*Features*
Understanding	Vallurupalli and Bose (2018), Ravelomanantsoa *et al.* (2019)	Interconnected performances Technological understanding Source of higher performance
Goals	Nudurupati *et al.* (2016), Chanias *et al.* (2019), Kamble *et al.* (2020), Reinking *et al.* (2020), Sardi *et al.* (2020)	Technological developments aligned with organizational strategic objectives Deploying strategy to lower levels Continuous review of performance measures
Resources	Nudurupati *et al.* (2016), Kamble *et al.* (2020), Ukko *et al.* (2020)	Effects beyond traditional performance dimensions (cost, quality, productivity, etc.) Behavioral factors concurrent with technical ones Human involvement
Management	Nudurupati *et al.* (2016), Seele (2016), Sahlin and Angelis (2019), Kamble *et al.* (2020), Nasiri *et al.* (2020)	Promoting behavior and collaboration Driving cultural change Transforming processes and routines Potential for decision-making
Responsibilities	Nudurupati *et al.* (2016), Ukko *et al.* (2020)	Need for personalization Subjects' engagement Trust between partners Information sharing

financial resources, human resources and employee skills related to the implementation of digital projects. The management scale included three items that assessed management's awareness of the digital technologies, its strategic capability in relation to the digital technologies and its ability to seek new opportunities through digital technologies. Finally, the responsibility scale was formed by two items that investigated the appointment and experience of the person in charge of managing digital transformation projects. Every item was assessed with a seven-tier Likert scale (with the responses varying from totally disagree to totally agree).

Control variables were used in the models to examine the effect of the variables on the results. The control variables included the customer group and industry of the respondent's company. The customer variable included two items: business-to-business and business-to-customer. The industry variable was composed of the following items: manufacturing and service. Respondents chose one of the alternatives for each of the control variables.

The survey dimensions and item reliability and validity were tested at various stages and through different analyses. First, we tested that all the constructs were unidimensional and that all the item loadings were above the minimum limit using factor analysis (Hair *et al.*, 2014). The loadings for all the items exceeded the required limit (> 0.50). In addition, the composite reliability (CR) and average variance extracted (AVE) were calculated to evaluate the validity and reliability of the construct of the model. All the AVE values were greater than the threshold (0.50), and the CR values were higher than 0.70, confirming the validity. Finally, the reliability of the variables was analyzed by calculating Cronbach's alphas. All the six dimensions had Cronbach's alpha values higher than the proposed limit (> 0.60). Thus, it can be stated that the construct of the model is reliable (De Vellis, 1991). Thus, the reliability and validity of the model construct are ensured.

Table 2 Survey dimensions and items and their validity and reliability

Dimension	*Format of the items*	*Items*	*Loadings*	*CR*	*AVE*	α
Understanding	The company considers and understands the impact of digital technology on the following (Totally disagree (1) – Totally agree (7))	1 Industry development 2 Digital projects 3 Competitive advantage	0.882 0.867 0.923	0.92	0.79	0.86
Goals	The company has set goals related to the utilization of digital technology (Totally disagree (1) – Totally agree (7))	1 Setting goals 2 Monitoring goals 3 Reaching goals	0.934 0.921 0.901	0.94	0.84	0.91
Resources	The company's resources support digital projects (Totally disagree (1) – Totally agree (7))	1 Financial resources 2 Human resources 3 Employee skills	0.880 0.873 0.757	0.88	0.70	0.79
Management	Management-related aspects related to digital technology (Totally disagree (1) – Totally agree (7))	1 Awareness 2 Capability 3 Activity	0.936 0.882 0.837	0.92	0.78	0.85
Responsibilities	Ability of person in charge of digital projects (Totally disagree (1) – Totally agree (7))	1 Appointment 2 Experience	0.903 0.903	0.90	0.82	0.77
PMM	The company utilizes PMM as follows (Totally disagree (1) – Totally agree (7))	1 To support management 2 To provide business information 3 To link measures to strategic objectives 4 To report regularly on measurement information 5 To support strategic decisions 6 To develop ideas etc. 7 To impact the activities of the staff	0.919 0.892 0.887 0.857 0.839 0.834 0.824	0.95	0.75	0.94

3.3 Bias

To address the problem of non-response bias, an analysis of variance (ANOVA) test was performed. The respondents were distributed into two groups: first respondents and late respondents. The results revealed that there was no significant difference (at the level of $p \leq 0.05$) between the two groups. Therefore, non-response bias does not have an effect.

Other sampling biases were additionally assessed to make sure that the sample was representative. The sample was randomly selected to decrease the potential of voluntary response bias. Random sampling is likely to ensure that sufficient numbers of distinct types of small- and medium-sized companies (SMEs) were included in the sample. Also, this procedure was adopted to make sure that only one response was received from each firm and respondent. As proposed by Podsakoff *et al.* (2003), several procedural remedies were utilized to decrease the influence of common method bias. The execution of the survey allowed anonymous responses, and the cover letter urged the respondents to reply to the questions as truthfully as possible. This is likely to decrease social desirability bias. Common method bias can also be minimized by the careful construction of the questions (taking into account the question wording and ease of understanding). The questions were reviewed by researchers familiar with the theme. Also, statistical remedies were performed to minimize the potential common method bias (Harman's one-factor test). All the questions utilized in the analyses were loaded into the exploratory factor analysis. The unrotated solutions factor solution did not indicate the presence of one factor or that the first factor corresponded to most of the variance (Podsakoff *et al.*, 2003). Thus, common method variance is not a problem in this case.

4. Results

The objective of this study was to examine the effect of digital business strategy on PMM. We examined digital business strategy through five dimensions: technological understanding, goals, resources, management and responsibilities. Table 3 shows the means, standard deviations and correlations of the construct.

The regression results of the relationships are shown in Table 4. The research model is significant at the $p < 0.01$ level ($R^2 = 0.27$). In the model, the goals dimension is significant at the $p < 0.05$ level, and the management dimension is significant at the $p < 0.01$ level, and thus, they positively influence PMM. Technological understanding, resources and responsibilities are insignificant. Thus, the results provide support for *H1b* and *H1d*, but not for *H1a*, *H1c* and *H1e*.

The results of the study reveal that if a company has excellent goals and management with regard to digital business strategy, it uses PMM in a more successful and effective way. A company's main industry and customer group, which acted as the control variables, did not influence the implementation of PMM.

Table 3 Correlation matrix

Dimension	*Mean*	*SD*	*1*	*2*	*3*	*4*	*5*	*6*
1 Understanding	5.84	1.25	*1*					
2 Goals	5.18	1.45	0.808**	*1*				
3 Resources	4.44	1.32	0.488**	0.656**	*1*			
4 Management	5.11	1.31	0.703**	0.761**	0.629**	1		
5 Responsibilities	4.29	1.77	0.481**	0.586**	0.579**	0.654**	1	
6 PMM	5.08	1.41	0.418**	0.467**	0.273**	0.582**	0.272**	1

Note: **Correlation is significant at the 0.01 level (two-tailed)

Table 4 Regression results

Model	*β*	*SE*	*St. β*	*R^2*	*Adj. R^2*	*SE*	*F*
Controls							
Customer group	0.217	0.186	0.078				
Industry	–0.220	0.262	–0.055				
Main effects							
Understanding	0.032	0.125	0.028				
Goals	0.294*	0.125	0.300				
Resources	–0.118	0.094	–0.111				
Management	0.406***	0.118	0.375				
Responsibilities	–0.066	0.069	–0.083				
Summary (Constant)	2.044	0.687		0.272	0.245	1.217	10.055

Notes: ***$p \leq 0.001$, **$0.001 < p \leq 0.01$, *$0.01 < p \leq 0.05$

5. Discussion

The objective of this study was to examine the effect of digital business strategy on PMM. Digital transformation has been found to be effective in terms of transforming PMM across industries (Nudurupati *et al.*, 2016; Ravelomanantsoa *et al.*, 2019; Kamble *et al.*, 2020; Nasiri *et al.*, 2020; Sardi *et al.*, 2020). Digital business strategy, in particular, is influencing PMM as it is the key to managing such transformations connecting technology and business (Bharadwaj *et al.*, 2013; Nasiri *et al.*, 2020). This study contributes to the research in the intersection of PMM and digital transformation by demonstrating that several dimensions of digital business strategy are important factors that influence PMM. The results indicate that if a company has excellent goals and management related to digital business strategy, it uses PMM in a more successful and effective way. On the other hand, understanding, resources and responsibilities related to digital business strategy do not directly influence PMM. The main findings are discussed next.

First, the study shows that management-related aspects of digital business strategy positively influence PMM. This supports the view that the ability of companies to adopt new digital technologies has become increasingly important for competitiveness, but it is not an easy task for management due to their inherent complexity and uncertainty. The results of this study also support the idea that companies should understand how digital technology tied to a strategy can create a competitive advantage and should exploit it using relevant behavioral measures (Nudurupati *et al.*, 2016). This requires new capabilities from management, as it should be aware of new technological opportunities, possess the necessary strategic and decision-making capabilities and actively lead technological change projects (Matt *et al.*, 2015; Chanias *et al.*, 2019). The study reveals that, when business leaders possess these leadership skills, they are positively reflected in PMM. According to the results, the management of digital business strategy has the greatest impact on PMM during digital transformation. This is in line with previous studies, for example, Nasiri *et al.* (2020), who showed that personal capabilities, such as adaptable mind-sets and skill sets together with digital know-how, have been linked to the better utilization of PMM. In addition, Horváth and Szabó (2019) suggested that one of the driving forces for adopting digital technologies was increased managerial emphasis on PMM that enables increased control and permits real-time performance measurement, which in turn, promote the adoption of new technologies and improve decision-making and performance appraisal. Also, Sahlin and Angelis (2019) found that PMM can serve as a useful tool for management in turbulent environments, as digitalization has facilitated much faster data access to support decision-making. Thus, the higher the level of management capabilities related to digital business strategy, the more effectively a company can leverage PMM to support its digital transformation.

Second, the study reveals that goals related to digital business strategy positively influence PMM. Thus, the study supports the notion that digital technology alone does not add much value to a company's operations without a connection to the company's strategic visions and goals. Alongside management, the importance of goal alignment in PMM has been highlighted in prior studies as well (Reinking *et al.*, 2020; Sardi *et al.*, 2020). Nudurupati *et al.* (2016) concluded that companies should integrate technological developments into their strategic and performance expectations. Sardi *et al.* (2020) highlighted the importance of defining and managing the entire PMM process for using digital technologies and resources in line with a company's strategic goals. In digital transformation, it is important to set goals and update them as and when required, which means that PMM will need continuous updates, as it has to keep up with changes in the external environment (Kamble *et al.*, 2020; Chanias *et al.*, 2019). Our research is in line with these studies, as it shows that if a company sets goals for the utilization of digital technology, monitors the achievement of these goals and strives to achieve them, it can use PMM more effectively to support digital transformation.

Finally, the results indicated no direct effect of technological understanding, resources and responsibilities with regard to digital business strategy on the way companies use PMM. This is somewhat inconsistent with previous studies, which suggest that adopting PMM in digital transformation requires understanding the potential of technologies, as well as the creation of joint platforms to share pertinent resources and skills to create competitive advantage via digital business strategy (Nudurupati *et al.*, 2016; Tardieu *et al.*, 2020). Because the impact of all the five dimensions of digital business strategy was studied in the same model, it may be that the management and goals dimensions diluted the impact of the other three. It may also be that the dimensions of technological understanding, resources and responsibilities do not have an impact without an adequate level of the management and goals dimensions. In the future, it will be interesting to explore in more detail the technological understanding, resources and responsibilities dimensions and their relation to PMM.

6. Conclusion

6.1 Theoretical contributions

The study contributes to the existing PMM literature in the context of digitalization by examining the connection between digital business strategy and PMM. It is among the first studies to examine PMM in terms of managing digital business strategy by trying to determine the extent to which the elements of digital business strategy can be integrated effectively into PMM. Specifically, the study contributes to recent literature as follow. First, it shows the influence of the specific dimensions of digital business strategy on PMM. The results explain which digital business strategy dimensions are more effective at influencing PMM. According to the results, goals and management related to digital business strategy directly influence PMM in digital transformation. Understanding, resources and responsibilities related to digital business strategy do not directly shape PMM in digital transformation. Second, this study offers a holistic framework for indicative research on digital business strategy’s influence on PMM. A better understanding of the dimensions of digital business strategy related to PMM will assist the development of a more comprehensive picture of performance management in line with digital business strategy.

6.2 Practical contributions

Digital transformation has been found to be effective in terms of transforming PMM across industries. Digital business strategy, in particular, is influencing PMM, as it is the key to managing such transformations connecting technology and business. First, this study contributes to practice by showing that management-related aspects of digital business strategy positively influence PMM. This supports the view that the ability of companies to adopt new digital technologies has become increasingly important for competitiveness, but it is not an easy task for management due to their inherent complexity and uncertainty. Thus, the study contributes to practice by highlighting the role of managers in digital transformation. The ability of management to adapt and understand new technologies and integrate them with objectives, performance metrics and decision-making is critical to digital business strategy to be effectively integrated into PMM.

Second, the study shows that if a company sets goals for the utilization of digital technology, monitors the achievement of these goals and strives to achieve them, it can use PMM more effectively to support digital transformation. Setting goals, in forming a digital business strategy, requires the company to be able to assess the significance of technology and digital transformation for its operations. Thus, to succeed in digital transformation, companies should integrate technological developments into their strategic and performance expectations, allowing PMM to serve as an effective tool to translate digital strategy to the lower levels of a company and evaluate performance against strategy.

6.3 Research limitations

This study's limitations are as follows. First, this study adopted a cross-sectional design. Future studies could use a longitudinal design to gain an in-depth assessment of the interconnections of the study variables over time. Second, the sample covers SMEs in one geographical district. Future research could collect data from specific industries, larger companies, or other geographical districts. This study did not target a specific type of PMM and instead looked at PMM in general. A more specific approach could be used in future studies to examine the types of PMM used. Different dimensions of digital business strategy may drive different types of PMM.

References

Beer, H.A. and Micheli, P. (2018), "Advancing performance measurement theory by focusing on subjects: lessons from the measurement of social value", *International Journal of Management Reviews*, Vol. 20 No. 3, pp. 755-771.

