Twin Transformation –
Conceptualizing the Interplay of Digital and Sustainability Transformation

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"We cannot solve our problems with the same thinking we used when we created them."

Albert Einstein

Copyright Statement

The following sections are partly comprised of content from the research papers included in this thesis. To improve the readability of the text, I omit the standard labeling of these citations.

Abstract

Digital transformation and sustainability transformation are urgent and essential phenomena that individuals, organizations, and societies must navigate in this century. The need for sustainability transformation arises from pressing social and environmental challenges such as environmental degradation, loss of biodiversity, and the depletion of natural resources. Digital transformation in general and digital technologies in particular offer potential solutions for sustainability transformation. For individuals, using digital technologies can enhance awareness and engagement in sustainability efforts, empowering them to make informed consumption choices and adopt more sustainable behaviors. For organizations, digital transformation is vital as it enables the integration of sustainable practices into their business models and enhances operational efficiency. For societies, digital technologies can enhance trust and transparency among different actors. However, digital technologies can also hinder sustainability transformation if the sustainability of the technologies themselves and their usage are not considered.

Although individual behavioral changes are necessary, the substantial impact of organizations reaching global sustainability objectives demands different perspectives. Thus, this doctoral thesis investigates the interplay of digital and sustainability transformation (i.e., twin transformation) on the individual, organizational, and societal level. Twin transformation leverages the synergies of these transformations and addresses the possible challenges of digital and sustainability transformation.

To establish a common ground, this thesis starts with conceptualizing twin transformation on an organizational level. The twin transformation interplay consists of two underlying mechanisms: digital transformation enables sustainability transformation, and sustainability transformation guides digital transformation. Research Paper 1 defines twin transformation and identifies dynamic capabilities essential for its effective execution, while Research Paper 2 reveals three pathways to achieving twin transformation maturity by presenting a Twin Transformation Capability Maturity Model. To deepen the understanding of the twin transformation interplay, Research Paper 3 analyzes organizational tensions arising from the interplay of digital and sustainability transformation and presents response mechanisms to effectively manage them.

Because the twin transformation concept also encompasses individuals and society, this thesis investigates the underlying twin transformation mechanisms on those levels. Research Paper 4 shows how digital transformation enables sustainability transformation on an individual level by presenting design principles for the design of information systems promoting improved waste-sorting behavior, thus enabling a circular economy. On the societal level, Research Paper 5 illustrates how sustainability transformation guides digital transformation by presenting a model to assess the sustainability value of digital (i.e., Smart City) solutions.

This thesis contributes to the existing literature on the nexus of digital sustainability in Information Systems research by introducing and investigating the twin transformation concept. The findings provide valuable insights for researchers and practitioners, guiding future research endeavors to advance and detail the twin transformation concept and develop integrated twin transformation solutions in practice. Ultimately, this thesis underscores the critical importance of fostering the synergies between digital transformation and sustainability transformation to ensure a resilient and sustainable future for individuals, organizations, and society.

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Acronyms

AI	Artificial intelligence
CE	Circular economy
DAX	Deutscher Aktienindex (in English: German stock index)
DO	Design objective
DP	Design principle
DSR	Design science research
DT	Digital transformation
ICT	Information Communication Technology
IS	Information Systems
IT	Information technology
SCS	Smart City solutions
SDG	Sustainable Development Goal
ST	Sustainability transformation
TPB	Theory of Planned Behavior
TTCMM	Twin transformation capability maturity model

I Introduction

I.1 Motivation

In 2004, the oil company British Petroleum launched a campaign called "Beyond Petroleum," which included the calculation of individuals' carbon footprints on its website (Kaufman 2020). This campaign popularized the calculation of individual greenhouse gas emissions and fostered individual accountability by pointing to their various sources in individuals' everyday lives (e.g., stressing individual emissions caused by their diet, housing, and transportation choices). Simultaneously, the campaign diverted attention from the responsibilities of organizations with a major impact on global greenhouse gas emissions, such as British Petroleum, to individuals with comparably small effects on these emissions (Kaufman 2020). While individual behavior and consumption choices exert some impact on sustainability, this effect is relatively modest compared to the leveraging impact of organizations (El Geneidy et al. 2021; Garnett and Balmford 2022). However, the collective adoption of sustainability practices by individuals (e.g., employees or customers) may generate a ripple effect, prompting large organizations to enact changes in their actions (Corbett 2013).

Organizations must change their behavior, as they wield substantial weight in realizing global sustainability objectives by reshaping their value-creation processes or business models. Notably, 78 large organizations are accountable for over 70% of global fossil fuel and cement carbon emissions since industrialization (InfluenceMap 2024), underscoring that the climate crisis cannot be mitigated through individual behavioral changes alone. At the same time, the need to enhance global sustainability has reached a critical point. At present, six out of nine planetary boundaries—fundamental environmental thresholds necessary for preserving the Earth's stability and supporting human advancement—have been surpassed (Richardson et al. 2023). Upholding the remaining three is not merely an environmental issue; it is a profound social problem that directly influences individuals' living conditions. The increasing number of extreme weather events, such as floods and heat waves, illustrate how exceeding these boundaries impacts the environment and individual's social well-being (Rockström et al. 2009).

