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Design and Data-Driven Strategic Management Model Based on Digital Twin

Osman Akarsu [1]

Abstract

This conceptual study introduces the design-oriented strategic management model developed for organizations to adapt to rapidly changing technological, economic and social environmental conditions. The main purpose of the study is to propose a holistic and applicable model that integrates technology, user-centered design and scientific solution generation into strategic decision-making processes. The model consists of four phases: data integration and digital twinning, development with a user-centered design approach, generation of scientific and innovative solutions, and predictive/scenario-based decision making. Each stage is structured in a way that is integrated with the principles of technological applicability, user desirability and economic sustainability. In the development of this model, the design science research method was adopted and a structured, theoretically based and practically applicable management model was put forward to produce solutions to organizational problems. The model allows organizations not only to analyze the current situation but also to develop proactive strategies by anticipating uncertain future scenarios. In this respect, the model allows decision-makers to assess technical competence, people orientation and organizational fit in a holistic manner. It advances the literature by providing a unique and practical strategic management framework that combines management, design thinking and advanced technologies. Additionally, the model enhances Porter's core strategies—cost leadership, differentiation, and focus—by integrating dynamic, data-driven feedback and user insights. It incorporates scenario-based modeling to guide strategic choices such as forward/backward integration and vertical/horizontal growth, and supports inter-firm alliances through data sharing and shared value creation enabled by digital twins. Grounded in complex systems theory, it offers a robust framework for rapid adaptation to uncertainty and complexity. This framework integrates the continuous and multi-layered nature of change, the pace of technological innovation, and the interactive dynamics predicted by complex systems theory, thereby offering a new perspective to the literature in today's uncertain environment.

Keywords: Strategic Management, Design Science Research, Design Thinking, Digital Twins, Complex Systems

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Dijital İkiz Tabanlı Tasarım ve Veri Odaklı Stratejik Yönetim Modeli

Osman Akarsu [1]

Öz

Bu kavramsal çalışma, örgütlerin hızla değişen teknolojik, ekonomik ve toplumsal çevre koşullarına uyum sağlayabilmesi amacıyla geliştirilen tasarım odaklı stratejik yönetim modelini tanıtmaktadır. Çalışmanın temel amacı, stratejik karar alma süreçlerine teknoloji, kullanıcı merkezli tasarım ve bilimsel çözüm üretimini entegre eden bütüncül ve uygulanabilir bir model önermektir. Model, veri entegrasyonu ve dijital ikiz oluşturma, kullanıcı merkezli tasarım yaklaşımıyla geliştirme, bilimsel ve yenilikçi çözümler üretme ve öngörüsel/senaryo tabanlı karar alma olmak üzere dört aşamadan oluşmaktadır. Her aşama, teknolojik uygulanabilirlik, kullanıcı arzulanırlığı ve ekonomik sürdürülebilirlik ilkeleriyle bütünleştirilmiş şekilde yapılandırılmıştır. Bu modelin geliştirilmesinde, tasarım bilimi araştırması yöntemi benimsenmiş ve örgütsel sorunlara çözüm üretmeye yönelik olarak yapısal, teorik temelli ve pratik uygulanabilirliği yüksek bir yönetim modeli ortaya konmuştur. Model, örgütlerin yalnızca mevcut durumu analiz etmesine değil, aynı zamanda belirsizlik içeren gelecek senaryoları öngörerek proaktif stratejiler geliştirmesine olanak tanımaktadır. Bu yönüyle model, karar vericilerin teknik yeterlilik, insan odaklılık ve kurumsal uyumu bütüncül biçimde değerlendirmelerine imkân vermektedir. Yönetim, tasarım düşüncesi ve ileri teknolojilerin bir arada ele alındığı özgün ve uygulamaya dönük bir stratejik yönetim çerçevesi sunarak literatürü ilerletmektedir. Ayrıca model, dinamik, veri odaklı geri bildirim ve kullanıcı içgörülerini entegre ederek Porter'ın maliyet liderliği, farklılaşma ve odaklanma temel stratejilerini geliştirmektedir. İleri/geri entegrasyon ve dikey/yatay büyüme gibi stratejik seçimlere rehberlik etmek için senaryo tabanlı modellemeyi bünyesinde barındırmakta ve dijital ikizlerin sağladığı veri paylaşımı ve paylaşılan değer yaratımı yoluyla firmalar arası ittifakları desteklemektedir. Karmaşık sistem teorisine dayanan bu yaklaşım, belirsizlik ve karmaşıklığa hızlı adaptasyon için sağlam bir çerçeve sunmaktadır. Bu çerçeve, değişimin sürekli ve çok katmanlı doğasını, teknolojik yeniliklerin hızını ve karmaşık sistemler teorisinin öngördüğü etkileşimsel dinamikleri bütünleştirerek günümüzün belirsizlik ortamında literatüre yeni bir perspektif kazandırmaktadır.

Anahtar Kelimeler: Stratejik Yönetim, Tasarım Bilimi Araştırması, Tasarım Düşüncesi, Dijital İkizler, Karmaşık Sistemler Teorisi

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Introduction

As we approach the mid-21st century, the increasing digitalization and revolutionary developments in today's business life have changed our strategy shaping processes (Kohtamäki et al. 2025, p. 3-4) especially in decision-making speed and data driven strategy selection (Barile, Secundo, & Del Vecchio, 2025; Irk and Döven, 2018). In a changing competitive environment, organizations require strategic management models that can be flexible and adaptive, or rigid and closed, while remaining compatible with their resources and goals and fully integrated into the organization. For managers in this era, strategy is no longer a static plan, but a continuously evolving and value-oriented process (Lähteenmäki et al., 2022, p. 504). Accessing the right information from the big-data driven information systems have become critical for strategic decision-making in order to make management decisions effectively and efficiently. From this perspective, it can be said that new technologies are adopted not when they are invented, but when a change or progress in management theory provides managers with the space to apply this new technology. The way in which existing organizational problems are addressed has naturally changed in this "fast-paced" world with its "volatile, uncertain, complex and ambiguous" (VUCA) environment (Aimar and Smith, 2021, p. 141-142), requiring managers to revise and review their organizations' strategies according to the changing conditions.

Digital transformation has enabled the decision-making mechanisms of businesses and their top management to become more data-driven and flexible (Gölzer and Fritzsche, 2017, p. 1336-1337). This issue can be seen in the rational decision-making of organizations (Chandler Jr, 1969, p. 142-143), improvisation due to the fact that technology affects the contingency of time (Mintzberg, 1987, p. 16), and overlap in terms of compatibility with the core competencies of today's digital workers (Prahalad and Hamel, 2009, p. 42; Porter, 1985, p. 73). In particular, companies that adopt "design thinking through a combination of problem finding, problem solving, and dynamic capabilities approaches are more likely to take a more effective and reactive stance to existing problems" (Cristofaro et al., 2025: 34), is in line with the strategy literature. In addition, since traditional strategy development approaches are considered to be insufficient to cover data-driven, rapid feedback, user-centered and cyclical models, this study will focus on a design-oriented dynamic strategic management model within the framework of today's popular topic of digital twin. Ivanov (2025) defines a traditional digital twin as a replication of the key components of a network, including its structure, products, customers, and associated processes such as production, distribution, and sourcing along with their control mechanisms. In this study, the design science research methodology introduced by Peffers et al. (2007, p. 52-56) was preferred as the methodology.