Bharadwaj, A., El Sawy, O.A., Pavlou, P.A. and Venkatraman, N. (2013), "Digital business strategy: toward a next generation of insights", *MIS Quarterly*, Vol. 37 No. 2, pp. 471-482.

Bititci, U.S. (2015), *Managing Business Performance: The Science and The Art*, John Wiley & Sons, Chichester.

Bititci, U., Garengo, P., Dörfler, V. and Nudurupati, S. (2012), "Performance measurement: challenges for tomorrow", *International Journal of Management Reviews*, Vol. 14 No. 3, pp. 305-327.

Bourne, M., Pavlov, A., Franco-Santos, M., Lucianetti, L. and Mura, M. (2013), "Generating organizational performance: the contributing effects of performance measurement and human resource management practices", *International Journal of Operations & Production Management*, Vol. 33 Nos 11/12, pp. 1599-1622.

Cardinal, L.B., Sitkin, S.B. and Long, C.P. (2004), "Balancing and rebalancing in the creation and evolution of organizational control", *Organization Science*, Vol. 15 No. 4, pp. 411-431.

Chanias, S., Myers, M.D. and Hess, T. (2019), "Digital transformation strategy making in pre-digital organizations: the case of a financial services provider", *The Journal of Strategic Information Systems*, Vol. 28 No. 1, pp. 17-33.

Chenhall, R.H. (2005), "Integrative strategic performance measurement systems, strategic alignment of manufacturing, learning and strategic outcomes: an exploratory study", *Accounting, Organizations and Society*, Vol. 30 No. 5, pp. 395-422.

Child, J. (1973), "Strategies of control and organizational behavior", *Administrative Science Quarterly*, Vol. 18 No. 1, pp. 1-17.

De Vellis, R.F. (1991), *Scale Development: Theory and Applications*, Sage, Newbury Park.

El Sawy, O.A., Kræmmergaard, P., Amsinck, H. and Vinther, A.L. (2016), "How LEGO built the foundations and enterprise capabilities for digital leadership", *MIS Quarterly Executive*, Vol. 15 No. 2, pp. 141-166.

Franco-Santos, M., Lucianetti, L. and Bourne, M. (2012), "Contemporary performance measurement systems: a review of their consequences and a framework for research", *Management Accounting Research*, Vol. 23 No. 2, pp. 79-119.

Frederico, G.F., Garza-Reyes, J.A., Kumar, A. and Kumar, V. (2020), "Performance measurement for supply chains in the industry 4.0 era: a balanced scorecard approach", *International Journal of Productivity and Performance Management*, Vol. 70 No. 4, pp. 789-807.

Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E. (2014), *Multivariate Data Analysis*, 7th ed., Pearson New International ed., Pearson Education, London.

Hall, M. (2008), "The effect of comprehensive performance measurement systems on role clarity, psychological empowerment and managerial performance", *Accounting, Organizations and Society*, Vol. 33 Nos 2/3, pp. 141-163.

Horváth, D. and Szabó, R.Z. (2019), "Driving forces and barriers of industry 4.0: do multinational and small and medium-sized companies have equal opportunities?", *Technological Forecasting and Social Change*, Vol. 146, pp. 119-132.

Ittner, C.D., Larcker, D.F. and Randall, T. (2003), "Performance implications of strategic performance measurement in financial services firms", *Accounting, Organizations and Society*, Vol. 28 Nos 7/8, pp. 715-741.

Kamble, S.S., Gunasekaran, A., Ghadge, A. and Raut, R. (2020), "A performance measurement system for industry 4.0 enabled smart manufacturing system in SMMEs-a review and empirical investigation", *International Journal of Production Economics*, Vol. 229, p. 107853.

Koufteros, X., Verghese, A.J. and Lucianetti, L. (2014), "The effect of performance measurement systems on firm performance: a cross-sectional and a longitudinal study", *Journal of Operations Management*, Vol. 32 No. 6, pp. 313-336.

Li, L., Su, F., Zhang, W. and Mao, J.Y. (2018), "Digital transformation by SME entrepreneurs: a capability perspective", *Information Systems Journal*, Vol. 28 No. 6, pp. 1129-1157.

McAdam, R., Bititci, U. and Galbraith, B. (2017), "Technology alignment and business strategy: a performance measurement and dynamic capability perspective", *International Journal of Production Research*, Vol. 55 No. 23, pp. 7168-7186.

Matt, C., Hess, T. and Benlian, A. (2015), "Digital transformation strategies", *Business & Information Systems Engineering*, Vol. 57 No. 5, pp. 339-343.

Mithas, S., Tafti, A. and Mitchell, W. (2013), "How a firm's competitive environment and digital strategic posture influence digital business strategy", *MIS Quarterly*, Vol. 37 No. 2, pp. 511-536.

Nasiri, M., Ukko, J., Saunila, M., Rantala, T. and Rantanen, H. (2020), "Digital-related capabilities and financial performance: the mediating effect of performance measurement systems", *Technology Analysis & Strategic Management*, Vol. 32 No. 12, pp. 1393-1406.

Neely, A., Gregory, M. and Platts, K. (1995), "Performance measurement system design: a literature review and research agenda", *International Journal of Operations & Production Management*, Vol. 15 No. 4, pp. 80-116.

Nudurupati, S.S., Garengo, P. and Bititci, U.S. (2020), "Impact of the changing business environment on performance measurement and management practices", *International Journal of Production Economics*, Vol. 232, p. 107942.

Nudurupati, S.S., Tebboune, S. and Hardman, J. (2016), "Contemporary performance measurement and management (PMM) in digital economies", *Production Planning & Control*, Vol. 27 No. 3, pp. 226-235.

Okwir, S., Nudurupati, S.S., Ginieis, M. and Angelis, J. (2018), "Performance measurement and management systems: a perspective from complexity theory", *International Journal of Management Reviews*, Vol. 20 No. 3, pp. 731-754.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y. and Podsakoff, N.P. (2003), "Common method biases in behavioral research: a critical review of the literature and recommended remedies", *Journal of Applied Psychology*, Vol. 88 No. 5, p. 879.

Ravelomanantsoa, M.S., Ducq, Y. and Vallespir, B. (2019), "A state of the art and comparison of approaches for performance measurement systems definition and design", *International Journal of Production Research*, Vol. 57 Nos 15/16, pp. 5026-5046.

Reinking, J., Arnold, V. and Sutton, S.G. (2020), "Synthesizing enterprise data to strategically align performance: the intentionality of strategy surrogation", *International Journal of Accounting Information Systems*, Vol. 36, p. 100444.

Sahlin, J. and Angelis, J. (2019), "Performance management systems: reviewing the rise of dynamics and digitalization", *Cogent Business & Management*, Vol. 6 No. 1, p. 1642293.

Sardi, A., Sorano, E., Cantino, V. and Garengo, P. (2020), "Big data and performance measurement research: trends, evolution and future opportunities", *Measuring Business Excellence*.

Seele, P. (2016), "Digitally unified reporting: how XBRL-based real-time transparency helps in combining integrated sustainability reporting and performance control", *Journal of Cleaner Production*, Vol. 136, pp. 65-77.

Smith, M. and Bititci, U.S. (2017), "Interplay between performance measurement and management, employee engagement and performance", *International Journal of Operations & Production Management*, Vol. 37 No. 9, pp. 1207-1228.

Tardieu, H., Daly, D., Esteban-Lauzán, J., Hall, J. and Miller, G. (2020), "Organization structure – allocating roles and responsibilities to support business strategy", *Deliberately Digital*, Springer, Cham, pp. 107-121.

Tortorella, G.L., Vergara, A.M.C., Garza-Reyes, J.A. and Sawhney, R. (2020), "Organizational learning paths based upon industry 4.0 adoption: an empirical study with Brazilian manufacturers", *International Journal of Production Economics*, Vol. 219, pp. 284-294.

Ukko, J., Saunila, M. and Rantala, T. (2020), "Connecting relational mechanisms to performance measurement in a digital service supply chain", *Production Planning & Control*, Vol. 31 Nos 2/3, pp. 233-244.

Vallurupalli, V. and Bose, I. (2018), "Business intelligence for performance measurement: a case based analysis", *Decision Support Systems*, Vol. 111, pp. 72-85.

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Publication IV

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The effects of digital business strategy on the collaboration performance of companies: the moderating effect of digitally enabled performance measurement

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The effects of digital business strategy on the collaboration performance of companies: the moderating effect of digitally enabled performance measurement

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Abstract

Purpose – Digital transformation shapes industries and influences the forms of collaboration between companies. This study aims to investigate digital business strategy as a key to facilitating collaboration beyond organizational boundaries.

Design/methodology/approach – The study focuses on the connection between digital business strategy and collaboration performance. The authors identify five types of digital business strategy elements based on the literature: development, objectives, resources, management capabilities, and digital leadership. The authors then studied the implications of these elements for collaboration performance using a survey. The study's empirical data were collected from manufacturing and service companies, and 202 valid responses were received. The implications of the research elements were tested through regression analysis, which included the moderating effects of digitally enabled performance measurement.

Findings – The theoretical research framework identifies digital business strategy as a key determinant of collaboration performance, thus advancing the understanding of how companies can utilize digital business strategies and achieve enhanced collaboration performance. The results also show that the effect of digital business strategy on collaboration performance may be moderated by digitally enabled performance management.

Practical implications – The results suggest that management capabilities associated with digital strategy are a crucial element in positively influencing collaboration performance. Further, digital strategy-related resources can be better managed with digitally enabled performance measurement system, which is reflected in improved collaborative performance. Thus, companies should invest in management capabilities and connect their digital business strategies and performance measurement systems to develop collaboration in digital transformation.

Originality/value – The study is among the first to translate an empirical understanding of the digital transformation of small and medium-sized companies into a conceptual framework of a digital business strategy.

Keywords Digital business strategy, Collaboration, Performance, Performance measurement, PM, Digitally enabled PM, Digital

Paper type Research paper

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1. Introduction

Digital technologies are reshaping how companies are doing business, their traditional business strategies and collaboration activities. As competition becomes more challenging and customer demands increase, companies increasingly feel the urge to become more digital, thus modifying their value propositions and business operations (Holopainen *et al.*, 2023a). This change brought about by digital technologies is described as digital transformation, which is a multifaceted phenomenon that includes the development of new digital offerings and the reinforcement of an organization's identity (Wessel *et al.*, 2021; Tekic and Koroteev, 2019; Hess *et al.*, 2016). It may also require new types of capabilities and resources that can be managed and enhanced through close internal and external collaboration in companies (Liu *et al.*, 2022; Konopik *et al.*, 2022; Holopainen *et al.*, 2022). Digital transformation also requires that companies reexamine their partnership strategy and business ecosystem (Sousa-Zomer *et al.*, 2020), which leads to the development of new collaborative organization networks in which companies choose the right partners to cope with digital transformation (Senyo *et al.*, 2019; Kane *et al.*, 2017).

To succeed in the digital environment, companies need a new kind of strategic approach (Holopainen *et al.*, 2022; Matt *et al.*, 2015) and are expected to define a specific digital business strategy for themselves by integrating IT strategy with business strategy to create novel value by utilizing digital resources (Bharadwaj *et al.*, 2013; Holotiuk and Beimborn, 2017; Yeow *et al.*, 2018). The digital business strategy has been called transfunctional, crossing the organization's traditional functional areas and business processes as well as boundaries outside the company (Bharadwaj *et al.*, 2013; Matt *et al.*, 2015; Yeow *et al.*, 2018) and emphasizing collaboration to achieve a competitive advantage. However, digital business strategy and its effects on performance have only been partially studied (Bharadwaj *et al.*, 2013; Ukko *et al.*, 2019; Wang *et al.*, 2020), leaving an apparent research gap regarding its effects on collaboration performance.

Further, a performance measurement (PM) of inter-organizational collaboration is important when evaluating the functionality of collaboration and digital initiatives (Büyüközkan and Göçer, 2018). According to Nudurupati *et al.* (2016), organizations should reexamine their measurement efforts so that their performance evaluations can be expanded in a wider network involving several different stakeholders. In addition, studies have shown that digital technologies can offer new solutions for implementing PM systems (Korsen and Ingvaldsen, 2022; Reinking *et al.*, 2020; Robert *et al.*, 2022; Sardi *et al.*, 2020). PM system combined with digital technologies enables real-time monitoring and the continuous evaluation of results to support adaptation in an ever-changing digital environment (Chanias *et al.*, 2019; Holopainen *et al.*, 2023b; Kamble *et al.*, 2020). PM also has the potential to support inter-company collaboration in the digital era, acting as a system of systems (Bourne *et al.*, 2018; Sardi *et al.*, 2020). However, there is a research gap in how digitally enabled PM can support the company's strategic operations. Thus, we studied how digitally enabled PM can serve as an excellent tool for facilitating the management of digital business strategies and thus enhancing collaboration performance.

We used a survey to examine the described research problem among Finnish manufacturing and service companies during 2021. The following research questions were proposed to answer the described research gaps: (1) Do digital business strategies positively affect collaboration performance? (2) How does digitally enabled PM positively moderate the relationship between digital business strategy and collaboration? More specifically, based on the literature, the study identifies five types of digital business strategy elements—development, objectives, resources, management capabilities and digital leadership—and elaborates on how these elements can affect collaboration performance and how the capability of digitally enabled PM can promote these effects. The results of the study show that management capabilities have a positive effect on successful collaboration. Further, a digital business strategy through the resources dimension enhances the collaboration performance between the company and its parties if the company uses digitally enabled PM effectively.

Although previous research has revealed the effect of digital business strategies on firm performance (Bharadwaj *et al.*, 2013; Ukko *et al.*, 2019; Wang *et al.*, 2020), little is understood about their connection with collaboration performance. Thus, this study theoretically contributes through a theoretical research framework that identifies digital business strategy as a key determinant of collaboration performance, thus advancing the understanding of how small and medium-sized companies (SMEs) can utilize digital business strategies and achieve enhanced collaboration performance. The study is also the first to offer empirically grounded evidence of the role of digitally enabled PM (e.g. Korsen and Ingvaldsen, 2022) in the association between digital business strategy and collaboration performance. Notably, this study translates an empirical understanding of SMEs' digital transformation into a conceptual framework of a digital business strategy. Although the literature emphasizes the essential elements of SMEs' strategic digital transformation (Bharadwaj *et al.*, 2013; Cennamo *et al.*, 2020; Holopainen *et al.*, 2022; Mithas *et al.*, 2013; Matt *et al.*, 2015), how these elements can be differentiated has not been thoroughly examined. Thus, the results of this study contribute to the literature on digital transformation, which seeks to resolve the format through which digital business strategy impacts collaboration (cf. Chi *et al.*, 2018; Matt *et al.*, 2015; Tekic and Koroteev, 2019). Further, this study proposes practical implications, suggesting that companies should invest in management capabilities and connect their digital business strategies and PM systems to strive for better collaboration performance in digital transformation.

The rest of the paper consists of the following sections. Section 2 reviews the relevant literature on the strategic approach to digital transformation and its implications for collaboration, followed by the development of the hypotheses and theoretical research framework. Section 3 describes the research methodology, and Section 4 presents the results. Section 5 discusses the results, while Section 6 presents the study's conclusion, theoretical and practical implications, limitations and suggestions for future studies.

2. Theoretical background

2.1 Strategic approach to digital transformation

Digital transformation refers to the change that occurs as a result of the utilization of digital technologies (Gong and Ribiere, 2021; Legner *et al.*, 2017), in which novel digital technologies shape strategy and operations via industries (Li, 2020). The utilization of digital technologies is a versatile phenomenon (Tekic and Koroteev, 2019), allowing the development of advanced and completely new services and products while affecting the company's culture, organizational structures, processes, capabilities and business models all the way to strategy and vision (Nadkarni and Prügl, 2021; Gurbaxani and Dunkle, 2019). The utilization of emerging digital technologies (e.g. mobile technology, analytics and social media) has also been reported to promote major business improvements, such as increasing the efficiency of operations, creating business models and advancing customer experience (Tekic and Koroteev, 2019; Fitzgerald *et al.*, 2014). Previous studies suggest that emerging digital technology cannot by itself create significant added value for the operations of a company if it is not integrated into the strategic-level visions and goals of the company (Lipsmeier *et al.*, 2020; Tabrizi *et al.*, 2019; Davenport and Westerman, 2018; Kane *et al.*, 2017). For example, according to Yeow *et al.* (2018) and Hess *et al.* (2016), digital business strategy is not isolated but must be connected to the company's strategy and other functional and operational strategies.

A digital business strategy has also been described as a continuous process, including doing and learning, implemented using digital resources to create novel value (Chanias *et al.*, 2019). As presented above, a digital business strategy consists of the desire to develop with the assistance of digital technologies, resources, capabilities and goals that are connected to the company's strategic objectives. Many studies have also highlighted management and leadership capabilities as crucial aspects of digital business strategies (Li, 2020; Nasiri *et al.*, 2020; Li *et al.*, 2018; El Sawy *et al.*, 2016). Matt *et al.* (2015) referred especially to the skills and experience developed by managers through technology projects, as well as their willingness to change, decision-making capabilities and strategic capabilities. These notions indicate that the promotion of a company's operations with emerging technologies is a matter of a strategic level, which significantly affects products, services, sales channels and supply chains, as well as other related business processes, all the way beyond the company's borders (Matt *et al.*, 2015; Horlach *et al.*, 2017).

2.2 Implications of digital technologies for collaboration

Digital technology often has major implications, especially for collaboration between companies (Holopainen *et al.*, 2023a; Jovanovic *et al.*, 2022; Suuronen *et al.*, 2022). These implications have been shown for various business areas, extending beyond the company's borders and affecting products, services, sales channels and supply chains (Horlach *et al.*, 2017; Matt *et al.*, 2015). Digital technologies implemented across an organization provide both internal and external stakeholders with a series of tools to enhance knowledge availability and capture (Silva *et al.*, 2021). More than a conveyer of resources, digital technology focuses on the provision of information as a type of sharing platform (Saunila *et al.*, 2022; Tao *et al.*, 2020). Digital platforms are considered one of the most relevant applications of digital technology when striving for value through collaboration (Jovanovic *et al.*, 2022; Reim *et al.*, 2023). Reim *et al.* (2023) indicated that digital platforms affect almost all industries now and in the future, revolutionizing value creation. Jovanovic *et al.* (2022) suggested that some companies utilize digital technologies to launch platforms (e.g. Airbnb, Netflix, Uber and Spotify), whereas machine manufacturers, for example, utilize them to collaboratively extend the platform value with their technology providers, suppliers, customers and rivals (e.g. BMW, Komatsu and Volvo) (Adner *et al.*, 2020; Cennamo *et al.*, 2020). Jovanovic *et al.* (2022) and Sjödin *et al.* (2020) defined digital industrial platforms as large-scale transformations that encompass the offerings, capabilities and processes of industrial companies and the related ecosystems for progressively capturing, delivering and creating multiple value for customers, resulting from a wide range of enabling digital technologies.

As indicated by these previous studies, companies should create a digital business strategy that combines the company's vision and existing strategies with technological guidelines to achieve value (Matt *et al.*, 2015; Chanias *et al.*, 2019). The increase in inter-organizational collaboration has been presented as a significant benefit that can be achieved with digital technologies because it simultaneously enables the strategic readiness of all partners to upgrade to digital operations (Holopainen *et al.*, 2022; Suuronen *et al.*, 2022). However, Reim *et al.* (2023) indicated that although collaboration is needed to successfully manage digital platforms, challenges arise, especially in the manufacturing industry, due to the need for large investments and the sharing of sensitive data. This indicates that the utilization of digital technologies in accordance with the digital business strategy must also be able to be measured and managed. For example, Jovanovic *et al.* (2022) stressed the need for collaboration platform management, measurement and governance at every stage of industrial digital platform development to expand the value of the platform through monitoring, optimization and independent service development. Korsen and Ingvaldsen (2022) suggested that the creative use of technologies (big data, IoT, etc.) should be implemented in the existing PM frameworks of organizations.

Several other studies have also suggested that the implementation of digital technologies, such as IoT and big data, affects PM and should therefore be connected to it (Bhimani, 2020; Ravelomanantsoa *et al.*, 2019; Nudurupati *et al.*, 2016, 2021). Bredmar (2017) showed the need for concepts that integrate digital technologies (e.g. IoT and big data) with organizational challenges, especially organizational control, such as PM. Aheleroff *et al.* (2021) showed that digital technologies, such as dashboards using IoT, combined with PM and data, enable strategy implementation through remote monitoring, forecasting and management of real-time. All of these elements can be connected to PM, providing considerable development potential for organizational and inter-organizational agility and performance via real-time data-driven intelligence and fast decisions (Parmar *et al.*, 2020; Min *et al.*, 2019; Oh and Jeong, 2019; Wesche and Sonderegger, 2019). In summary, to fully exploit digital technologies in the development and improvement of collaboration, a company must have a digital business strategy connected to the PM of the company.

2.3 Hypothesis development

2.3.1 Digital business strategy, its elements and effects on collaboration performance. Digital technology, considered a strategic issue, has a huge influence beyond organizational borders by affecting business processes, supply chains, sales channels, etc. (Kraus *et al.*, 2021; Tortorella *et al.*, 2020; Matt *et al.*, 2015). It transforms existing operations to build links with the surrounding environment and opportunities for collaboration (Tekic and Koroteev, 2019). Horlach *et al.* (2017) suggested that digitalization changes the communication channels, sales and product/service offerings of companies, all of which have an impact on organizations' functions, including new ways of customer collaboration (Matt *et al.*, 2015). For example, Bharadwaj *et al.* (2013) proposed that digital business strategies have enabled the democratization of business-related content shared by companies in digitalizing business environments and on distinct digital platforms. Thus, companies can utilize digital business strategies to grow business and sales by offering customers more variation in their offerings (Holopainen *et al.*, 2023a; Grover and Kohli, 2013). Bharadwaj *et al.* (2013) also suggested that companies using digital business strategies can revise their operations and offerings based on customer preferences. By allowing customers to choose and customize their purchases, digital business strategies can advance product launches (Bharadwaj *et al.*, 2013).

When the adoption of digital technology becomes a strategic issue—that is, followed by a digital business strategy—it enables quick adaptation through collaboration that crosses company boundaries (Holotiuk and Beimborn, 2017). Digital collaboration promotes the influence of digital business strategies on performance (Chi *et al.*, 2018). Therefore, this study proposes that a digital business strategy is key to facilitating collaboration beyond organizational boundaries. Thus, the following hypotheses were set:

H1. A digital business strategy positively affects collaboration performance. Hence,

H1a. Development, relative to digital business strategy, positively affects collaboration.

H1b. Objectives, relative to digital business strategy, positively affect collaboration.

H1c. Resources, relative to digital business strategy, positively affect collaboration.

H1d. Management capability, relative to digital business strategy, positively affects collaboration.

H1e. Digital leadership, relative to digital business strategy, positively affects collaboration.

2.3.2 Digitally enabled PM as a moderator. Implementing digitality in business requires that skills must be developed to deal with digital tools and to have digital mind-sets, as well as to be ready to move toward digitality (Wessel *et al.*, 2021; Gong and Ribiere, 2021; Kache and Seuring, 2017; El Sawy *et al.*, 2016). The development of the technology is vital to exploit it with the aim of boosting decision-making (Nudurupati *et al.*, 2016; Parida *et al.*, 2015;

Srivastava and Shainesh, 2015). Therefore, development, objectives, resources, management and leadership rank among the most important elements of digital business strategy; however, applied inappropriately any of these elements causes challenges in operating in the digital business era (Kache and Seuring, 2017). Simultaneously, digital technologies authorize the prediction, control and remote monitoring of strategy implementation, utilizing different types of data, IoT-enabled dashboards and real-time performance measures (Aheleroff *et al.*, 2021). All of these elements are facilitated by PM and offer the possibility of improving organizational agility through real-time data-based intelligent decisions (Holopainen *et al.*, 2022; Parmar *et al.*, 2020; Min *et al.*, 2019; Oh and Jeong, 2019; Wesche and Sonderegger, 2019). Bredmar (2017) suggested that some new data analytical PM systems could even alter goals and targets as the organization learns and has new experiences (Bredmar, 2017). Thus, to manage a digital business strategy, companies require measures of performance (Reinking *et al.*, 2020; Nasiri *et al.*, 2020; Bharadwaj *et al.*, 2013), because digitally enabled PM can allow deeper analysis (Korsen and Ingvaldsen, 2022; Sardi *et al.*, 2020; Nudurupati *et al.*, 2016) to attain collaboration performance.

Based on this background, we propose that digitally enabled PM becomes effective in boosting digital business strategy implementation and eventually facilitating collaboration performance. We therefore expect the liaison between digital business strategy, together with its elements and collaboration performance to be moderated by digitally enabled PM. Thus, we hypothesize:

H2. Digitally enabled PM positively moderates the relationship between digital business strategy and collaboration. Hence,

H2a. Digitally enabled PM positively moderates the relationship between development relative to digital business strategy and collaboration.

H2b. Digitally enabled PM positively moderates the relationship between objectives relative to digital business strategy and collaboration.

H2c. Digitally enabled PM positively moderates the relationship between resources relative to digital business strategy and collaboration.

H2d. Digitally enabled PM positively moderates the relationship between management capability relative to digital business strategy and collaboration.

H2e. Digitally enabled PM positively moderates the relationship between digital leadership relative to digital business strategy and collaboration.

2.4 Theoretical research framework: digitally enabled PM in facilitating the implications of elements of digital business strategy

This study focuses on five types of digital business strategy elements and their effects on the performance of collaboration between companies. Companies formulate, implement and develop a digital business strategy with the aim of improving their business performance (Kraus *et al.*, 2021; Li, 2020; Verhoef *et al.*, 2021; Bharadwaj *et al.*, 2013; Mithas *et al.*, 2013). This new kind of strategic approach requires companies to focus on novel kinds of capabilities and ways of operating (Holopainen *et al.*, 2022; Nasiri *et al.*, 2020). When forming a digital business strategy, different factors should be taken into account. Based on previous literature, we identify these elements as follows: development, goals, resources, management capabilities and digital leadership (Table 1). Further, studies have shown that digital transformation has resulted in the development of new collaborative organizational networks (Senyo *et al.*, 2019). Companies must be able to manage the operation of this collaboration, for which digitally enabled PM has been found to be the appropriate tool (Robert *et al.*, 2022; Reinking *et al.*, 2020; Nudurupati *et al.*, 2016).

Information	Categories	No.	%
The turnover of the company	Small (0–2 million)	18	8.8%
	Medium (2–10 million)	139	67.8%
	Large (>10 million)	48	23.4%
	No response	0	
The main industry of the company	Service	106	51.7%
	Manufacturing	97	47.3%
	No response	2	1.0%
The company's main customer group	B2B (business-to-business)	172	83.9%
	B2C (business-to-customer)	28	13.7%
	No response	5	2.4%

Source(s): Authors' own work

Table 1.
Respondents' information

Thus, this study focuses specifically on the influence of these five elements on collaboration performance and the capability of digitally enabled PM to promote these effects. The theoretical research framework is shown in Figure 1.

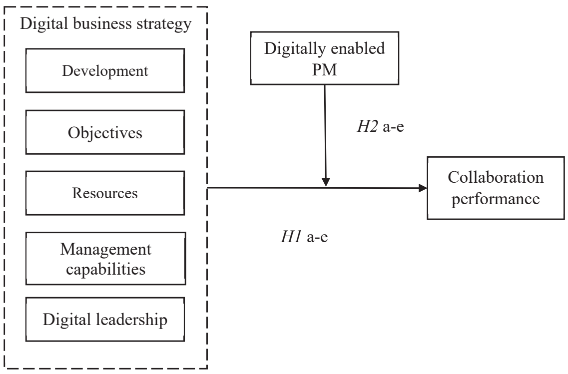
3. Methodology

3.1 Data collection and sample description

The research data were collected using a survey conducted in September and October 2021. The survey was sent to 5,665 manufacturing and service companies in Finland. The survey was sent in four waves. Initially, randomly selected companies were sent an email with a link to the survey; thereafter, reminder messages were sent weekly for 3 weeks to enable a sufficient sample size. Overall, 205 companies responded, of which 202 were valid. Of these respondents, 96% worked in the top management of the company, and the rest in lower-level positions. The respondents' detailed information is described in Table 1.