A digital twin is a real-time digital simulation of a physical object, process, or system, allowing its behavior, performance, and interactions to be monitored virtually (Bolton, McColl-Kennedy, Cheung, Gallan, Orsingher et al., 2018). By providing a precise representation of physical systems in the digital environment, digital twin technology enables businesses to make their decision-making processes more predictable, optimizable, and data-driven. Design science, on the other hand, focuses on efforts to 'search, understand and improve potential components in order to create an artifact that aims to solve the problem' (Baskerville, 2008, p. 441), complementing the use of digital twins by offering a structured approach to designing and improving organizational solutions. Design science seems to be more of a research paradigm than a research methodology (Iivari, 2007, p. 50). On the business side of the issue, evaluating information systems through the active and intensive use of information technologies and designing information in line with the needs of the organization are becoming important today. There are calls in the literature for how design science studies should be created and integrated with other fields such as entrepreneurship and strategy (Dimov et al., 2023, p. 1543). While this is the case in theory, it is possible to see similar calls in practice. Most of the current job advertisements emphasize the value of design thinking, building a facilitative experience with the customer. The importance given to user interface (UI) and user experience (UX) is indicative of this (Hamidli, 2023, p. 8-9). In order to use design effectively in organizations, it is necessary to understand how design is managed and guided. Design management and leadership is also vital, especially for organizations that want to use design effectively as a tool for technological innovation and change (Laamanen, 2024, p. 12).

Using the perspectives of design science in general and design thinking in particular, this paper sheds light on the systematic and sequential integration, management, monitoring and optimization of the digital twin concept into business strategies. The model is expected to offer a dual contribution, both by guiding strategic planning processes and by enhancing the efficiency of operational processes. Existing studies often focus on micro areas such as technology management (Adomavicius et al., 2008; Tuunanen et al., 2024), product development (Van Aken, 2005; Frischknecht et al., 2009), innovation (Hevner et al., 2019; Huseynli et al., 2022), etc., lacking an original framework on how to utilize this combination in macro-level business strategy formulation. Similar studies in the literature are noteworthy, but they differ from this study in terms of the context they examine. While this study focuses on developing a more holistic, application-oriented, and integrated strategic management model, Efeoglu and Møller (2025) provide a conceptual and qualitative contribution to how design thinking can be perceived and used by managers in strategic contexts. The authors' study does not present a model-based, phased, and application-oriented framework, nor does it propose concrete, integrated solutions to abstract strategic problems from a management perspective. Instead, it discusses the potential of design thinking and how it can be used by managers. Moll et al. (2007) conceptualize design as a strategic resource and demonstrate through concrete case studies that this approach strengthens market focus and improves business performance. Firms pursue strategies byconsidering elements of market structure (Dilek and Kesgingöz, 2020: 973) and competitiveness level (Kesgingöz et al., 2019). While Rocco & Selinšek (2020) highlight the relationship between design orientation and market orientation and the impact of managers' approaches on this relationship, our model offers a more comprehensive and application-oriented strategic management framework. Although many studies in the literature converge on the "importance of design in strategic management" (Chen and Venkatesh, 2013; Barzelay, 2023), the model proposed in this study offers a more advanced and ready-to-implement framework in terms of technological integration, predictive analysis and systematic structure.

This research aims to propose a dynamic model that combines digital twin and design thinking to enable businesses to create more iterative and data-driven decision-making mechanisms in their strategies. In this study, we argue that today's firms' strategic management models alone are insufficient to adapt and shape the changing digitalized world. We base our argument on the fact that the ways in which current organizational problems are addressed are naturally changing in this turbulent business environment and that digital transformation is making strategic decision-making more data-driven and flexible. Unlike traditional strategic management models that often focus on static planning and linear decision-making (De Toni and Tonchia, 2003), the proposed model adopts a dynamic, iterative, and feedback-driven structure that integrates data, design, and scientific reasoning in real time. By combining the principles of digital twin, design thinking, and design science, it offers an adaptive and learning-oriented framework that aligns technological innovation with organizational and human dimensions. This study is important because it provides a systematic framework for strategy development, especially in sectors with high uncertainty and complexity. In particular, the model adds a new dimension to Porter's core strategies of cost leadership, differentiation and focus with dynamic and data-driven feedback and user insights. It also offers scenario-based modeling for determining orientation such as forward-backward integration, vertical and horizontal growth. In terms of suitability for alliances between firms, it is linked to the dynamics of data sharing and shared value creation through digital twins. Drawing on complex systems theoretical background, this study proposes a design-oriented strategic management model for rapid adaptation to changing conditions and demand-side changes.

This study consists of 6 chapters. The second chapter briefly introduces design science research, which forms the methodological basis of the study. In the second chapter, complex systems theory, which constitutes the theoretical background of the study, is briefly defined and its potential effects on business strategy are discussed. In the third chapter, the concept of digital twin and its importance for businesses is discussed. In the fourth section, the effects of design thinking and design science approaches on business strategy are discussed. The fifth section introduces the design and data-driven strategic management model based on the digital twin. In the last section, discussion and conclusion are discussed and suggestions are made for future studies.

Methodology and Theoretical Framework

The research methodology in this study is based on the design science research methodology proposed by (Peffers et al., 2007, p. 52-56). The design-oriented strategic management model developed in this study is based on the Design Science Research Methodology (DSRM) framework. The research process is structured in line with the six-stage methodological approach developed by Peffers et al. (2007, p. 52-56). Within the scope of this approach, firstly, the need to adapt to the technological, economic and social environmental changes faced by organizations was identified as the main problem. In this context, the theoretical framework of the study is based on complex systems theory and technology acceptance model. Then, objectives were defined that reflect the capacity of the proposed model to produce solutions for businesses in line with the principles of technology integration, user-centeredness and economic sustainability. In the design and development phase, the four-stage structure of the model was created in the light of the theoretical foundations. The applicability of the model was demonstrated through hypothetical scenarios, while its theoretical consistency was assessed through comparative analysis with existing literature and mathematical decision functions. Finally, care has been taken to present the model effectively for both academic and practitioner audiences. This systematic approach deepens the theoretical contributions of the proposed model while making its application potential clear and structured.

In this context, the model developed in this study is not only a design proposal but also a structural framework and theoretical contribution to the field of strategic management. The construction process of the model, in addition to producing a solution for a specific problem, also serves the production of scientific knowledge with its observable and evaluable structure at every stage of the process. Thus, the research not only proposes a new model for strategic decision-making processes, but also makes a theoretical contribution to the academic literature by drawing on methodological integrity based on design science (Cronholm and Göbel, 2015, p. 471; Hevner et al., 2004, p. 83; Tuunanen et al., 2024, p. 427).

The design science research method, which is mostly characterized by natural sciences, has started to be used in the field of management information systems as a product of methodological expansion (Leong et al., 2025, p. 701). The fact that the method used in this research provides a theoretical framework for a model proposal that can be used by businesses in strategy development processes has the potential to provide solutions to some methodological problems under the umbrella of management sciences such as the problem of utilization (Aken, 2004, p. 219) and the dilemma of rigor and relevance (Argyris and Schön, 1989, p. 612). In addition, a growing body of literature (Çanakoğlu et al., 2018, p. 604; Demirel et al., 2024: 564), in which the challenges, adaptation problems, and customer demands are advised to be addressed in a data-driven manner alongside the opportunities offered by technology, suggests that the design science research method will be increasingly used.

In today's world, where we are experiencing the Fourth Industrial Revolution (Industry 4.0), the transition towards a circular economy has become essential (Bücker et al., 2025, p. 1). This transformation requires a shift from traditional production processes to more sustainable, resource-efficient and closed-loop systems (He and Bai, 2021, p. 12). This value creation process makes it imperative for users to make products meaningful to them (Verganti, 2009, p. 4) and for businesses to evolve their operations and strategies into transformative business models (Heyes et al., 2018, p. 621). Change can be driven by changes in a single element of the environment (e.g. technological advancement) or by changes in multiple elements (e.g. a technological innovation coinciding with changing consumer preferences) (Cristofaro et al., 2025, p. 30). The impact of innovative approaches such as cyber-physical systems (CPS) on production planning and control (PPC) and modern production processes is manifested in the evolution of production towards increasingly autonomous and decentralized network structures (Antons and Arlinghaus, 2022, p. 4344).