3.2 Survey instruments

The research focused on digital business strategy and its effects on collaboration performance. The instruments of the study were built based on previous literature, as



Source(s): Authors' own work

Figure 1.
Theoretical research framework

presented in Table 2. The independent variable was digital business strategy, which included five elements (development, objectives, resources, management capabilities and digital leadership). These five elements contained two to three items each and were measured using a 1–7-point scale. The dependent variable was collaboration performance measured using a 1–4 point scale, and the moderator was digitally enabled PM measured using a 1–7 scale. Both contained only one item to assess the element, and control variables were used to evaluate their effects on the results. These included the company's turnover (small, medium and large), the company's industry (service and manufacturing) and the company's customer groups (B2B and B2C) (see Table 1).

Elements		Description of the items	References
Assessment of the argument on a scale of 1–7 points			
Development	1	Our company has recognized the importance of digital technology in relation to the development of industry	Konopik *et al.* (2022), Sousa-Zomer *et al.* (2020), Vial (2019), Kane *et al.* (2017)
	2	Our company has ongoing projects related to digital technology	
	3	Our company strives to achieve a competitive advantage with the help of digital technologies	
Objectives	1	Our company has defined objectives related to the utilization of digital technology	Reinking *et al.* (2020), Tabrizi *et al.* (2019), Chanias *et al.* (2019), Nudurupati *et al.* (2016)
	2	Our company follows the realization of the objectives defined for digital technologies	
	3	Our company has the ability to utilize digital technology in achieving strategic objectives	
Resources	1	Our company has the financial resources to make digital technology investments	Holopainen *et al.* (2022), Sousa-Zomer *et al.* (2020), Mittal *et al.* (2018), Matt *et al.* (2015)
	2	Our company's employees have time to implement digital technology projects	
	3	Our company's employees have the know-how to implement digital technology projects	
Management capabilities	1	The management of our company is aware of and follows the changes brought about by digital technology in the industry	Konopik *et al.* (2022), Holopainen *et al.* (2022), Li (2020), Nasiri *et al.* (2020), Sousa-Zomer *et al.* (2020)
	2	Our company's management has the ability to form a digital strategy	
	3	The management of our company is actively looking for opportunities brought by digital technology	
Digital leadership	1	Our company has appointed a person who is responsible for implementing digital strategic activities	Vial (2019), Chanias *et al.* (2019), Matt *et al.* (2015)
	2	In our company, the responsible persons have the knowledge, skills and experience to manage projects related to digital technology	
Digitally enabled PM	1	Our company's performance measurement is combined with our company's digital strategy/ digital operations	Reinking *et al.* (2020), Bhimani (2020), Kamble *et al.* (2020), Nudurupati *et al.* (2016)
Assessment of the argument on a scale of 1–4 points			
Collaboration performance	1	Over the last three years, how do you assess your company in terms of collaboration with external parties?	Konopik *et al.* (2022), Reim *et al.* (2023), Senyo *et al.* (2019), Büyüközkan and Göçer (2018), Kane *et al.* (2017)

Source(s): Authors' own work

Table 2. The research elements, items and references to the literature

3.3 Testing the validity, reliability and bias of the study

We verified the reliability and validity of the results using various tests (in Table 3). First, a factor analysis was conducted to ensure that the constructs were unidimensional and that the loadings of each item exceeded the critical limit of greater than 0.50 (Hair *et al.*, 2014). Second, utilizing the results of these tests, the average variance extracted (AVE) and composite reliability (CR) were calculated to ensure the validity and reliability of the construct. The results of the calculations exceeded the limit values (AVE >0.50 and CR > 0.70) determined in the literature (Hair *et al.*, 2014; Fornell and Larcker, 1981), thus guaranteeing the validity and reliability of the study structure. Third, a reliability analysis of the instruments was performed. We confirmed the instruments' reliability by calculating Cronbach's alpha values, which were higher than the proposed limit (0.70) (Taber, 2018). These tests were performed to guarantee the validity and reliability of the instruments and constructs resulting from the calculations.

Fourth, an analysis of variance (ANOVA) test was executed to solve the problem of non-response bias. The test was performed by dividing the respondents into early and late respondents and comparing the p-values of these groups. With this, no significant deviation in the values was found. Differences between groups were at the level of $p \leq 0.05$, so the outcomes of the test showed that there was no problem with non-response bias. Fifth, Harman's single-factor test was performed to check common method variance. Based on this analysis, all items loaded on more than one factor; however, the first factor explained 51.56% of the variance. According to Podsakoff and Organ (1986), common method bias is a possible and well-known problem when the same respondents answer the entire survey. Thus, other methods can also be used to reduce common method bias: the survey was answered anonymously, reducing the social desirability problem, the research questions were carefully formulated, ensuring their clarity and the research sample was chosen randomly (Podsakoff *et al.*, 2003). Thus, the results of these statistical tests and other methods confirmed that the effects of research bias were minimized and ensured.

4. Analysis and results

The correlation analysis of the study is presented in Table 4, which shows the mean and standard deviation of the study's items. The results showed that the mean of the responses was the highest in the development element and the lowest in the digital leadership element, considering only items on a scale of 1–7 points.

Elements	Loadings	α	AVE	CR
Understanding	0.882	0.86	0.79	0.92
	0.867			
	0.923			
Goals	0.934	0.91	0.84	0.94
	0.921			
	0.901			
Resources	0.880	0.79	0.70	0.88
	0.873			
	0.757			
Management	0.936	0.85	0.78	0.92
	0.882			
	0.837			
Responsibilities	0.903	0.77	0.82	0.90
	0.903			

Source(s): Authors' own work

Table 3.
Structural validity and reliability calculations

The hypotheses were tested through regression analysis, and the results of the analysis are presented in Table 5. In the main effects model, digital business strategy through management capability had a statistically significant and positive effect on collaboration performance. By contrast, development had a statistically significant but negative influence on collaboration performance. No significant effect was found for the other elements. Thus, H1d was supported, but H1a, H1b, H1c and H1e were not supported.

Elements	Mean	St. Dev	1	2	3	4	5	6	7
1 Development	5.85	1.23	*1*						
2 Objectives	5.19	1.44	0.808**	*1*					
3 Resources	4.44	1.31	0.488**	0.656**	*1*				
4 Management capability	5.11	1.29	0.703**	0.761**	0.629**	1			
5 Digital leadership	4.27	1.76	0.481**	0.586**	0.579**	0.654**	1		
6 Digitally enabled PM	4.41	1.69	0.495**	0.574**	0.342**	0.552**	0.387**	1	
7 Collaboration performance	2.76	0.67	0.022	0.115	0.090	0.167*	0.080	0.100	1

Note(s): **Significant at the 0.01 level (2-tailed); *Significant at the 0.05 level (2-tailed)
Source(s): Authors' own work

Table 4. Correlations of the digital business strategy and its elements, digitally enabled PM and collaboration

Variables	Main effects model β	St. β	*t*	Full model β	St. β	*t*
Controls						
Company's industry	−0.093	−0.070	−0.881	−0.041	−0.031	−0.393
Company size	0.034	0.028	0.368	0.038	0.031	0.421
Company's customer	0.029	0.015	0.202	0.069	0.036	0.491
Main effects						
Development	−0.161*	−0.288	−2.311	−0.212	−0.378	−1.260
Objectives	0.077	0.164	1.068	0.076	0.162	0.473
Resources	−0.022	−0.043	−0.426	−0.295	−0.572	−2.259
Management capability	0.139*	0.264	2.065	−0.015	−0.029	−0.089
Digital leadership	−0.028	−0.073	−0.737	0.351	0.914	2.954
Digitally enabled PM	0.024	0.059	0.642	−0.147	−0.363	−1.146
Interaction effects						
Development Digitally enabled PM				0.024	0.448	0.647
Objectives Digitally enabled PM				0.002	0.034	0.051
Resources Digitally enabled PM				0.055*	0.859	2.010
Management capability Digitally enabled PM				0.018	0.323	0.478
Digital leadership Digitally enabled PM				−0.076***	−1.359	−3.411
Model summary						
F	1.385			2.114*		
R^2		0.064			0.143	
Adjusted R^2		0.018			0.075	

Note(s): ***$p \leq 0.001$, ** $0.001 < p \leq 0.01$, * $0.01 < p \leq 0.05$
Source(s): Authors' own work

Table 5. The results of the regression analysis

The second regression test analyzed the moderating effect of digitally enabled PM. The results indicated that digital business strategy through the resources element enhanced the collaboration performance between the company and its parties if the company used digitally enabled PM effectively, thus supporting H2c. However, the results also demonstrated that digitally enabled PM moderated a significant but negative effect between the company's digital business strategy through digital leadership and collaboration performance. Other significant results were not detected. Thus, Hypothesis 2 was partly supported (H2c) and partly not supported (H2a, H2b, H2d, H2e). Lastly, the control variables were found to have no effect on either model.

5. Discussion

Digital transformation is shaping industry, influencing the forms of collaboration between companies (Jovanovic *et al.*, 2022; Li, 2020; Silva *et al.*, 2021; Suuronen *et al.*, 2022). The findings of this study contribute to previous research on digital transformation that seeks to resolve the format through which digital business strategy impacts collaboration (cf. Chi *et al.*, 2018; Matt *et al.*, 2015; Tekic and Koroteev, 2019). We investigated whether a digital business strategy is key to facilitating collaboration beyond organizational boundaries in different industries. The results elucidated some interesting findings. Next, the key findings of the main effect model are presented.

First, the results showed that management capabilities, as an element of digital business strategy, had a positive effect on collaboration performance. This is in line with previous studies that have highlighted management capabilities as crucial aspects of digital business strategy (Matt *et al.*, 2015; El Sawy *et al.*, 2016; Li, 2020; Nasiri *et al.*, 2020). Managers with digital skills and experience are likely to be better equipped to carry out the continuous renewal required by the digital age (Sousa-Zomer *et al.*, 2020). The study contributes to previous research by highlighting an important role for management capabilities in the success of collaboration performance. Managers are required to have new capabilities, be aware of and follow the changes brought about by digital technology in the industry, and thus integrate these technological expectations into strategic objectives (Holopainen *et al.*, 2022; Nasiri *et al.*, 2020; Li, 2020; Nudurupati *et al.*, 2016).

Second, the results revealed that the development element of digital business strategy negatively influences collaboration performance. These results contradict the existing literature (Konopik *et al.*, 2022; Sousa-Zomer *et al.*, 2020), which has suggested that developing digital transformation capabilities might reflect positively on a company's performance. For example, Sousa-Zomer *et al.* (2020) noted that companies creating performance improvement through digitality invest heavily in increasing digital intensity through digital partnerships, technology-based acquisitions and investments. However, digital transformation often creates industry-specific difficulties for companies that challenge managers to achieve performance impacts (Li, 2020; Nadkarni and Prügl, 2021; Tabrizi *et al.*, 2019). The study findings support Reim *et al.*'s (2023) view that the utilization of digital platforms in industrial cooperation can be challenging due to large investments and the sharing of sensitive data. In contrast to the original hypothesis, our results demonstrated that if the company's internal development capabilities and operations are well developed, it can be reflected in an imbalance of collaboration between companies, and thus weaken the collaboration performance. This is a new perspective and is in line with a previous study that emphasized the importance of collaboration in concurrently improving the strategic readiness of partners and customers for digital operations (Holopainen *et al.*, 2022). Thus, the study contributes to previous research arguing that if the digital leap is unbalanced between partners, it can have a negative effect on collaboration performance.

Digital transformation influences methods of collaboration and their management (Li, 2020; Büyüközkan and Göçer, 2018). Senyo *et al.* (2019) stated that it was important to consider the strategic direction of digital platforms for the benefit of all participants. Jovanovic *et al.* (2022) stressed the need for collaboration platform management, measurement and governance at every stage of industrial digital platform development. The study assessed whether digitally enabled PM can act as a promoter to foster the liaison between a digital business strategy—along with its elements—and collaboration performance. In what follows, we discuss the key findings from the full model of the study.

First, the results indicated that a digital business strategy through the resources dimension enhanced the collaboration performance between the company and its parties if the company used digitally enabled PM effectively. This is in line with Nudurupati *et al.* (2016), who stated that performance evaluation can be expanded to the network level, taking into account the importance of digital technologies in creating a competitive advantage combined with strategy, and leading these with appropriate and behavioral measures. Further, digital technologies, such as dashboards using IoT, combined with PM and data, enable strategy implementation through remote monitoring, forecasting and management of real-time data (Aheleroff *et al.*, 2021; Reinking *et al.*, 2020; Kamble *et al.*, 2020; Chanias *et al.*, 2019). The study agrees with previous studies that companies should integrate digital technologies into their PM systems to achieve performance effects (Aheleroff *et al.*, 2021; Korsen and Ingvaldsen, 2022; Nudurupati *et al.*, 2016; Reinking *et al.*, 2020). However, the study contributes to the literature by suggesting that with digitally enabled PM, the resources related to digital strategy are better managed, which is reflected in improved collaboration performance.

Second, the results demonstrated that digitally enabled PM moderated a significant but negative influence on the relationship between digital leadership and collaboration performance. The previous literature emphasizes the creation of new leadership roles (Vial, 2019; Chanias *et al.*, 2019; Matt *et al.*, 2015). According to Vial (2019), hiring a chief digital officer to communicate the strategic nature of digital transformation to the organization can ensure continuing the task of maintaining the proper utilization of digital technology and its alignment with strategic goals. However, contrary to the original hypothesis, the results show that digitally enabled PM can be perceived as too controlling, negatively affecting collaboration performance. The challenges of collaboration have also been noted in previous studies (e.g. Holopainen *et al.*, 2022; Reim *et al.*, 2023). Thus, this study is in line with Nudurupati *et al.* (2021) and contributes to the literature emphasizing the need to move away from command and control to more empowering management, including the participatory use of PM to achieve better collaboration performance.

Lastly, the results showed that digitally enabled PM did not enhance the effects of other elements (development, objectives and management capabilities) of the digital business strategy on collaboration performance. This contradicts previous research, which concluded that PM has the potential to support inter-company collaboration in a digital era, acting as a system of systems (Bourne *et al.*, 2018; Sardi *et al.*, 2020). The results may reflect the assumption that although digital development is taking place in companies, goals and measures have not necessarily been set from the perspective of collaboration. This may be reflected in the finding that the effects of the development element on collaboration performance remained invisible in the entire model of this study.