Considering these multidimensional and multifunctional environmental factors together can lead organizations towards unclear conclusions or excessive focus. Since no problem or solution is valid without context, organizations cannot keep their strategies away from the effects of this transformation. For this reason, the theoretical background of complex systems is utilized in this study. Complex systems are characterized by a large network of multiple components, multiple communication channels, and sophisticated information processing processes that make it difficult to predict system states.

Ackoff (1994, p. 175) defined organizations as mechanical, organic and social systems in which people individually and collectively play important roles. They are systems that have their own purposes, are composed of parts that have their own purposes, and are parts of larger systems that include other systems that have their own purposes. For organizations, this approach can predict and satisfy the needs of today's world of pleasure and speed by increasing the diversity of means and ends. As a product of theoretical expansion, complex systems, which are mostly used in technologically intensive systems such as aircraft engines, spacecraft, power plants, etc., can be used in strategy development processes in businesses and in the design and reconstruction of social systems. Schneider et al. (2017, p. 183) stated in their study that the complexity difference between a system and its environment is the defining element of all social systems. From this point of view, within the scope of the study, the theoretical infrastructure was formed around the complex systems theory with the assumption that organizations are highly influenced by their technological environment as well as all kinds of environments in their strategy formulation processes.

Complex systems theory is an interdisciplinary approach that explores how individual components of a system interact to produce emergent, often unpredictable, macro-level outcomes (Gharajedaghi, 2011. 139-140). Characterized by features such as non-linearity, feedback loops, adaptation and self-organization, the theory provides a robust theoretical lens for analyzing dynamic and interdependent systems across disciplines, including biology, economics and organizational studies. In this study, complex systems theory will be used specifically to understand the behavior of stakeholders, and then its potential implications for strategy development processes will be evaluated within the framework of the theory's discourse on the holistic inquiry process (Gharajedaghi, 2011: 136). We argue that business strategy can be significantly shaped through the integration of design science thinking and digital twins, with complex systems theory as a backdrop.

Sayğan (2014) made a significant contribution to the organizational science literature by conceptually integrating complex systems theory into the field of management. The study provides an in-depth explanation of the multilayered and interactive nature of organizations through principles such as nonlinear relationships, the butterfly effect, self-organization, and emergence. In this respect, Sayğan's approach provides a strong theoretical foundation for understanding the nature of organizational behavior in dynamic environmental conditions. However, the capacity of complex systems to learn and adapt over time, the impact of digital data flows on system evolution, and the modeling of agent-based interactions are inherently limited within this theoretical framework. The current study takes this strong foundation a step further and proposes a dynamic model that integrates digital twin technology and design science approaches. Thus, the learning, adapting, and insight-generating aspects of complex systems can be concretely monitored and managed in digital environments.

Design thinking guides stakeholders to explore problems iteratively, while digital twins provide real-time simulations and feedback loops that reveal emergent behaviors and enable dynamic adaptation of strategies. This integration allows organizations to test scenarios, continuously refine solutions, and align micro-level interventions with macro-level strategic objectives. By explicitly modeling agent interactions, learning processes, and system interdependencies, the approach captures both the unpredictability and adaptive potential inherent in complex systems. Ultimately, it offers a practical framework for data-driven, user-centered, and resilient strategy development, effectively translating theoretical principles into actionable business strategy. Design thinking offers a human-centered, iterative framework for overcoming complexity and fostering innovation (Plattner et al., 2009, p. 123-124). This iterative process aligns well with the adaptive nature of complex systems, focusing on empathy, experimentation and continuous feedback. On the other hand, digital twins are known to be able to provide real-time, data-driven simulations of physical entities, processes or systems. By enabling scenario testing, predictive analytics and the exploration of systemic interdependencies, digital twins can enable strategic foresight and more flexible decision-making.

By synthesizing complex systems theory with design thinking and digital twins, organizations can shape their strategies, better manage uncertainty, predict emergent behavior, and co-create strategic solutions that are both innovative and adaptive in rapidly evolving environments. These phenomena have been discussed in the literature in recent years under separate headings in terms of business process management and business models (Adelsberger et al., 2024, p. 410), design thinking (Nakudom et al., 2023, p. 11), process optimization (Karkaria et al., 2024, p. 322; Zhang et al., 2023, p. 1), business intelligence (Tanev, 2024, p. 57) and digital twin. This study is in line with the discourses of the expectation confirmation model (ECM), which examines users' adoption and acceptance of new technologies (Hossain and Quaddus, 2011, p. 445-446), and the Technology Acceptance Model (TAM), a theoretical model that predicts the acceptance and use of technology by identifying two key factors: perceived usefulness and perceived ease of use (Davis, 1989, p. 3). These phenomena, which can also be considered as a dynamic capability for businesses, have been addressed within the scope of the study in the axis of complex systems theory as it includes a multidisciplinary perspective.

The Concept of Digital Twin and Its Importance for Businesses

Rooted in product lifecycle management, digital twin technology is a virtual representation of physical assets and provides businesses with real-time data collection, analysis and simulation capabilities (Bécue et al., 2020, p. 8). A digital twin is an integrated, multi-physical, multi-scale, multi-scale and probabilistic simulation of a complex product that reflects the life cycle of its twin (Glaessgen and Stargel, 2012, p. 7). As such, it functions as a bridge between the physical world and the digital world. An infinite number of copies can be produced. In the future, it is claimed that everything in the physical world will be replicated in the digital space thanks to digital twin technology (Qi et al., 2021, p. 3). Digital twin technology has been widely adopted with Industry 4.0, especially in the manufacturing, logistics and service sectors (Javaid et al., 2023, p.84; Vachálek et al., 2017, p. 258). Digital twins are important for businesses in terms of real-time decision-making (Fathy et al., 2021, p. 1), instant analysis of physical systems (Rasheed et al., 2020, p. 21982), and improving strategic decision-making that prioritizes value co-creation, especially in service businesses by predicting possible future scenarios (West et al., 2021, p. 1; Yan et al., 2022, p. 1095).

Although strategies have been proposed in different contexts and by different people, their common goal is to capture the opportunities brought by the integration of physical and virtual spaces (Semeraro et al., 2021, p. 1). In addition, strategies can also enable businesses to use resources more effectively and increase efficiency through predictive analysis and data-driven optimization (Min et al., 2019, p. 517). As such, the literature suggests that the use of digital twin technology can make the decision-making processes of businesses more predictable and optimizable as the representation of physical systems in the digital environment. Particularly in terms of strategic management, we would like to draw attention to the iterative, explicit and implicit customer needs-centered process that emphasizes the feedback loops of design thinking through digital twins at the point of achieving goals and objectives.

Competitive advantage for businesses will be redesigned in the light of potential data from an unknown future, and this will offer a more flexible and expectation-oriented strategic management model with an approach that focuses on customer needs. In this way, the operational plan will be created with the digital twin integration of the necessary changes and these will be addressed with design thinking elements within the framework of customer feedback. This issue will also contribute to the process of instant monitoring of demand-driven external change in the environment, harmonization and integration of internal changes in which the design elements brought by technological innovations are put to work.