According to Robert *et al.* (2022), going digital allows companies to collect real-time PM information through transparent indicators across the supply chain, and to utilize the gathered information to enhance operations, and offerings through instant feedback. The study showed that if no goals or measures have been set for collaboration, the effects of the objective element on collaboration performance are not concretized. According to Tabrizi *et al.* (2019), managers often have a certain digital technology or tool selected in their minds, although digital transformation should be directed by a broader business strategy and should define concrete goals before making any investments. Finally, from the perspective of management, managing digital strategy and collaboration performance is a new and difficult entity for managers to handle (Li, 2020; Fitzgerald *et al.*, 2014), requiring a new kind of expertise and understanding. According to Li (2020), digital transformation requires new management skills related to the ability to manage novel digital technologies, strategies and operating models in order to achieve performance growth. Together, these findings show that managers do not know how to connect these topics to their PM systems to support the improvement of collaboration performance. Thus, the study contributes to practice by suggesting that companies should invest in management capabilities and connect their digital business strategies and PM systems to develop collaboration in digital transformation.

6. Conclusion

6.1 Theoretical implications

This study provides the consequent theoretical implications for the literature. First, the theoretical research framework identifies digital business strategy as a key determinant of collaboration performance, thus advancing the understanding of how SMEs can utilize digital business strategies and achieve enhanced collaboration performance. The empirically grounded validation of the theoretical research framework contributes to the stream of research on strategic change; therefore, this study departs from previous research that principally provides conceptual evidence of the implications of digital business strategies.

Second, the results show that the effects of digital business strategies and their elements on collaboration performance may be moderated by digitally enabled PM. To our understanding, the current research is the first to offer empirically grounded evidence of the role of digitally enabled PM in the association between digital business strategy and collaboration performance.

Third, the study identifies five types of digital business strategy elements: development, objectives, resources, management capabilities and digital leadership. It is among the first to translate an empirical understanding of SMEs' digital transformation into a conceptual framework of a digital business strategy. Although prior research has emphasized the essential elements of SMEs' strategic digital transformation, how these elements can be differentiated has not been thoroughly examined before.

6.2 Practical implications

The study also suggests a number of implications from a practical perspective. To facilitate collaboration performance through digital business strategy, companies must invest in their practical knowledge of the development of digital technologies and their ability to create digital strategies and look for new opportunities with the help of digital technologies. This can mean, for example, as versatile training and motivation as possible that companies offer to their managers and employees at different levels. Although the development element of the digital business strategy was considered to hinder collaboration performance, it may be possible to compensate for this by developing companies' capabilities. Thus, through advanced capabilities, a company can better identify the possibilities of utilizing digital technologies, the competitive advantage that can be achieved, and, eventually, choose the most suitable projects that utilize digital technologies. In this way, the development element of digital business strategy becomes a driver instead of a hindrance when aiming for higher collaboration performance.

Further, to achieve higher collaboration performance, companies must ensure that digitally enabled PM is connected to the use of a variety of digital technology-related resources. This is because financial resources for investments in digital technologies and, importantly, the time and know-how to implement them are resources whose impact on collaboration performance can be improved when they are connected to digitally enabled PM. However, digitally enabled PM should not be too detailed or linked to monitoring the individual activities of persons responsible for introducing and experimenting with digital technologies, as this will lead to a negative impact on collaboration performance. When trying out new technologies, learning often happens through mistakes and excessive monitoring can feel controlling, which prevents, for example, the utilization and experimentation of new technologies outside company borders.

6.3 Limitations and future directions

This study has certain methodological and theoretical limitations that provide opportunities for future studies. The first limitation is related to the selected research sample. The study focused mainly on Finnish SMEs (76.6%) and their management. Thus, in the future, the research could be expanded to cover a larger geographical area. Further, focusing mainly on management's views may have influenced the results of the study. In the future, we suggest that the research can be extended more to large companies, and from the top level to the lower levels. Future study samples could also include large companies to determine whether digitally enabled PM supports the effects of digital business strategies on collaboration between different departments within the company.

Notably, the instruments of the study were built based on previous literature, as presented in Table 2. The digital business strategy included five elements (development, objectives, resources, management capabilities and digital leadership) to investigate the effects of collaboration. Given that we explored the effects of these five elements in the same framework, it is possible that this has shaped our results. Thus, we encourage the evaluation of the impact of the different independent elements, for example, common objectives between companies, more precisely in the future.

Finally, the study did not address a specific PM system or its implementation. In the future, it would be informative to consider how the effects of digital strategies and their elements on collaboration could be enhanced by choosing different measurement systems. In addition, in-depth case studies could be conducted related to the formulation and implementation of a digital strategy and the related digitally enabling PM system. Thus, empirical experiences on the research topic should be studied.

References

Adner, R., Chen, J. and Zhu, F. (2020), "Frenemies in platform markets: heterogeneous profit foci as drivers of compatibility decisions", *Management Science*, Vol. 66 No. 6, pp. 2432-2451.

Aheleroff, S., Xu, X., Zhong, R.Y. and Lu, Y. (2021), "Digital twin as a service (DTaaS) in industry 4.0: an architecture reference model", *Advanced Engineering Informatics*, Vol. 47, 101225.

Bharadwaj, A., El Sawy, O.A., Pavlou, P.A. and Venkatraman, N. (2013), "Digital business strategy: toward a next generation insights", *MIS Quarterly*, Vol. 37 No. 2, pp. 471-482.

Bhimani, A. (2020), "Digital data and management accounting: why we need to rethink research methods", *Journal of Management Control*, Vol. 31 No. 1, pp. 9-23.

Bourne, M., Franco-Santos, M., Micheli, P. and Pavlov, A. (2018), "Performance measurement and management: a system of systems perspective", *International Journal of Production Research*, Vol. 56 No. 8, pp. 1-12.

Bredmar, K. (2017), "Digitalisation of enterprises brings new opportunities to traditional management control", *Business Systems Research: International Journal of the Society for Advancing Innovation and Research in Economy*, Vol. 8 No. 2, pp. 115-125.

Büyüközkan, G. and Göçer, F. (2018), "Digital supply chain: literature review and a proposed framework for future research", *Computers in Industry*, Vol. 97, pp. 157-177.

Cennamo, C., Dagnino, G.B., Di Minin, A. and Lanzolla, G. (2020), "Managing digital transformation: scope of transformation and modalities of value co-generation and delivery", *California Management Review*, Vol. 62 No. 4, pp. 5-16.

Chanias, S., Myers, M.D. and Hess, T. (2019), "Digital transformation strategy making in pre-digital organizations: the case of a financial services provider", *The Journal of Strategic Information Systems*, Vol. 28 No. 1, pp. 17-33.

Chi, M., Lu, X., Zhao, J. and Li, Y. (2018), "The impacts of digital business strategy on firm performance: the mediation analysis of e-collaboration capability", *International Journal of Information Systems and Change Management*, Vol. 10 No. 2, pp. 123-139.

Davenport, T.H. and Westerman, G. (2018), "Why so many high-profile digital transformations fail", *Harvard Business Review*, Vol. 9 No. 4, 15.

El Sawy, O.A., Kræmmergaard, P., Amsinck, H. and Vinther, A.L. (2016), "How LEGO built the foundations and enterprise capabilities for digital leadership", *MIS Quarterly Executive*, Vol. 15 No. 2, pp. 141-166.

Fitzgerald, M., Kruschwitz, N., Bonnet, D. and Welch, M. (2014), "Embracing digital technology: a new strategic imperative", *MIT Sloan Management Review*, Vol. 55 No. 2, 1.

Fornell, C. and Larcker, D.F. (1981), "Evaluating structural equation models with unobservable variables and measurement error", *Journal of Marketing Research*, Vol. 18 No. 1, pp. 39-50.

Gong, C. and Ribiere, V. (2021), "Developing a unified definition of digital transformation", *Technovation*, Vol. 102, 102217.

Grover, V. and Kohli, R. (2013), "Revealing your hand: caveats in implementing digital business strategy", *MIS Quarterly*, Vol. 37 No. 2, pp. 655-662.

Gurbaxani, V. and Dunkle, D. (2019), "Gearing up for successful digital transformation", *MIS Quarterly Executive*, Vol. 18 No. 3, p. 6.

Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E. (2014), *Multivariate Data Analysis*, 7th ed., Pearson new international ed., Pearson Education, Harlow.

Hess, T., Benlian, A., Matt, C. and Wiesböck, F. (2016), "Options for formulating a digital transformation strategy", *MIS Quarterly Executive*, Vol. 15 No. 2, pp. 103-119.

Holopainen, M., Ukko, J. and Saunila, M. (2022), "Managing the strategic readiness of industrial companies for digital operations", *Digital Business*, Vol. 2 No. 2, 100039.

Holopainen, M., Saunila, M. and Ukko, J. (2023a), "Value creation paths of organizations undergoing digital transformation", *Knowledge and Process Management*, Vol. 30 No. 2, pp. 125-136.

Holopainen, M., Saunila, M. and Ukko, J. (2023b), "Enhancing the order-to-delivery process with real-time performance measurement based on digital visualization", *Production and Manufacturing Research*, Vol. 11 No. 1, 2217237.

Holotiuk, F. and Beimborn, D. (2017), "Critical success factors of digital business strategy", in Leimeister, J.M., Brenner, W. and Hrsg (Eds), *Proceedings der 13. Internationalen Tagung Wirtschaftsinformatik (WI 2017)*, St. Gallen, S, pp. 991-1005.

Horlach, B., Drews, P., Schirmer, I. and Böhmann, T. (2017), "Increasing the agility of IT delivery: five types of bimodal IT organization", *Proceedings of the 50th Hawaii International Conference on System Sciences*.

Jovanovic, M., Sjödin, D. and Parida, V. (2022), "Co-evolution of platform architecture, platform services, and platform governance: expanding the platform value of industrial digital platforms", *Technovation*, Vol. 118, 102218.

Kache, F. and Seuring, S. (2017), "Challenges and opportunities of digital information at the intersection of big data analytics and supply chain management", *International Journal of Operations and Production Management*, Vol. 37 No. 1, pp. 10-36.

Kamble, S.S., Gunasekaran, A., Ghadge, A. and Raut, R. (2020), "A performance measurement system for industry 4.0 enabled smart manufacturing system in SMMEs-A review and empirical investigation", *International Journal of Production Economics*, Vol. 229, 107853.

Kane, G.C., Palmer, D., Nguyen-Phillips, A., Kiron, D. and Buckley, N. (2017), "Achieving digital maturity", *MIT Sloan Management Review*, Vol. 59 No. 1, pp. 1-29.

Konopik, J., Jahn, C., Schuster, T., Hoßbach, N. and Pflaum, A. (2022), "Mastering the digital transformation through organizational capabilities: a conceptual framework", *Digital Business*, Vol. 2 No. 2, 100019.

Korsen, E.B.H. and Ingvaldsen, J.A. (2022), "Digitalisation and the performance measurement and management system: reinforcing empowerment", *International Journal of Productivity and Performance Management*, Vol. 71 No. 4, pp. 1059-1075.

Kraus, S., Jones, P., Kailer, N., Weinmann, A., Chaparro-Banegas, N. and Roig-Tierno, N. (2021), "Digital transformation: an overview of the current state of the art of research", *Sage Open*, Vol. 11 No. 3, 21582440211047576.

Legner, C., Eymann, T., Hess, T., Matt, C., Böhmann, T., Drews, P. and Ahlemann, F. (2017), "Digitalization: opportunity and challenge for the business and information systems engineering community", *Business and Information Systems Engineering*, Vol. 59 No. 4, pp. 301-308.

Li, F. (2020), "Leading digital transformation: three emerging approaches for managing the transition", *International Journal of Operations and Production Management*, Vol. 40 No. 6, pp. 809-817.

Li, L., Su, F., Zhang, W. and Mao, J.Y. (2018), "Digital transformation by SME entrepreneurs: a capability perspective", *Information Systems Journal*, Vol. 28 No. 6, pp. 1129-1157.

Lipsmeier, A., Kühn, A., Joppen, R. and Dumitrescu, R. (2020), "Process for the development of a digital strategy", *Procedia Cirp*, Vol. 88, pp. 173-178.

Liu, Z., Sampaio, P., Pishchulov, G., Mehandjiev, N., Cisneros-Cabrera, S., Schirrmann, A. and Bnouhanna, N. (2022), "The architectural design and implementation of a digital platform for Industry 4.0 SME collaboration", *Computers in Industry*, Vol. 138, 103623.

Matt, C., Hess, T. and Benlian, A. (2015), "Digital transformation strategies", *Business and Information Systems Engineering*, Vol. 57 No. 5, pp. 339-343.

Min, Q., Lu, Y., Liu, Z., Su, C. and Wang, B. (2019), "Machine learning based digital twin framework for production optimization in petrochemical industry", *International Journal of Information Management*, Vol. 49, pp. 502-519.

Mithas, S., Tafti, A. and Mitchell, W. (2013), "How a firm's competitive environment and digital strategic posture influence digital business strategy", *MIS Quarterly*, Vol. 37 No. 2, pp. 511-536.

Mittal, S., Khan, M.A., Romero, D. and Wuest, T. (2018), "A critical review of smart manufacturing & industry 4.0 maturity models: implications for small and medium-sized enterprises (SMEs)", *Journal of Manufacturing Systems*, Vol. 49, pp. 194-214.

Nadkarni, S. and Prügl, R. (2021), "Digital transformation: a review, synthesis and opportunities for future research", *Management Review Quarterly*, Vol. 71, pp. 233-341.

Nasiri, M., Ukko, J., Saunila, M., Rantala, T. and Rantanen, H. (2020), "Digital-related capabilities and financial performance: the mediating effect of performance measurement systems", *Technology Analysis and Strategic Management*, Vol. 32 No. 12, pp. 1393-1406.

Nudurupati, S.S., Tebboune, S. and Hardman, J. (2016), "Contemporary performance measurement and management (PMM) in digital economies", *Production Planning and Control*, Vol. 27 No. 3, pp. 226-235.

Nudurupati, S.S., Garengo, P. and Bititci, U.S. (2021), "Impact of the changing business environment on performance measurement and management practices", *International Journal of Production Economics*, Vol. 232, 107942.

Oh, J. and Jeong, B. (2019), "Tactical supply planning in smart manufacturing supply chain", *Robotics and Computer-Integrated Manufacturing*, Vol. 55, pp. 217-233.

Parida, V., Sjödin, D.R., Lenka, S. and Wincent, J. (2015), "Developing global service innovation capabilities: how global manufacturers address the challenges of market heterogeneity", *Research-Technology Management*, Vol. 58 No. 5, pp. 35-44.