The idea of transferring and adapting the digital twin concept to business processes opens up new potentials, perspectives and pathways for advanced digital transformation of businesses (Rabe and Kilic, 2023, p. 353). The literature emphasizes that digital twins are transforming the way individuals and organizations work through the Internet of Things, monitoring and automating physical processes, mostly through the widespread deployment of sensors and actuators. In this context, the concept of digital twin needs to be diversified and restructured in line with these technological developments. Fornari et al. (2024, p. 1) emphasized this necessity in their study and stated that "combining business process models with real-time data and simulation capabilities can provide a new way to guide daily organizational activities".

As a response to this call, in this study, digital twins are used in a new model that is instrumentalized to create and shape business strategies that can guide the daily operational activities of businesses, not only as a mate, a virtual counterpart of the data coming from the Internet of Things. Digital twins are critical for businesses to promote differentiation and value-creating strategies. Digital twins have started to emerge as an emerging phenomenon in the literature not only in terms of addressing business processes (Karagiannis, 2024, p. 134) but also in terms of creating business processes enhanced by the Internet of Things (Janiesch et al., 2020, p, 34-35).

The potential impacts of digital twins on business model components such as improving strategic resource allocation (Wang et al., 2021, p. 165), leveraging customer experience through smart, high-quality product and service offerings (Setia et al., 2013, p. 571-572), and innovating production, supply, and financial models to maximize value creation are discussed in the literature (Lim et al., 2020, p. 1327). Apart from these, digital twins are increasingly addressed in different contexts in the literature with concepts such as digital twin for manufacturing, digital twin of systems and digital twin for business model (Kritzinger et al., 2018, p. 1016-1018). However, studies that integrate digital twin technology into strategy formulation processes are not found in the literature. In addition, addressing this integration with design thinking and design science approaches reveals the originality of the study.

The Impact of Design Thinking and Design Science Approaches on Business Strategies

Tim Brown expresses the concept as follows at the beginning of his groundbreaking article introducing design thinking. "Thinking like a designer can change the way you develop products, services, processes and even strategies" (Brown, 2008, p. 1). In the author's work, design thinking is expressed as what people want and need in their lives and what they like or dislike about the way certain products are produced, packaged, marketed, sold and supported (Brown, 2008, p. 1). When we consider the concept from this point, design thinking summarizes an approach that emerges as a result of communication between layers in terms of shaping the strategies of businesses regarding their products and services. These layers, in their simplified form, include stages such as data, technology, product, experience, system and result. Design thinking is based on a systematic method for developing innovative solutions in products, services and processes. It also includes a way of thinking about how to apply these methods and defines innovation as the intersection between desirability (human dimension), feasibility (technological dimension) and sustainability (business dimension) (Goller and Bessant, 2023, p. 215). With this study, digital twin, design thinking and business strategy can be seen as an effort to combine, although they are thought to cover different areas of innovation. Design thinking has stages such as empathy, definition, idea generation, prototyping, testing and implementation (Goller and Bessant, 2023, p. 218-223).

• Empathy is an approach that aims to develop solutions that are in line with users' needs rather than assumptions by trying to deeply understand their real behaviors, experiences, and contexts.

• Definition is a process that accepts that the apparent problem may actually be a symptom of a wider problem, and that explores different problem definitions and develops a common understanding, paving the way for creative and effective solutions.

• The idea generation phase is a creative process that encourages innovative thinking by postponing judgment, utilizes extreme ideas and visual tools, and focuses on developing new solutions by combining individual unconscious processes with group interaction.

• Prototyping is a gradual discovery process that allows for experimentation, learning, and revealing potential flaws in the design by embodying ideas instead of planning the perfect solution from scratch, progressing with interactive experiences and providing structure to the solution process.

• The testing phase is an experimental process that aims to learn from mistakes and continuously improve solutions by testing hypotheses on users with rapid trial-learning cycles instead of a comprehensive development process.

• Implementation is the process of bringing an idea to life, but it is not the end of the process; it is a continuous transformation phase that reveals opportunities for improvement and redefinition with new feedback and allows ideas to evolve as they spread.

In this respect, design thinking has become a dynamic approach to embedding innovation into business strategy, especially in increasingly complex and fast-paced markets (Diderich, 2020, p. 6). It has also been stated that design thinking combines empathy towards the user, idea generation, prototyping and iterative testing to develop innovation with adaptable and responsive strategies to changing customer needs and market conditions (Luchs et al., 2015, p. 303). This process, which often involves cross-functional teams, encourages a more flexible and holistic strategy approach that aligns well with digital disruption, sustainability initiatives and changing consumer expectations (Attah et al., 2024, p. 3251).

A new theoretical perspective for design thinking in strategy is "Design for Value and Growth" (D4VG) (Walters and Helman, 2019, p. 171-172), which emerged from design-to-value (DTV) practices. In their work, the authors state that design for value and growth focuses on creating both customer and corporate value by aligning well with business environments that require more sustainable, user-centered strategies. Unlike traditional cost-focused strategies, D4VG considers user experience, sustainability, and growth as interconnected drivers. It has been emphasized in the literature that this framework integrates broader design thinking into strategic development by considering not only immediate market needs but also future demands and long-term value creation (Park and Lee, 2021, p. 160).

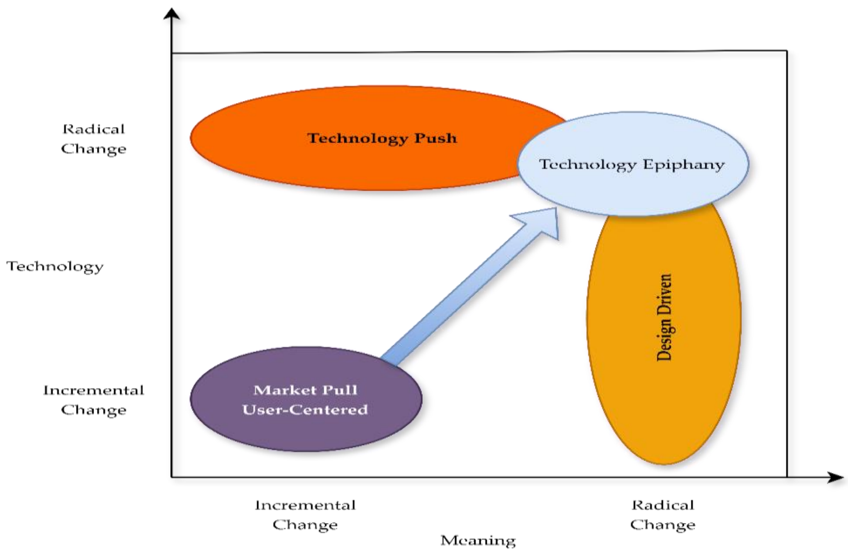
In addition, modern applications of design thinking in strategic contexts are known to embrace systems thinking, which enables organizations to address the complexities of interconnected markets. The systems approach in design thinking allows companies to increase resilience in their strategies by aligning strategic actions with broader societal and environmental impacts (Kannengiesser and Gero, 2019, p. 6-9). By using systems thinking, companies can better anticipate and adapt to market disruptions, regulatory changes, and social changes, thereby creating a strategy that is both sustainable and adaptable to complex business environments. In contrast to traditional strategy approaches, the literature shows that design thinking prioritizes flexibility and sensitivity to uncertainty (Gembarski et al., 2021, p. 563).

Design thinking can be defined as a human-centered, iterative, and creative problem-solving process (Foster, 2021, p. 123; Nandan et al., 2020, p. 311-312). This approach allows for developing innovative solutions in uncertainty (Niehaus and Mocan, 2024, p. 4). It has been stated that when design thinking is combined with a digital twin, it can provide benefits such as improving user experience, creating data-driven iterative loops, and establishing dynamic decision-making mechanisms (Karagiannis, 2024, p. 127). Brown (2008, p. 2) defines design thinking as a discipline in which the designer "uses his sensitivity and methods to match people's needs with what is technologically feasible and what a viable business strategy can transform into customer value and market opportunity." The combination of empathy, integrative thinking, optimism, experimentalism, and collaboration processes makes the idea of design thinking valuable in this respect.

Design-related big data is abundantly available on the Internet and the Internet of Things. On the other hand, some of the big data is generated by customers over the Internet (Tao et al., 2019, p. 3935-3936). An example of this is the complaint management phenomenon that companies carry out with big data analytics from end users about their products (Gray et al., 2020, p. 101).

The value of design thinking is that "professional designers' problem-solving methods are valuable for companies trying to innovate and societies trying to create change" (Kimbell, 2011, p. 285). In this study, the author extends the scope of design thinking beyond managers and professional designers, who may be subject to biases such as anchoring on limited information (Furnham and Boo, 2011, p. 35). Instead, the proposed model emphasizes solving problems with feedback from customers, the end users of products or services, thereby contributing to value creation through the implementation of innovations and changes. The foundations of this perspective were laid by Verganti (2009, p. 52). However, it is thought that the main point is missed in addition to the deficiencies in the author's perspective, the search for meaning, and emphasizing that designers are also human. Being limited to feedback from designers only will mean missing the meanings that end users or consumers create in products, services and systems, and issues such as acceptance and legitimacy. Although the author does not express these issues in this way, he refers to them as "undiscovered enigma". This study aims to clarify this undiscovered enigma. This issue at the intersection of technology and meaning, which the author addresses in the innovation matrix, is expressed with the term "technological epiphany", where the essence of something is suddenly understood (Verganti, 2009, p. 52). Figure 1 presents the interaction between technology-focused innovation and design-focused innovation.

Figure 1. Interaction between technology-driven innovation and design-driven innovation



Source: Verganti (2009, p. 52; 2011, p. 386)

Providing meaningful, purposeful and game-changing products and services from the universe based on big data, revising their strategies with various data from the environment and the customer itself can give businesses a serious competitive advantage over their competitors. The situation will be concretized with a few examples and a design and data-driven strategic management model based on digital twins will be introduced.

Apple Inc., is a world-famous technology company whose products reach countless people all over the world. Let's think that the company shapes the design of its next new models with user data from the product itself or from end users. The company can have a huge design pool by integrating the design of the iPhone phone and the iPad tablet with digital twins and design processes. Similar designs will have a meaning in themselves. In this way, companies will be able to base their strategies on the designs in this data they obtain through digital twins. Big data analytics can facilitate and make this possible. Examples can also be given from outside this sector where there is intense technology.

Let's think about world-famous car brands. Companies currently allow certain levels of configuration of their own designed vehicles via their websites and can leave some product-related issues to individualized preferences. However, let's think about companies that, if not entirely, open up their strategy to the end user through the digital twins of their vehicles, largely, if not entirely, of design innovations from their customers. With their enormous feedback loop and big data analytics capabilities, these companies can shape the design of their vehicles according to current customer requests and potential customer preferences. This can allow companies to determine their strategies based on the data in this feedback, not just for products or services. For example, companies can reduce the production of certain products that do not have time and data allocated to their designs through the digital twins of certain models. With the help of digital twins and design science, companies can learn that they need to increase the quality of some products or cut investments at some points that are unnecessarily costly.

So can this strategy creation process be applied in service businesses? Of course it can be applied. In the case of service businesses, customers can be included in the process by rewarding and gamifying their data contributions as if they were part-employees in the joint production of the service. A private health worker who provides psychological counseling services can change his business strategy by taking the advice of the author of this article that he should switch to virtual and augmented reality applications. A large number of similar recommendations will also have meaningful results for service businesses. In another service business example, an organization that sells insurance can provide data on the digital equivalent of people's risk perception in the physical environment (policies) by using digital twins and design elements. Companies can also shape their strategies around these designs with the data from the digital twins of the policies. They can learn through this channel that they need to offer different product ranges and packages to their customers. In another example, a university that sells an online business strategy certificate course to students from all over the world can determine the strategy to transform the "value creation for customers" module in its curriculum into a "value creation with customers" module with the data it receives from its users through digital twins (curriculum modules) and design elements.

Companies can obtain valuable information about developing artifacts by using digital twins of systems, products and design science advantages of end users and can determine their strategies or micro tactics in a holistic sense. Design element includes different stages of a product's life cycle including production, distribution, usage, maintenance, upgrade and recycling. Integrated feedbacks about each of these stages can use the advantage of creating wholes from seemingly complex and impractical parts in terms of determining and revising strategies. While digital twins provide this technological infrastructure, designing will provide freedom to users in terms of desired choices rather than predicting the future and will provide findings in terms of strategic decisions for businesses.

Just as it is not known whose prayers will be answered, it is also not known who will provide the groundbreaking innovation. Companies can offer this digital twin-based design opportunity to their employees, even if their departments are different, as well as their customers. The issues that the company deems important and invests in large amounts may not have a counterpart in changing customer requests and demands. Similarly, it is a fact that some small elements that the company does not care about regarding products or services may alienate and distance the customer from the product or service. Since the designed product, service or systems will be owned by the user, they can provide very valuable insights in terms of determining strategies. Thus, it will be possible to create a synchronized and integrated whole in terms of design from differentiated parts through digital twins.

The users of products, services or systems are segmented and have their own unique customer base. The ability of mothers looking for a pacifier for their child to design an existing pacifier with a digital twin will provide valuable strategic insights to that company. First of all, only mothers, mothers who have just given birth, and mothers who want the best for their child are people of the same segment. The company, which develops its design competence with the data from these customers, will be able to shape its strategies according to the feedback from these customers. In terms of this contextual integration, determining the strategy with this interactive solution in terms of determining priorities and desired and pragmatic solutions can make meaningful contributions to companies.

It is known that companies are increasingly faced with legitimacy problems (Fisher, 2020, p. 1) originating from both shareholders and non-shareholders. This proposed framework has the potential to eliminate a significant problem, especially in terms of customer stakeholder participation in the products of companies. Apart from these, the developed framework is compatible with the perspectives of companies' own legitimacy (Überbacher, 2014, p. 674) and solving the innovation problem (Gümüsay and Smets, 2020, p. 169-170), combating the biases and misconceptions of existing designers (Furnham and Boo, 2011, p. 35), combating resource dependency, one size fits all mentality (Gregory and Chapman, 2012, p. 1), and helping decision makers reduce their cognitive biases at the individual level (Liedtka, 2015, p. 925). This framework is also compatible with the perspectives of design for value and growth (Walters and Helman, 2019, p. 171-172), digitalization of corporate strategies (Reuter and Floyd, 2024, p. 103-104), creation of a global value chain, digital supply and value chain (Ageron et al., 2020, p. 133-134) and resilient strategy creation. In addition, the model put forward has the potential to contribute to the diversification of the three basic business models (modularity, open innovation and platforms) that form the basis of the organization of the digital economy (Sturgeon, 2021, p. 35).

Design and Data-Driven Strategic Management Model Based on Digital Twin

In this section, a model for the integration of digital twin and design thinking into business strategies will be proposed. Brown (2008, p. 4) defines the design process as “not a series of predefined regular steps but metaphorically a system of spaces”. It is emphasized to understand design as a multidimensional, exploratory and situationally shaped journey rather than a linear and mechanical process. In this respect, each space contains new questions, new insights and new directions. In today’s digital space where pleasure and speed are prioritized, it is important for the phenomenon to include different expansions such as the experience focusing on how the user feels and the interface focusing on what the user sees.