Parmar, R., Leiponen, A. and Thomas, L.D. (2020), "Building an organizational digital twin", *Business Horizons*, Vol. 63 No. 6, pp. 725-736.

Podsakoff, P.M. and Organ, D.W. (1986), "Self-reports in organizational research: problems and prospects", *Journal of Management*, Vol. 12 No. 4, pp. 531-544.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.Y. and Podsakoff, N.P. (2003), "Common method biases in behavioral research: a critical review of the literature and recommended remedies", *Journal of Applied Psychology*, Vol. 88 No. 5, 879.

Ravelomanantsoa, M.S., Ducq, Y. and Vallespir, B. (2019), "A state of the art and comparison of approaches for performance measurement systems definition and design", *International Journal of Production Research*, Vol. 57 Nos 15-16, pp. 5026-5046.

Reim, W., Andersson, E. and Eckerwall, K. (2023), "Enabling collaboration on digital platforms: a study of digital twins", *International Journal of Production Research*, Vol. 61 No. 12, pp. 3926-3942.

Reinking, J., Arnold, V. and Sutton, S.G. (2020), "Synthesizing enterprise data to strategically align performance: the intentionality of strategy surrogation", *International Journal of Accounting Information Systems*, Vol. 36, 100444.

Robert, M., Giuliani, P. and Gurau, C. (2022), "Implementing industry 4.0 real-time performance management systems: the case of Schneider electric", *Production Planning and Control*, Vol. 33 Nos 2-3, pp. 244-260.

Sardi, A., Sorano, E., Cantino, V. and Garengo, P. (2020), "Big data and performance measurement research: trends, evolution and future opportunities", *Measuring Business Excellence*, Vol. ahead-of-print No. ahead-of-print, pp. 1-18.

Saunila, M., Holopainen, M., Nasiri, M., Ukko, J. and Rantala, T. (2022), "Digital transformation with digital twins-distinct mechanisms of enabling and controlling uses", *Technology Analysis and Strategic Management*, pp. 1-14, doi: 10.1080/09537325.2022.2090917.

Senyo, P.K., Liu, K. and Effah, J. (2019), "Digital business ecosystem: literature review and a framework for future research", *International Journal of Information Management*, Vol. 47, pp. 52-64.

Silva, H.D., Azevedo, M. and Soares, A.L. (2021), "A vision for a platform-based digital-twin ecosystem", *IFAC-PapersOnLine*, Vol. 54 No. 1, pp. 761-766.

Sjödin, D., Parida, V., Kohtamäki, M. and Wincent, J. (2020), "An agile co-creation process for digital servitization: a micro-service innovation approach", *Journal of Business Research*, Vol. 112, pp. 478-491.

Sousa-Zomer, T.T., Neely, A. and Martinez, V. (2020), "Digital transforming capability and performance: a microfoundational perspective", *International Journal of Operations and Production Management*, Vol. 40 Nos 7/8, pp. 1095-1128.

Srivastava, S.C. and Shainesh, G. (2015), "Bridging the service divide through digitally enabled service innovations; evidence from Indian health care service providers", *MIS Quarterly*, Vol. 39 No. 1, pp. 245-267.

Suuronen, S., Ukko, J., Eskola, R., Semken, R.S. and Rantanen, H. (2022), "A systematic literature review for digital business ecosystems in the manufacturing industry: prerequisites, challenges, and benefits", *CIRP Journal of Manufacturing Science and Technology*, Vol. 37, pp. 414-426.

Taber, K.S. (2018), "The use of Cronbach's alpha when developing and reporting research instruments in science education", *Research in Science Education*, Vol. 48 No. 6, pp. 1273-1296.

Tabrizi, B., Lam, E., Girard, K. and Irvin, V. (2019), "Digital transformation is not about technology", *Harvard Business Review*, Vol. 13, pp. 1-6.

Tao, F., Zhang, Y., Cheng, Y., Ren, J., Wang, D., Qi, Q. and Li, P. (2020), "Digital twin and blockchain enhanced smart manufacturing service collaboration and management", *Journal of Manufacturing Systems*, Vol. 62, pp. 903-914.

Tekic, Z. and Koroteev, D. (2019), "From disruptively digital to proudly analog: a holistic typology of digital transformation strategies", *Business Horizons*, Vol. 62 No. 6, pp. 683-693.

Tortorella, G.L., Vergara, A.M.C., Garza-Reyes, J.A. and Sawhney, R. (2020), "Organizational learning paths based upon industry 4.0 adoption: an empirical study with Brazilian manufacturers", *International Journal of Production Economics*, Vol. 219, pp. 284-294.

Ukko, J., Nasiri, M., Saunila, M. and Rantala, T. (2019), "Sustainability strategy as a moderator in the relationship between digital business strategy and financial performance", *Journal of Cleaner Production*, Vol. 236, 117626.

Verhoef, P.C., Broekhuizen, T., Bart, Y., Bhattacharya, A., Dong, J.Q., Fabian, N. and Haenlein, M. (2021), "Digital transformation: a multidisciplinary reflection and research agenda", *Journal of Business Research*, Vol. 122, pp. 889-901.

Vial, G. (2019), "Understanding digital transformation: a review and a research agenda", *The Journal of Strategic Information Systems*, Vol. 28 No. 2, pp. 118-144.

Wang, H., Feng, J., Zhang, H. and Li, X. (2020), "The effect of digital transformation strategy on performance: the moderating role of cognitive conflict", *International Journal of Conflict Management*, Vol. 31 No. 3, pp. 441-462.

Wesche, J.S. and Sonderegger, A. (2019), "When computers take the lead: the automation of leadership", *Computers in Human Behavior*, Vol. 101, pp. 197-209.

Wessel, L., Baiyere, A., Ologeanu-Taddei, R., Cha, J. and Blegind-Jensen, T. (2021), "Unpacking the difference between digital transformation and IT-enabled organizational transformation", *Journal of the Association for Information Systems*, Vol. 22 No. 1, pp. 102-129.

Yeow, A., Soh, C. and Hansen, R. (2018), "Aligning with new digital strategy: a dynamic capabilities approach", *The Journal of Strategic Information Systems*, Vol. 27 No. 1, pp. 43-58.

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Digital twins' implications for innovation

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RESEARCH ARTICLE

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Digital twins' implications for innovation

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ABSTRACT

Digital transformation and emerging technologies create new business opportunities that differ from traditional requirements. Digital twins, referring to digital replicas of a physical entity, are rapidly developing and creating novel innovation opportunities. This study focuses on increasing the understanding of the implications of the use of digital twins for innovation, and case studies were used to gather evidence. The study offers an interesting contribution to the literature on digital twins, presenting a framework that demonstrates how digital twins are characterised, and how they contribute (impact) and are used (scope) in innovation processes in the context of innovation and technology management. In addition, the findings provide interesting implications for different practitioners interested in the utilisation of digital twins. Using the results of this study, managers can enhance their companies' digital transformation by acknowledging the multiple uses of digital twins.

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1. Introduction

Innovation and technology management in companies is increasingly being shaped by the business potential of distinct digital technologies, such as digital twins (Hilbolling et al. 2020; Blichfeldt and Faullant 2021; Muscio and Ciffolilli 2020; Urbinati et al. 2020). Digital twins are digital replicas of physical entities such as products, processes, or systems. Digital twins differ from other related concepts in the level of data integration between the physical and digital counterparts, as they are fully integrated with real-time data exchange (Kritzinger et al. 2018). Technical solutions offered by digital twins are rapidly developing, and from a technical point of view, their application is constantly becoming easier and more cost-effective. Research on digital twins has mainly been conducted in different fields of engineering science. However, a meaningful application of digital twins requires an understanding of the connection of the concept to innovation. Tao et al. (2019) argue that little effort has been devoted to exploring the applicability of digital twins for product design with respect to how communication, synergy, and coevolution between a physical product and its digital representation (virtual product) can lead to a more informed, expedited, and innovative design process.

Digital twins provide several innovation opportunities, as they offer great avenues for the interoperation and fusion of the physical world and the cyberworld of manufacturing (Liu et al. 2019). Digital twins can facilitate visualisation, promote collaboration, and further decision-making, among others (Bao et al. 2019). More specifically, Zhou et al. (2020) suggest that digital twins can help in understanding, predicting, or optimising the performance of manufacturing processes through an intelligent analysis and decision-making process enabled by dynamic knowledge and

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skills. Tao et al. (2019) present that digital twins are mostly used for fault diagnosis, predictive maintenance, and performance analysis, with only some effort devoted to more innovative design processes or innovations. Despite the growing trend toward digital twins–driven innovations and their commercialisation, the literature is deficient in several important ways. Business and management researchers have reported only a few studies on the utilisation of digital twins. Since digital twins play an important role in providing value for stakeholders and generating profit, a comprehensive analysis of the benefits of digital twins is required (Lim, Zheng, and Chen 2020). Hence, the implications of digital twin utilisation should be systematically studied.

There has been a significant rise in digital twin studies in recent years. Despite the profusion of digital twin studies published, most of the studies focus on the technical aspects. Little is known about how digital twins are integrated into a firms' innovation development. This study contributes to previously identified research gaps by investigating the utilisation of digital twins in innovation. The research question is as follows: What implications do digital twins have for innovation? The study presents a framework that demonstrates how digital twins are characterised, and how they contribute (impact) and are used (scope) in innovation processes in the context of innovation and technology management. Thus, this study aims to enhance the understanding of the implications of using digital twins in the contexts of innovation and technology management.

2. Literature review

2.1. The digital twin concept

The commonly agreed definition of a digital twin currently highlights two important features. First, a digital twin provides a connection between a physical entity and its virtual counterpart (He and Bai 2021). Second, the connection between the physical entity and its virtual twin is established by sensors to provide real-time information (Tao et al. 2019; Wang et al. 2017). As mentioned earlier, a digital twin is typically considered a digital replica of a living or nonliving entity (He and Bai 2021)—with a two-way dynamic mapping between a real-life object and its digital counterpart, which has a structure of connected data and metainformation (Aheleroff et al. 2021; Shao and Helu 2020; Tao et al. 2019; Zhou et al., 2020). A digital twin enables real-time data transfer by connecting physical and virtual entities (such as processes, products, assets, and personnel), making it possible for virtual entities to occur simultaneously with physical ones (He and Bai 2021). Digital twins have various characteristics and can be utilised in many phases of organisation, production, sales, and innovation processes and activities. The next section presents the possibilities of digital twins in the context of innovation.

2.2. Digital twins through the lens of innovation

2.2.1. Innovation as a process

The rise of digital twins includes transformations in technology and production (Cimino, Negri, and Fumagalli 2019; Liu et al. 2019; Tao et al. 2019). This, in turn, results in significant organisational implications (Parmar, Leiponen, and Thomas 2020), such as emphasising decision-making support for optimising production or maximising profitability (Lim, Zheng, and Chen 2020). Thus, digital twins are changing the nature of innovation. Innovation, in general, can be viewed as 'a value-added novelty in economic and social spheres' (Crossan and Apaydin 2010, 1155). Innovation has two roles: innovation as a process and innovation as an outcome (Crossan and Apaydin 2010). Regarding innovation as a process, the current digital era especially highlights the challenges of companies in generating innovation in isolation. This emphasises the locus of an innovation process, which may be either a firm-only or a network-level process (Crossan and Apaydin 2010).

In this sense, digital twins have various applications that can be exploited in different business areas (Fuller et al. 2020; Qi et al. 2021; Rasheed, San, and Kvamsdal 2020). As an innovation process, a digital twin enables collaboration throughout the value chain, not only in the integration and sharing of data between upstream and downstream companies but also in collaborative product development, manufacturing, operation, and maintenance (Cheng et al. 2020). Users can take part in the innovation and development processes of future products, services, processes, and business innovations via cloud computing (Lim, Zheng, and Chen 2020; Zheng et al. 2018), enabling the development of innovation through cooperation both within the company and with external parties. Using digital twins in the design phase, users can monitor the progress of the design of a digital model, implement and test modifications to the model, and provide direct online feedback on product features to the company (Tao et al. 2019).

2.2.2. Innovation as an outcome

The other role of innovation—innovation as an outcome—considers innovation to be more than a creative process and includes utilisation (Crossan and Apaydin 2010). Prior research identifies different forms of innovation—namely, product innovation, service innovation, process innovation, and business model innovation. Product innovation refers to novel products targeted at technological competitiveness to serve the markets (Carboni and Russu 2018). Some scholars have defined service innovation as a specific type of product innovation connected to the actions by which services are designed or improved to meet customer needs (Wang et al. 2015). Process innovation covers the application of novel production, management, and process-related approaches (Wang and Ahmed 2004). Business model innovation is about 'designing a new or modifying the firm's extant activity system' (Amit and Zott 2010, 2).

In this sense, the introduction of digital twins provides novel innovation and value creation opportunities for industrial companies (Chirumalla 2021; Blichfeldt and Faullant 2021). Digital twins applications can be utilised in the design, production, and use phases of the product life cycle, allowing designers to digitalise, visualise, and materialise complex systems such as ships, aircraft, and factories, enabling product innovations (Qi et al. 2021). Digital twins can be used, for example, in digital design, where they can provide a framework for product design or the optimisation of physical parameters (Tao et al. 2019). In addition, services are an important component of digital twins. Liu et al. (2021) mention that the possible applications of digital twins as a service are predictive maintenance, fault detection and diagnosis, state monitoring, performance prediction, and virtual testing. When digital twins are utilised in service operations, they provide opportunities, for example, for preventive maintenance and equipment status monitoring (Errandonea, Beltrán, and Arrizabalaga 2020; Kritzinger et al. 2018). In addition, according to Qi et al. (2021), the potential of digital twins as a service is related to simulation, verification, monitoring, optimisation, diagnosis, and prognostic and health management. By enabling the transmission of data between the physical and virtual world, digital twins have the potential to provide real-time information on equipment and production operations as well as potential actions, increasing production predictability and enabling process innovations leading to process and performance improvements (Aheleroff et al. 2021; Fuller et al. 2020). In addition, digital twins can be utilised in production optimisation through process simulation to support virtual production and productivity (He and Bai 2021; Zheng et al. 2018). By acting as a real-time monitoring and forecasting tool, digital twin technology can be utilised in the development phase of buildings, structures, and smart cities, as well as in their maintenance (Fuller et al. 2020). Digital twins' ability to synchronise the real and digital worlds also enables novel types of business model innovation, changing existing ways of operating. These innovations can be used to create new types of earning models—for example, to offer smart solutions in the construction, transportation, and energy sectors (Rasheed, San, and Kvamsdal 2020).