In the digitalizing world, the use of digital twin technology in the design of products and services has become widespread (Attaran and Celik, 2023, p. 1-2; Augustine, 2020, p. 2). Businesses can re-create their strategies by shaping design thinking, which includes inspiration, idea generation and implementation stages, around the concept of digital twin, which is the platform competence of the digital field. Thus, iterative and continuous improvement cycle can be operated by providing real-time data integration with the analysis of data collected from physical systems. As a system methodology, basing the source of convergent and divergent creative thinking on data from end users in terms of its effects on design thinking will enable businesses to create flexible and adaptable strategies, not static, in terms of competencies such as developing future predictions and scenario analysis, and in terms of predictive decision-making. In this section, the model developed for the integration of digital twin, design thinking and design science into business strategies is presented. The components of the model are defined as follows.

Phase 1: Data Integration and Digital Twin Creation

• Real-time data collection from physical systems or users about the legacy product, service or system.

• Use of sensors, IoT and AI-powered data processing algorithms from users.

• Create a dynamic reflection of the physical system, product or service in a virtual environment.

The concept of digital twin is based on cyber-physical systems theory (Alam and El Saddik, 2017, p. 2050-2051; Wolf, 2009, p. 88). In the strategy literature, the concept of real-time strategic responsiveness (La Piana, 2018) is another theoretical expansion that we want to associate at this stage. As an application proposal, it can offer future strategic prediction opportunities by integrating process and output data (sensor, ERP, CRM). In addition, real-time strategic response competence can be provided with real-time data from end users. In support of our claim, Kolko (2010, p. 15) defined the role of the designer as developing appropriate solutions by "organizing complexity and finding meaning in chaos" by blending the needs of the consumer and business world together with aesthetic, cultural and technological trends. This blending process is expressed as an inductive way of thinking aimed at producing solutions, including the steps of data collection, organization, elimination and filtering (Kolko, 2010, p. 21-27).

Phase 2: User-Centered Development with Design Thinking

• User-centered problem definition and hypothesis development.

• Creation of decision support mechanisms with prototyping and simulations.

• Preparation for iterative strategy updates with feedback mechanisms.

Empathy and problem definition in design thinking are related to the concepts of strategic intuition (Khatri and Ng, 2000, p. 57; Shapira et al., 2017, p. 285-286) and sensemaking (Rylander Eklund et al., 2022, p. 24) in strategy development. Persona-based strategic roadmaps with insights from the digital twin as an application recommendation will enable user-centered development. Moscato et al. (2013, p. 165-166) stated in their study that the biggest challenges encountered in the digital ecosystem are the development of new methods to represent user behaviors (i.e., interests), the inclusion of more accurate product descriptions in the design of recommendation models, and the use of multi-criteria ratings to increase the effectiveness of recommendation systems.

Phase 3: Creating Scientific and Innovative Solutions with Design Science

• Artifact development: Designing digital twin-supported management models.

• Evaluation processes: Testing the impact of the model on business strategies.

• Continuous improvement: Making the model more efficient with scientifically based revisions.

The theoretical foundations of design science's production of innovative solutions are based on studies emphasizing relevance and rigor cycles (Hevner, 2007, p. 5; Maula and Stam, 2020, p. 1059-1060). As an application suggestion, the repeatability of the model and its integration into institutional learning processes can be emphasized. Simon (2019, p. 121) defines the nature of this cycle as generating design alternatives and evaluating alternatives according to requirements until a satisfactory design is obtained.

Phase 4: Predictive and Scenario-Based Decision Making

• Generating alternative scenarios with machine learning and analytical models.

• Developing decision mechanisms based on risk assessments and simulation results.

• Continuously optimizing the strategy with an agile and flexible structure.

• Obtaining a new state of the product, service or system, an iterative process.

Mintzberg's (1994, p. 1) strategic decision-making approaches (planning, adaptive, intuitive, etc.) constitute the theoretical basis of predictive and scenario-based decision-making (Holgersson and Gotora, 2013, p. 14). This stage is also compatible with the design school discourses in strategic management, which advocates that strategies should be unique, that the best strategies can emerge as a result of the creative design process, and that strategies will emerge when this design process is fully formulated (Chandler, 1962, p. 212; Mintzberg, 1990, p. 178). An application suggestion for this stage can be to test alternative strategic scenarios in a digital twin environment and create risk-reducing decision sets.

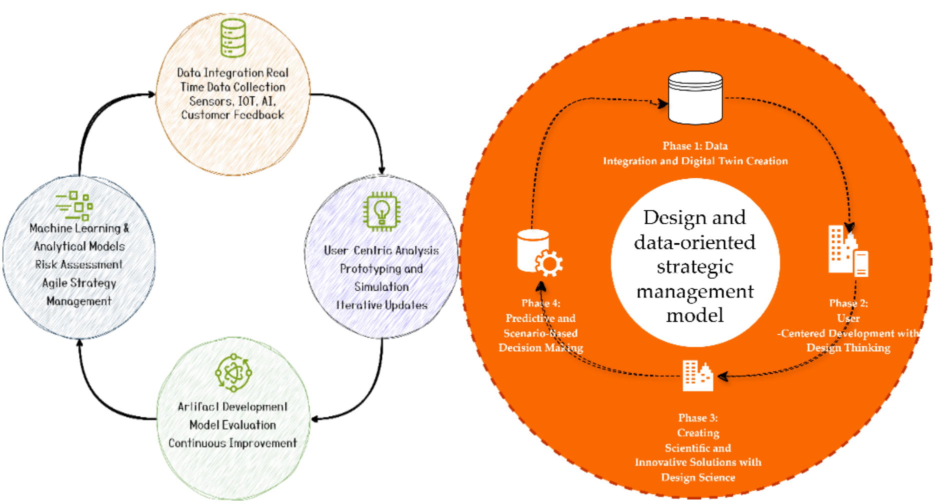
In the data-driven strategic management model that we address with a cyclical model, the aim is to integrate the physical world with the virtual world rather than integrate it and to make the data continuous. This is important in terms of the physical product adapting to the recommendations coming from the virtual product and completing the cycle and providing data in the next cycle. This is critical in terms of providing an infinite amount of data that can come from the end user. Data can be collected during different stages of a product's life cycle such as "design, production, distribution, use, maintenance, upgrade and recycling" (Tao et al., 2019, p. 3936). Although there are some difficulties in using this proposed model in strategy formation processes, the continuity and agility it offers will provide businesses with a competitive advantage against their competitors beyond product design, at least in terms of technological strategy and estimation of future potential products.

The approach proposed with this model is far beyond data-driven product design or big data analytics and is also close to second-degree cybernetics. Beer (1972, p. 30) based the fundamental discovery of cybernetics on the fact that "the behavior of large and complex systems depends on the structures of these systems." Namely, shaping business strategy with "self-feeding, self-organizing and mass-privileged" data coming from the end user at various times, from different contexts, and from different demographic and cultural backgrounds has the potential to prevent the destructive effects of environmental and sectoral entropy on a product or service basis and to increase longevity for businesses.

This data-driven strategic management model contributes to the field in terms of affecting the formation of strategy, which is the main criterion that feeds synergistic outputs such as increased automation, accuracy, efficiency and productivity of businesses, just as the Internet of Things increases the re-formation of data collected from products on their digital twins. The autonomy of the user experience, the sense of privilege and all the potentials brought by individualization, together with the voluntary participation and creativity of people in the process of products, services and systems of which they are the end users through digital twins within the framework of design thinking and design science, constitute the most fundamental argument put forward by this model.

Businesses will be able to use the advantage of having their customers or end users make the design decisions regarding their experiences, which they shape according to constructive or destructive criticisms about their products or services in the virtual world, through digital twins, without leaving it to the limited rationality and imagination of their own designers, and to base their strategy formation on this feedback, in terms of competitive advantage. Thus, algorithmic decisions and inferences will be included in strategy formulation instead of intuitive decisions or predictions. In this process, where the tools of design thinking such as co-creation, prototyping and field experiments can be used, a design and data-oriented strategic management model based on digital twins is presented in Figure 2.

Figure 2. Design and data-oriented strategic management model



Source: Created by the author.

To explain this model mathematically, we can express each stage as a functional component and the entire system as a composite decision support model. The strategic decision function can be defined as follows.

$$\mathrm{D} = \mathrm{f}(\mathrm{S}, \mathrm{U}, \mathrm{A}, \mathrm{P})$$

S : System data (sensor, IoT, historical data)

U : User needs (empathy, problem definition)

A : Artifacts and solutions (model prototypes)

P : Can be expressed as parametric and scenario-based decision models.

This model works as a cyclic-iterative optimization system. It takes data (S) as input, is processed with user-oriented analysis (U), solution (A) is produced and the system is closed with predictive decisions (P). The decision output is reflected back to the input of the system and continuous improvement is achieved. The formulas given in this model are not deterministic but heuristic and parametric models. For more complex systems, regression, neural networks or other Bayesian approaches can also be adopted. Since parameter selections are not empirical, these values should either be assumed or calibrated with data. In addition, since sociocultural factors are not included in this model, their potential effects are ignored.

Phase 1: Data Integration and Digital Twin Creation

$$X(t) = g(St) \; or \; X(t) = \{x1(t), x2(t), \ldots, xn(t)\}$$

St: Real-time data stream

X(t): Time-varying multivariate digital twin state (state space)

This stage is user feedback, data integration with IoT/sensor data, and creation of the virtual twin.

Phase 2: User-Centered Development (Design Thinking)

$$U = h(X\;, C)$$

C: User scenarios and feedback

h: User need function (empathy, analysis, prototyping)

The output is a user-focused iterative product/process prototype.

Phase 3: Generating Scientific and Innovative Solutions (Design Science)

$$A = m(U) = \; \{a1, a2, \ldots, ak\}$$

m: Modeling, testing and continuous development function

A : Developed strategic models, artifacts (simulations, algorithms)

Phase 4: Predictive and Scenario-Based Decision Making

$$P = \underset{\mathrm{p} \in P}{arg\max} \; \mathrm{E}[R(\mathrm{p} \mid \mathrm{A}, X)]$$

P: Scenario space (different strategy combinations)

R(p): Risk/performance assessment of the selected scenario

E[R]: Expected value – forecast models (ML, analytical models)

Final Decision Function

$$D *= \underset{d \in D}{arg\max} \; U\mathrm{D}(\mathrm{d} \mid \mathrm{P}, A)$$

From this model, a generalizable mathematical formula can be obtained for the factors that determine a firm's strategic decisions in a dynamic, agent-based, data-sensitive and design-oriented structure. The total strategic value of a firm at time t can be expressed by the following formula.

$$S_k(t) = \sum_{i=1}^{nk} w_{ki}.U_{ki}(t) + \sum_{j=1}^{mk} \alpha_{kj}.f_{kj}(t) + \sum_{l \in Pk} C_{kl}(t).[S_l(t) + \phi_{kl}(t)] - R_k(t)$$

$S_k(t) =$	The total strategic value of firm k at time t
$w_{ki}(t) =$	Agent i i's production, service, design or data contribution
$w_{ki} =$	Weight of the agent (importance, influence)
$f_{kj}(t) =$	Contribution function of intra-firm strategy types (product differentiation, cost, integration, etc.)
$\alpha_{kj} =$	Impact/priority coefficient of each strategy for the firm
$P_k =$	The set of other firms with which firm k cooperates
$C_{kl}(t) =$	Level of cooperation between firms k and l
$\phi_{kl} =$	Synergy resulting from collaboration
$R_k(t) =$	Risk/cost/loss of value due to non-compliance

The evaluation of this mathematical model for each strategy type and the explanation of the model components are presented in Table 1.

Table 1. Strategy Types and Formulation of Model Components

Strategy Type	Description of Model Components
Cost Leadership $f_{cost}(t) = \frac{1}{C_k(t)}$	The company analyzes production processes with digital twin data, identifies recurring cost elements and increases efficiency through automation and standardization. Contributions come from low-cost production practices, strategy is shaped by in-process data.
Differentiation $f_{diff}(t) = designvariety * customer\ satisfaction$	Detailed feedback from users (design, user experience, aesthetics, etc.) is processed on digital twins. With the insights obtained, innovative designs that differentiate from competitors and increase customer satisfaction are developed. Strategy is guided by originality and user interaction.
Focus (Niche Market) $f_{focus}(t) = nichecustomer\ contribution * loyalty$	Special designs or services are produced by deeply analyzing the digital data of a specific customer group. Data contributions are narrower but intensive and based on expertise. Strategy is formed by the synergy of micro-targeting and expertise.
Growth Strategy $f_{growth}(t) = numberofnewproducts * penetrationrate$	Digital twin data from new markets or segments triggers strategic decisions for product diversification and market expansion. The model translates broad-based user feedback into new investments.
Vertical Integration $f_{vert}(t) = supplier\ integration * distribution\ control$	Data from suppliers and distribution channels allow the company to make its production and logistics processes more efficient. The model focuses on process integration, improving control and quality.
Horizontal Integration $f_{hor}(t) = \sum f_{b \in competitors} marketshare_b$	Digital twins from similar product segments are combined to ensure product compatibility and brand integrity. Data-level compatibility with companies in the same sector paves the way for strategic integration.
Strategic Alliance $\sum C_{kl}(t) \cdot (S_l + \phi_{kl})$: $contribution\ from\ collaboration$	Digital twin data created in partnership with collaborating companies enables the design of innovations that benefit both parties. The model guides knowledge sharing and joint development strategies.
Digital Transformation $f_{digital}(t) = data\ production * automation\ level$	Data from IoT, artificial intelligence, sensor technologies and users are processed through digital twins. This data forms the basis of strategies that increase the company's digital competence. The strategy is data-intensive and technology-centric.

Source: Created by the author.

Conclusion and Discussion

In this study, a model that allows businesses to develop data-driven, iterative and agile strategies is proposed by combining digital twin and design thinking approaches using the design science research method. This study provides both theoretical and practical contributions to the field of digital transformation and strategic management. Design thinking and system thinking are one of the methods of thinking about how technology and people work together. In this respect, this study aims to offer an iterative solution to the processes of creating strategies of businesses within the triangle of technology, design and management. In this context, a design and data-driven strategic management model based on the digital twin expressed in Figure 2 is presented in this study. Within the scope of the study, the working principle of the model is tried to be explained with mathematical models. Within the framework of strategy science, an attempt is made to formulate the frequently used strategy types and model components. Since this study is a conceptual study, the fact that it has not been tested should be stated among the limitations of the study.

The study aims to go beyond traditional strategic management approaches and present a more flexible, multidimensional model that can respond to the needs of the age in terms of technology, design and management. In one such study in the literature, Szostak and Boughzala (2020) emphasized that design thinking supports innovation in the development of corporate social responsibility (CSR) strategies and integrates social, environmental, and economic dimensions. In this study, design thinking, by integrating digital twins and complex systems theory, goes beyond CSR-focused strategies and systematically supports data-driven, iterative, and adaptive strategic management processes.