2.2.3. Summary

It can be argued that despite the promising possibilities that digital twins offer organisations, the phenomenon from the perspective of innovation has been underexplored. Previous studies have focused on how digital twins can support the optimisation of an organisation's internal operations and processes by streamlining existing activities through data collection and visibility. Although the use of digital twins is likely to contribute to the development of innovation (e.g. Cheng et al. 2020; Lim, Zheng, and Chen 2020; Zheng et al. 2018), and an increasing number of organisations are taking advantage of various forms of digital twins as part of their operations, understanding of the implications of their use is relatively limited (e.g. Aheleroff et al. 2021; Fuller et al. 2020; He and Bai 2021). The focus on streamlining and optimising internal operations diverts attention from innovation, in the form of new business models, services, and products, as an outcome. Thus, a systematic understanding of the implications of the use of digital twins, covering scope, characteristics, and impact and based on empirical evidence, is necessary.

3. Research approach

Digital transformation and emerging technologies create new business opportunities that differ from traditional requirements. We studied digital twins in the industrial environment to answer the following question: What implications do digital twins have for innovation? The research was conducted using a qualitative case study approach (Eisenhardt 1989). This is an appropriate research methodology when there are many variables in the study and the study consists of a specific, complex phenomenon in a real-world context (Yin 2014). A case study approach allows an in-depth and multi-faceted understanding of the researched phenomenon in its natural context (Crowe et al. 2011).

3.1. Case selection and data collection

Following Stake (1995), the study used a collective case study approach. A multiple (Yin 2003) or collective case study (Stake 1995) involves consideration of more than one case study in order to allow researchers to explore differences within and between cases, providing a broad understanding. In addition, as using multiple case studies constitutes an appropriate research methodology when the same phenomenon is thought to occur in multiple situations (Yin 1981). This research approach helped us identify the similarities and differences in how companies seek to leverage digital twins in their innovation activities. The research utilised multiple cases involving small – and medium-sized companies (SMEs) and large companies. SMEs are defined as companies with less than 250 employees and an annual turnover not exceeding EUR 50 million or a balance sheet total not exceeding EUR 43 million. In order to achieve higher external validity, multiple cases were used (Voss, Tsikriktsis, and Frohlich 2002) with the goal of identifying repeat findings in the different cases (Yin 2003).

Case selection is an important part of a successful case study (Eisenhardt 1989). Cases were carefully selected to allow comparison and replication (Yin 2003) using the following criteria: (1) the company must be taking concrete initiatives to develop and/or implement digital twins, (2) the company must allow access to relevant information concerning their use of digital twins and innovation processes, and (3) the interviewee(s) should be aware of their company's use of digital twins and the relevant organisational areas and processes. A total of six companies and 14 interviewees participated in the study (Table 1). Both SMEs and large companies were selected to provide a comprehensive picture of the development and use of digital twins, particularly in relation to innovation.

Furthermore, this research is based on the analysis of open-ended interviews conducted among digital twin solution providers and utilisers. The case companies are actively developing or using digital twin solutions and were therefore selected as cases for this study. To gain a complete view of the mechanisms of digital twins in innovation processes, representatives from different units, hierarchical levels, and job descriptions were interviewed. Because the utilisation of digital twins in innovation development is evolving, preliminary questions were constructed. Thus, the interview execution permitted unofficial discussions and allowed researchers to ask support questions. In

Table 1. Informants of the interviews.

Company	Description	Size	Interviews	Interviewees' roles
Utilisers of the digital twin solutions				
Company A	Operating in the technology industry by developing cloud service-based software solutions	SME	1	The CEO
Company B	Operating in the metal industry by providing smart technology and total life cycle solutions for the marine and energy markets	Large	3	The chief technology officer, the product development director, the product development manager
Company C	Operating in the engineering industry by designing, manufacturing, and selling plywood and veneer-manufacturing equipment	Large	4	The director of products, technologies, and RandD; the development manager; the business line manager; the product development manager
Digital twin solution providers				
Company D	Operating in the technology industry by providing digital twins and real-time simulation technology solutions	SME	2	The chief technology officer, the customer project manager/production manager
Company E	Operating in the technology industry by providing digitalisation and robotisation solutions	Large	4	The investigator, the data model specialist, the software business manager/ development director, the research team leader
Company F	Operating in the technology industry by providing digital twin solutions	SME	3	The R&D director, the chief operating officer, the business director

particular, the interviews focused on how the company currently utilises digital twins to support its operation and how digital twins and their multiple characteristics could support companies in the future. These provided important insights into how digital twins can be leveraged to support innovation and development processes, enabling new types of products, services, processes, and business model innovations.

The interviews were conducted in 2020. They were carried out with the entire research team, each interview lasting approximately between 60 and 80 min. The interview questions focused on predefined dimensions taken from a review of the literature (Scope, Table 2). Building interview questions based on these dimensions helped ensure the reliability of the data (Yin 2003). Given that the topic of digital twins is evolving, the interview protocol allowed for informal discussions and supporting questions from the researchers. The flexibility of the data collection made it possible to obtain a detailed description of each individual case (Crowe et al. 2011). The interviews were recorded and transcribed to facilitate the analysis phase.

3.2. Data analysis

The study can be classified as a theory-generating case study in which several cases were exploited and in which researchers looked for both similarities and differences between cases in pursuit of theoretical generalisations (Ketokivi and Choi 2014). Existent theoretical considerations guided the predefined dimensions of the interviews (Scope, Table 2), but empirical analysis informed and shaped the findings (Ketokivi and Choi 2014). The collected data were coded with the help of the predefined dimensions and were analyzed using within-case and cross-case analyses (Eisenhardt 1989). The unit of analysis was companies, specifically companies' experiences with the use of digital twins and their potential for innovation. The within-case analysis provided more detailed information on how each company uses or develops digital twins and identified the related innovation mechanisms. Cross-case analyses were conducted between companies to identify repetitive patterns and to support the creation of the framework of the results (Table 2). The analyses were performed by a single researcher. After that, there was an open discussion between the four researchers about the results of the cases. Finally, the results were analyzed during the discussion, and theory-generating proposals were formed (Figure 1).

Table 2. The implications of digital twins in different scopes.

	Scope	Impacts	Main Characteristic	Innovation as a process	Innovation as an outcome
Product development and design	Digital twins can be leveraged to support product design and development, bringing new opportunities for these mechanisms.	Designing and testing products virtually reduce errors and surprises, increase collaboration, save time, and enhance information sharing for all parties. New experiments and innovations are also facilitated by the research and experimental capabilities of the digital twins.	Exploration	Network	Process
Sales and marketing	The digital twin can be utilised to support sales by providing additional information about the product to the customer. The customer has the opportunity to see and try a virtual copy of the product already at the sales stage.	Boost sales, promoting the time of making offers and increases the flow of information. Customers will be able to see and possibly try out the features of the upcoming product with the help of digital twins and thus influence the outcome.	Experimentation	Network	Product/ service
Maintenance service	The digital twin can be utilised in the maintenance and upkeep of machines/ equipment. This can be used to optimise the use of equipment over the entire life cycle and offers the opportunity for new types of maintenance services.	Saves money and time by optimising maintenance (e.g. optimising the use of spare parts, preventive maintenance). Information is provided on machines/ equipment to support development. Enables new types of maintenance services, like training, remote support.	Optimisation	Network	Product/ service
Cooperation with the customer and within the company	Digital twins can be used to increase collaboration with the customer and within the company. The digital twin provides information for all parties to use and its features also allow products to be developed to meet the needs.	Increasing the availability of information and improving its sharing. Also enhancing doing things together instead of silos. Information is available from one place remotely and in real time to all users.	Interaction	Network/ firm	Process
Finding new business	With the help of digital twins, it is possible to better understand customers and increase knowledge of their needs, which will help companies to explore completely new types of business opportunities.	Increase knowledge of the customers and their needs, support in finding business opportunities. Combining information silos enables innovation.	Discovery	Firm	Product/ service, process, business model

(*Continued*)

Table 2. Continued.

	Scope	Impacts	Main Characteristic	Innovation as a process	Innovation as an outcome
Production processes	Digital twins can be used to monitor production processes in real time and obtain information about their functionality. This can be used, for example, for production optimisation, design and testing, maintenance, and forecasting.	More efficient and sustainable production. Better decision-making. Transparency of the information for workers and management.	Guidance	Firm	Process

4. Findings

In examining the impact of digital twins on innovation, we focused on the different scopes of digital twin utilisation. In analyzing these scopes, the implications of digital twins were analyzed in terms of their impact, characteristics, and two roles of innovation: as a process and as an outcome. This section describes the main results and the propositions (P) derived from them. Table 2 provides a summary of the results.

The findings show the impacts of digital twins based on their characteristics in different areas of business, verifying the diverse possibilities of digital twins.

> *The same digital twin can be used throughout the product life cycle as a design aid, for validation and testing, and in part, also for production, training, marketing, maintenance, and service.* (The chief technology officer, Company D)

The results of this study show the ways that digital twins contribute to innovation processes (impacts) and how digital twins are used in innovation processes (scope). For example, digital twin exploration characteristics could be applied in the product design and development areas, enabling experiments, innovations, and new opportunities through digital twins' simulation capabilities.

> *It allows you to go through different operating situations without breaking anything. Different situations can be simulated, and customers also want to do different tests on operating situations that would be tricky on the right machine.* (The customer project manager/production manager, Company D)

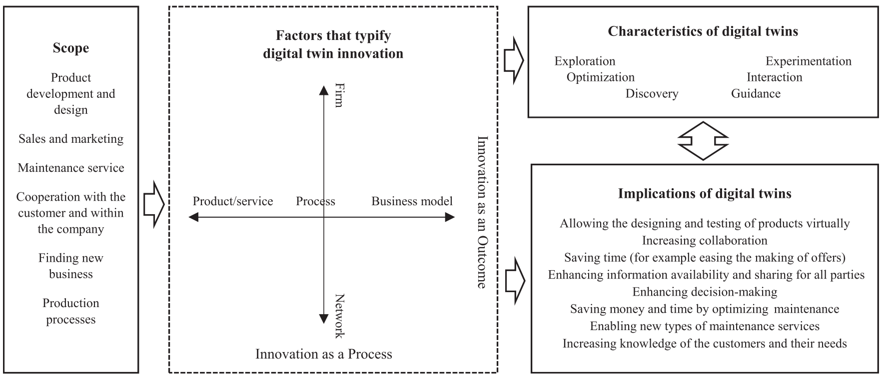

Figure 1. Framework: Digital twins' implications for innovation.

P1: Making greater use of a digital twin facilitates product development, as it allows designing and testing products virtually, reducing errors and surprises, increasing collaboration, saving time, and enhancing information sharing for all parties.

On the other hand, digital twins offer opportunities for more efficient production processes because they can be used to implement real-time production monitoring and control, enhancing the guidance of the operations.

> *With the help of the digital twin, you have access to real-time production information, so it is very easy to develop the production and modify processes so that the entire production capacity can be utilized. … the benefit of real-time monitoring is that everyone in the organization has the same knowledge of what enables development and of data-based decisions to be made*. (The chief operating officer, Company F)

P2: Making greater use of a digital twin facilitates production processes, as it enhances the quality of decision-making and information transparency for workers and management.

According to the study, digital twins serve as an excellent communication tool. Possessing interaction characteristics, digital twins enable information sharing and communication between different parties both within and outside the company.

> *The digital twin is a great channel of communication with partners and customers. It kind of allows us to speak the same language when we are wondering at the digital twin together. It also allows you to try things out, look at the machine in action, see the work process, and much more. So, it is a good channel for dialogue with other parties. … And then within the company, it is, of course, a great communication channel in the sense that usually, the company has its own department which is responsible for electrical components, its own department which is responsible for hydraulics, for mechanics, and for the control system. And then all these departments now have a conversation around the digital twin. When changes are made, their effects on department-specific issues are immediately seen, and it helps to go through a wide range of problems in different situations*. (The customer project manager/production manager, Company D)

P3: Making greater use of a digital twin facilitates cooperation, as it increases the availability of information and improves information sharing.

The digital twin model has various implications for sales and marketing processes, enhancing their execution. At the sales stage, the customer can see and try out the features of the products, influencing the customer's purchasing decision and speeding it up.

> *If we have a good digital twin at the sales stage, then with the customer we can customize and optimize the operation of the real product as desired*. (The product development director, Company B)

> *With digital twin of the products, our customers have been able to streamline the early stages of the sales process. For example, two to four weeks of work can be condensed to 15 min, the solution can be presented in a much clearer form to the end customer, and the salesperson does not have to be an expert with 10 years of experience*. (The chief operating officer, Company F)

P4: Making greater use of a digital twin facilitates sales and marketing, as it promotes the making of offers in a timely manner and increases the flow of information to customers.

Also, the study showed that digital twins have various implications for the companies' maintenance services. By optimising the maintenance of the products and spare parts, and using preventive maintenance, companies saw that savings in both money and time could be achieved. In addition, the companies found that digital twins will create new types of after-sales maintenance services in the future, such as education and remote support services.

> *With digital twins, we can get help with the timeliness and planning of maintenance, so that it is not necessary to stop a piece of equipment or the whole factory when a place breaks down unexpectedly, but to monitor the whole chain so accurately and in good time that it is not known when any part will break down and then plan maintenance and repairs*. (The business director, Company F)

P5: Making greater use of a digital twin facilitates product maintenance and preventative maintenance, as it saves money and time by optimising maintenance and enables the application of new types of maintenance services, such as training and remote support.

Digital twins offer completely new opportunities for business discovery and development. By learning more about customer needs and integrating information silos, new service opportunities can be found.

> *I want to emphasize that, in a way, the integration of these silos is one of the key issues. Because, firstly, it would allow a lot of new business at no extra cost if the world of information between these silos were kind of connected.* (The CEO, Company A)

One of the new possibilities was the utilisation of the digital twin for learning purposes, which was already taken advantage of by Company E.

> *The more technology evolves, the easier it is for it to be used for both internal and external learning purposes. For example, when we are supplied with an entire factory and we have a good digital twin from it, then we can utilize the digital twin as a tool to help the customer learn how to operate the factory or the complex production lines.* (The product development manager, Company C)

> *Well, we utilize digital twins in driver training. We have two simulator chairs where drivers can try our systems and how they work in the virtual world.* (The research team leader, Company E)

P6: Making greater use of a digital twin facilitates finding new business, as it increases knowledge of the customer and their needs.

The findings demonstrate how businesses are moving from technology-centric to value-centric innovation processes to create value with digital twins. This was reflected in the fact that companies—both providers and users—were actively looking for new ways to leverage the digital twins in their business, looking for new business opportunities and seeking answers to various challenges. The results showed how companies were seeking new opportunities and developing their operations with digital twins (innovation as a process); some of the companies' innovation activities were conducted as firm-only processes, while others as network-level processes. Overall, the development of networking was emphasised, as the digital twin will enable cooperation between different parties.

> *In my opinion, it would be good to be an open platform that has these digital twins, and it would also not hinder, that it would reach out to external developers, that external parties would have more information and skills, that innovations would probably increase, and that it would then help the whole ecosystem to develop.* (The development manager, Company C)

P7: The characteristics of a digital twin are dependent on the understanding of innovation either as a process or as an outcome.

The results also demonstrate the importance of the distinct characteristics of digital twins. Distinct characteristics impact the extent to which digital twins can be utilised to achieve different benefits—for example, enhancing decision-making, improving information sharing and collaboration, optimising processes, and boosting sales.

P8: The characteristics of a digital twin determine its implications.

5. Discussion

This study enhances the understanding of how digital twins are integrated into a firm's innovation. The research question is as follows: What implications do digital twins bring to innovation? The study offers an interesting contribution to the digital twin literature: we consider digital twins in the context of innovation and investigate the implications of digital twins in terms of different scopes of operation.

The results of the study show that companies are more actively searching for possibilities to support innovation through the utilisation of digital twins. The findings of the study further indicate that organisations are able to recognise the scope where the utilisation of digital twins can best support innovation and produce positive results. The possible and searched impacts of the utilisation of digital twins in innovation are also recognised both from the service provider's and utiliser's perspectives. However, these recognised advantages seem to rely on boosting existing business elements and optimising processes. It is still uncommon to add digital twin support to a product during its early design phase, even though their supporting elements as a part of innovation are understood.

Thus, the study reveals three distinct issues that describe the current state of digital twins' utilisation in innovation activities. First, the efforts of companies toward value-centric innovation through digital twin solutions were recognised (cf. Lim, Zheng, and Chen 2020). The technology and product-oriented innovations around digital twins are considered just one aspect of innovation, and the focus is shifting rapidly toward the entire value chain to strive for new business opportunities for the entire network. This is in line with prior research suggesting that the use of digital twins provides novel innovation and value creation opportunities for industrial companies (Chirumalla 2021; Blichfeldt and Faullant 2021). Thus, this study proposes that the characteristics of digital twins are dependent on the understanding of innovation as either a process or an outcome.

Second, the findings indicate that innovations related to digital twins allow for a completely new kind of cooperation, for example, in the form of open platforms. This means simultaneous and mutual creation of all types of innovations around digital twins, where digital twins are considered as open platforms that in turn allow simultaneous upgrading of technologies, communication, and data sharing among partners. This study shows that these efforts require various characteristics of digital twins, such as exploration, experimentation, optimisation, interaction, discovery, and guidance. The result is in line with Cheng et al. (2020), who concluded that digital twins enable collaboration that is more than just the integration and sharing of data between upstream and downstream companies. As the rise in the use of digital twins includes transformations in technology and production (Cimino, Negri, and Fumagalli 2019; Liu et al. 2019; Tao et al. 2019), the organisational implications may also vary (Lim, Zheng, and Chen 2020; Parmar, Leiponen, and Thomas 2020). Thus, this study proposes that the characteristics of digital twins determine the implications of their use.

Third, the results support prior research concluding that digital twins have various applications in multiple scopes (Fuller et al. 2020; Qi et al. 2021; Rasheed, San, and Kvamsdal 2020). Some studies (e.g. Rasheed, San, and Kvamsdal 2020) have highlighted digital twins' ability to combine the real and digital worlds in a way that enables novel types of business model innovation, but this possibility has not been fully exploited in the studied companies. Although the companies were actively striving for new ways to leverage digital twins in their businesses, looking for new business opportunities and seeking answers to various challenges, the focus was still developing existing operations. This development perspective can prevent companies from understanding the potential of twin-based innovations to create novel earning models. Thus, we propose that making greater use of a digital twin facilitates product development and design, sales and marketing, maintenance services, cooperation with the customer and within the company, finding new business, and production processes. However, the topic requires further research, because the findings may indicate a need for stand-alone development activities in the companies, focusing only on novel business model innovations around digital twins.

Finally, based on the findings, the study suggests a framework (Figure 1) for the innovation implications of the use of digital twins. The framework provides a foundation for researchers exploring the use of digital twins in innovation. The framework emphasises the need to understand the developmental scope before the type of digital twin innovation can be understood and defined. The type of innovation influences the desired characteristics of the digital twin. Demonstrating the characteristics of digital twins will also help in understanding the type of innovation required and indicate the related implications. In this way, the framework can also promote the exploitation of digital twins as an innovation process that enables collaboration throughout the value chain of product development, manufacturing, operation, and maintenance (cf. Cheng et al. 2020).

6. Conclusion

This study investigates the implications that digital twins have for innovation, presenting empirical evidence supporting a framework for the implications of digital twins. Thus, our study contributes to the existing literature by providing a systematic understanding of the implications of digital twins.

From a theoretical perspective, this study uniquely contributes to the field of innovation and technology management by investigating digital twins with respect to innovation. Our results emphasise the importance of first defining the scope of operation that the digital innovation targets. This typifies the nature of the innovation to be developed. Our findings also suggest that the use of digital twins requires not only an understanding of the nature of innovation but also knowledge of the characteristics of digital twin development. The characteristics of digital twins determine their implications. The developed framework builds on the recognised classification of innovation and specific characteristics of digital twins, which the more technically oriented digital twin studies tend to overlook. Second, the research is the first to systematically study the actual use cases of digital twins and to provide implications for further theoretical and empirical studies on innovation. The study shows that making greater use of digital twins has implications for various scopes of operation, including product development and design, sales and marketing, maintenance services, cooperation, finding new business, and production processes. This framework can be used in future studies investigating the implications of the use of digital twins.

From a practical point of view, the findings of this study provide interesting implications for different practitioners interested in the utilisation of digital twins. Currently, there is growing interest by different innovation management professionals in the use of digital twins, and by studying their actual use, the study provides examples to practitioners concerning how digital twins can be utilised in different contexts. As such, the study findings provide possibilities for the adoption of digital twins to practitioners to support their innovation processes. The framework can be used as a design tool to facilitate the implementation of digital twins. In summary, using the results of this study, managers can enhance their companies' digital transformation by acknowledging the multiple uses of digital twins.

While the results of this study reveal that both digital twin service providers and utilisers can recognise the scopes and impacts of the utilisation of digital twins in innovation processes, an understanding of their actual effectiveness is still rare. As such, further studies may be needed to explore the effectiveness of digital twins in the innovation processes in organisations. It may be valuable and important to understand more about the characteristics of a digital twin that generate value in innovation processes.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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References

Aheleroff, S., X. Xu, R. Y. Zhong, and Y. Lu. 2021. "Digital Twin as a Service (DTaaS) in Industry 4.0: An Architecture Reference Model." *Advanced Engineering Informatics* 47: 101225.
Amit, R., and C. Zott. 2010. Business model innovation: Creating value in times of change. Working Paper, No. WP-870. IESE Business School, Spain.
Bao, J., D. Guo, J. Li, and J. Zhang. 2019. "The Modelling and Operations for the Digital Twin in the Context of Manufacturing." *Enterprise Information Systems* 13 (4): 534–556.
Blichfeldt, H., and R. Faullant. 2021. "Performance Effects of Digital Technology Adoption and Product & Service Innovation – A Process-Industry Perspective." *Technovation* 105: 102275.
Carboni, O. A., and P. Russu. 2018. "Complementarity in Product, Process, and Organizational Innovation Decisions: Evidence from European Firms." *R&D Management* 48 (2): 210–222.
Cheng, J., H. Zhang, F. Tao, and C. F. Juang. 2020. "DT-II:Digital Twin Enhanced Industrial Internet Reference Framework Towards Smart Manufacturing." *Robotics and Computer-Integrated Manufacturing* 62: 101881.
Chirumalla, K. 2021. "Building Digitally-Enabled Process Innovation in the Process Industries: A Dynamic Capabilities Approach." *Technovation* 102256.
Cimino, C., E. Negri, and L. Fumagalli. 2019. "Review of Digital Twin Applications in Manufacturing." *Computers in Industry* 113: 103130.
Crossan, M. M., and M. Apaydin. 2010. "A Multi-Dimensional Framework of Organizational Innovation: A Systematic Review of the Literature." *Journal of Management Studies* 47 (6): 1154–1191.
Crowe, S., K. Cresswell, A. Robertson, G. Huby, A. Avery, and A. Sheikh. 2011. "The Case Study Approach." *BMC Medical Research Methodology* 11 (1): 1–9.
Eisenhardt, K. M. 1989. "Building Theories from Case Study Research." *The Academy of Management Review* 14 (4): 532–550.
Errandonea, I., S. Beltrán, and S. Arrizabalaga. 2020. "Digital Twin for Maintenance: A Literature Review." *Computers in Industry* 123: 103316.
Fuller, A., Z. Fan, C. Day, and C. Barlow. 2020. "Digital Twin: Enabling Technologies, Challenges and Open Research." *IEEE Access* 8: 108952–108971.
He, B., and K. J. Bai. 2021. "Digital Twin-Based Sustainable Intelligent Manufacturing: A Review." *Advances in Manufacturing* 9 (1): 1–21.
Hilbolling, S., H. Berends, F. Deken, and P. Tuertscher. 2020. "Complementors as Connectors: Managing Open Innovation Around Digital Product Platforms." *R&D Management* 50 (1): 18–30.
Ketokivi, M., and T. Choi. 2014. "Renaissance of Case Research as a Scientific Method." *Journal of Operations Management* 32 (5): 232–240.
Kritzinger, W., M. Karner, G. Traar, J. Henjes, and W. Sihn. 2018. "Digital Twin in Manufacturing: A Categorical Literature Review and Classification." *IFAC-PapersOnLine* 51 (11): 1016–1022.
Lim, K. Y. H., P. Zheng, and C. H. Chen. 2020. "A State-of-the-art Survey of Digital Twin: Techniques, Engineering Product Lifecycle Management and Business Innovation Perspectives." *Journal of Intelligent Manufacturing* 31: 1313–1337.

Liu, M., S. Fang, H. Dong, and C. Xu. 2021. "Review of Digital Twin About Concepts, Technologies, and Industrial Applications." *Journal of Manufacturing Systems* 58: 346–361.
Liu, Q., H. Zhang, J. Leng, and X. Chen. 2019. "Digital Twin-Driven Rapid Individualised Designing of Automated Flow-Shop Manufacturing System." *International Journal of Production Research* 57 (12): 3903–3919.
Muscio, A., and A. Ciffolilli. 2020. "What Drives the Capacity to Integrate Industry 4.0 Technologies? Evidence from European R&D Projects." *Economics of Innovation and New Technology* 29 (2): 169–183.
Parmar, R., A. Leiponen, and L. D. Thomas. 2020. "Building an Organizational Digital Twin." *Business Horizons* 63 (6): 725–736.
Qi, Q., F. Tao, T. Hu, N. Anwer, A. Liu, Y. Wei, L. Wang, and A. Y. C. Nee. 2021. "Enabling Technologies and Tools for Digital Twin." *Journal of Manufacturing Systems* 58: 3–21.
Rasheed, A., O. San, and T. Kvamsdal. 2020. "Digital Twin: Values, Challenges and Enablers from a Modeling Perspective." *IEEE Access* 8: 21980–22012.
Shao, G., and M. Helu. 2020. "Framework for a Digital Twin in Manufacturing: Scope and Requirements." *Manufacturing Letters* 24: 105–107.
Stake, R. E. 1995. *The art of Case Study Research*. Thousand Oaks, CA: Sage.
Tao, F., F. Sui, A. Liu, Q. Qi, M. Zhang, B. Song, Z. Guo, S. C. Y. Lu, and A. Y. Nee. 2019. "Digital Twin-Driven Product Design Framework." *International Journal of Production Research* 57 (12): 3935–3953.
Urbinati, A., D. Chiaroni, V. Chiesa, and F. Frattini. 2020. "The Role of Digital Technologies in Open Innovation Processes: An Exploratory Multiple Case Study Analysis." *R&D Management* 50 (1): 136–160.
Voss, C, N Tsikriktsis, and M Frohlich. 2002. "Case Research in Operations Management." *International Journal of Operations and Production Management* 22 (2): 195–219.
Wang, C. L., and P. K. Ahmed. 2004. "The Development and Validation of the Organisational Innovativeness Construct Using Confirmatory Factor Analysis." *European Journal of Innovation Management* 7 (4): 303–313.
Wang, Y., H. S. Ma, J. H. Yang, and K. S. Wang. 2017. "Industry 4.0: A way from Mass Customization to Mass Personalization Production." *Advances in Manufacturing* 5 (4): 311–320.
Wang, Q., C. Voss, X. Zhao, and Z. Wang. 2015. "Modes of Service Innovation: A Typology." *Industrial Management & Data Systems* 115 (7): 1358–1382.
Yin, R. K. 1981. "The Case Study as a Serious Research Strategy." *Knowledge* 3 (1): 97–114.
Yin, R. K. 2003. *Case Study Research: Design and Methods (3rd ed.)*. Thousand Oaks, CA: Sage.
Yin, R. K. 2014. *Case Study Research: Design and Methods. (5th edn.)*. Thousand Oaks, CA: SAGE.
Zheng, P., Lin, T. J., Chen, C. H., & Xu, X. (2018). A Systematic Design Approach for Service Innovation of Smart Product-Service Systems. Journal of Cleaner Production, 201, 657-667.
Zhou, G, C Zhang, Z Li, K Ding. 2020. "Knowledge-Driven Digital Twin Manufacturing Cell Towards Intelligent Manufacturing." *International Journal of Production Research* 58 (4): 1034–1051.

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