In today's world where uncertainties and rapid changes prevail, the design-oriented strategic management model offers decision makers a thinking framework that is both analytical and intuitive, using a relatively new research method. The four basic stages of the model, data integration and digital twin creation, user-centered design, scientifically based solution generation and scenario-based decision making, are structured in a cyclical structure that supports each other. One of the most striking aspects of the model is that it combines both technological competence and a human-centered perspective by bringing together different areas of expertise. In this respect, the study is compatible with the discourses of human-computer interaction and technology management models. This is particularly important since knowledge management plays an increasingly critical role in enabling organizations to adapt to rapidly changing environments and to achieve sustainable competitive advantage (İpçioğlu and Kâhya, 2016, p. 179).

Digital twin technology enables understanding the current situation through data, while design thinking principles guide the development of solutions that address real user needs. While the process of producing solutions based on scientific foundations ensures that decisions are based on a solid theoretical basis, scenario-based decision-making allows for the development of flexible strategies by taking into account different possibilities for the future. Of course, it is possible to encounter some difficulties in the implementation of this model. In particular, stages that require advanced technology, such as digital twins and scenario modeling, are directly related to the technical infrastructure and data analytics capacity of organizations. The competencies of employees in organizations may be lagging behind in this respect. Therefore, in order for the model to be successful, it requires a transformation process not only technically but also culturally and administratively.

Building on the theoretical foundations discussed in the literature, the proposed design-oriented strategic management model extends prior insights from complex systems theory (Gharajedaghi, 2011), design thinking (Plattner et al., 2009), and digital twin applications (Tanev, 2024) to offer a comprehensive framework for agile strategy formulation. Unlike traditional models that often treat strategy as a linear and static process, this model operationalizes continuous feedback loops, iterative problem-solving, and scenario-based decision-making, reflecting the adaptive and emergent nature of modern organizations (Sayğan, 2014). By integrating user-centered design principles with real-time, data-driven simulations, organizations are better equipped to align micro-level interventions with macro-level strategic objectives, manage uncertainty, and co-create value in complex and rapidly evolving environments. In this respect, the model not only reinforces theoretical propositions regarding dynamic capabilities and technology adoption (Hossain & Quaddus, 2011; Davis, 1989) but also provides a practical blueprint for translating these concepts into actionable strategic decisions. Therefore, the study demonstrates how the combination of theory-driven approaches and digital innovation can enhance both analytical rigor and managerial applicability in contemporary strategic management practice.

As a result, this model offers an innovative approach that does not reduce strategic management to planning alone, but rather treats it as an agile process aimed at constantly learning, thinking together, and shaping the future together by adopting data-based decision-making approaches. Thus, decision-makers will not only analyze the present, but will also be better equipped to navigate the uncertainties of the future. In the conclusion section of the study, theoretical, methodological and practical contributions are presented with the support of relevant literature.

Theoretical contribution: To the best of the author's knowledge, this study is the first original framework in which three methodologies (digital twins, design thinking, design science) that are usually examined separately in the strategy literature are integrated. It can be considered as an effort to use decision support systems for organizational strategy. Saaty (2004, p. 133-134) states in his study that feedback can better capture the complex effects of interaction in human society. The study can lead to theoretical expansion in strategy science by expanding the literature in terms of its compatibility with the discourses of the interactive decision support systems literature (Alves and Clímaco, 2004, p. 258). In this form, the study is compatible with the strategy selection methods commonly used in the literature. Since the model proposed in the study is a type of optimization, it resembles Markowitz's (1991, p. 469) "portfolio optimization model" that derives the most appropriate rule among risky assets in a static environment. Apart from this, it is compatible with the "analytic hierarchy process" (AHP) (Ho et al., 2012, p. 10842; Nepal et al., 2010, p. 6775-6776), which treats the decision as a system and offers a structured approach to solving complex problems, and with "multi-criteria decision-making methods" in general. It is also compatible with models that design Web-based "group decision support systems" that aim to support decision makers anytime and anywhere (Carneiro et al., 2018, p. 109). It is similarly compatible with the literature that uses "portfolio matrices" to help managers evaluate and create strategic plans (Chien et al., 1999, p. 357). The framework presented is especially compatible with the "data-based decision support systems" literature within decision support systems (Vera-Baquero et al., 2015, p. 6-7). It is also compatible with the OLAP (Online Analytic Processing) and data mining literature, which address patterns and trends over large data sets (Ren et al., 2023, p. 2228). The study has the potential to expand the decision support systems studied within the scope of operations and industrial engineering science to the management and strategy literature.

Methodological contribution: This study offers a live, continuously updated, data-driven and user-centered strategic decision support system instead of traditional static analysis tools such as SWOT and BCG. It does this with a relatively new methodological expansion. Considering that managers have cognitive (limited information processing capacity) and economic (access to information and processing cost) limits when making decisions, which affect decision results, this model can help managers overcome some of these limits. This study includes three main contributions in terms of methodology by developing a holistic model for strategy formation and decision-making processes. These bring together data science, design-oriented thinking and management science, which explain the integration of multidisciplinary approaches, and ensure that strategic decision-making processes are structured not only analytically but also based on user-centered and scientific foundations. The four-stage structure in staged modeling (data integration, user-centered design, scientific solution generation and scenario-based decision-making) allows strategic decisions to be modeled systematically, and this structure allows the different dimensions of the decision process to be separated and addressed together. The last contribution includes the formulation of the normative model. The components and strategy types of the model are formulated based on mathematical and logical foundations. In this respect, although it is not deterministic, it offers a framework that is not only explanatory but also predictive and transferable to practice. Thus, it brings theoretical depth and methodological innovation to the field of managerial modeling.

Contribution to practice: Using this model and the decision support system expressed in this model, businesses can create an iterative, innovative support system for determining their strategies. The effects of different strategy paths can be tested before making a decision with real-time scenario simulations. In this study, a holistic and applicable model is proposed that integrates technology, design thinking, user-centered design and scientific solution production into strategic decision-making processes through digital twins. To the best of the author's knowledge, no studies similar to this model have been found, especially in the management and organization and strategy literature.

Limitations of the Study and Recommendations for Future Research: This study provides a digital twin-based, design science and design-focused strategic management model, enabling businesses to adopt a more agile, data-driven, and scientific management approach. Based on the study, future research can focus on the applicability and scalability of the model in different industries, further developing the model's strategy creation and revision processes with artificial intelligence and big data analytics, studies on how data security and ethical issues can be addressed in the model, and a detailed examination of the impact of design science methodology and digital twin technologies on the performance of the model. Going forward, it is of great importance to apply this model in different sectors and test it empirically. With case studies to be conducted in different areas such as healthcare, manufacturing, education, and the service sector, it can be discussed more clearly in which contexts the model works. In addition, more in-depth studies on which tools will support each stage in practice will increase the practical impact of the model. For example, tools such as user experience mapping, system dynamics modeling, or artificial intelligence-supported decision systems can enhance the applicability of the model. In terms of future research within the scope of the study, digital twin-supported production planning and process optimization in smart factories can be studied in the manufacturing sector. In the healthcare sector, it is also suitable for expansions on modeling patient data with digital twins and creating personalized treatment plans. In the finance and insurance sector, the validity of the model can be tested in terms of improving risk management and decision support systems by analyzing customer behavior.

As with every study, this study, which has not been addressed with quantitative data, whose theoretical integration has not yet been tested, and which has been created in the light of theoretical knowledge, has some limitations within itself. Although the proposed model has been addressed with support from current publications emphasized throughout the text, it still has limitations regarding generalizability. The technological adaptation and adjustment process of this model may take years. The limited rationality and subjective perspective of the researcher should also be expressed as another limitation. The non-determinism of the mathematical models expressed in the study can also be expressed as another limitation.

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