Sustainability can be investigated on individual, organizational, and societal levels (Elliot 2011; Melville 2010). The individual level of sustainability focuses on individual's behaviors and choices that contribute to global sustainability goals (Henkel and Kranz 2018). The organizational level encompasses organizations' adoption of practices and strategies to minimize their negative environmental impact while enhancing social and economic outcomes (Dyllick and Muff 2016). The societal level comprises collective initiatives of communities (i.e., groups of individuals) and institutions to establish policies that promote and shape global sustainable development (Meadows et al. 1972). These three sustainability levels affect social, environmental, and economic sustainability dimensions, which are intertwined (Purvis et al. 2019). Economic sustainability yields welfare and economic growth, social sustainability encompasses the protection of human rights and well-being, and environmental

sustainability fosters the protection of the environment (Purvis et al. 2019). While the focus in recent decades has mainly been on economic sustainability, the social and environmental aspects are becoming increasingly important as the pressure for sustainability actions in these areas is intensifying (Pasamar et al. 2023). Therefore, organizations must change their operations, value creation, and business models to improve global environmental and social sustainability (e.g., El Geneidy et al. 2021; Wolf et al. 2024).

On the societal level, one milestone in reaching global sustainability objectives was the Paris Climate Agreement of 2015, which obliges countries that have ratified it to set and communicate their nationally determined contributions to reduce greenhouse gas emissions. Moreover, these countries aim to enhance climate resilience, fostering accountability and global collaboration to limit global warming to 1.5 degrees Celsius above pre-industrial levels (United Nations 2024).

At the same time, individuals, organizations, and society are impacted by digitalization, namely the "sociotechnical phenomena and processes of adopting and using [digital] technologies" (Legner et al. 2017 p., 301). Individuals and organizations must face the rapid introduction of new digital technologies, which simultaneously form the basis for developing new digital innovations (Kohli and Melville 2019). The proliferation of digital technologies establishes an increasingly networked and technology-driven society at an unprecedented pace. For instance, large language models such as ChatGPT open new possibilities for individuals (e.g., support informed decision-making) and organizations (e.g., enhance productivity and efficiency; Seita and Kurahashi 2024), digital technologies such as digital platforms enable collaboration among different organizations and individuals (Veile et al. 2022), and blockchain allows a secure data exchange among parties (Centobelli et al. 2022).

In response to these rapidly evolving environments, there has been a noticeable shift as organizations strive to keep pace with technological advancements. As part of their digital transformation (DT), organizations are both adapting to the digital environment and changing it (Markus and Rowe 2023). Organizations are also confronted with the challenges posed by sustainability, leading them to change their actions during a sustainability transformation (ST) to achieve sustainability goals (Dyllick and Muff 2016). Consequently, they are under pressure to transform digitally and sustainably as well as to change internal processes, partnerships, or even their business models regarding these objectives. Thus, DT and ST have become critical for redefining the future of individuals, organizations, and society (e.g., Vial 2019; Patterson et al. 2017).

ST aims at integrating environmental, social, and economic aspects into individual and organizational decision-making processes, which is crucial in addressing global challenges such as the climate crisis, human rights abuses, and resource depletion (Dyllick and Muff 2016). Thereby, ST represents a paradigmatic shift in terms of individual, organizational, and societal changes within the environmental and social sustainability dimensions (Dao et al. 2011; Lahtinen and Yrjölä 2019), forming the foundation for global future resilience (Boh et al. 2023). Sustainability can be defined as "meeting the needs of the

present without compromising the ability of future generations to meet their own needs" (Brundtland 1987, p. 34). To do so, sustainability encompasses environmental, social, and economic dimensions (Purvis et al. 2019; Elkington 1997). The efforts to achieve sustainability objectives in organizations have increasingly captured the attention of researchers (e.g., Sancak 2023; Dorninger et al. 2020; Patterson et al. 2017) because organizations are a main lever to reach global sustainability goals (e.g., Garnett and Balmford 2022). Dyllick and Muff (2016) define a truly sustainable organization as one that creates a substantial positive impact in critical areas pertinent to individuals, society, and the planet. The sustainability of organizations can be assessed via three categories: the what (input), how (process), and what for (output; Dyllick and Muff 2016). When all three categories meet social and environmental standards, the organization's primary purpose shifts to serving the common good, which is defined as benefiting individuals, society, and the Earth as a whole (Dyllick and Muff 2016).

ST is undertaken by organizations that review and involve the external environment (i.e., individuals, other organizations, and society) in which they operate, asking themselves how to overcome pressing sustainability challenges (Bocken et al. 2014; Geissdoerfer et al. 2018). Moreover, the collaboration of organizations enables the creation of new sustainable business models by redefining the value-creation strategies of single organizations to apply to close partnerships (Bocken et al. 2014; Geissdoerfer et al. 2018). As a result, various sustainable business models exist, with one prominent approach touting the concept of a circular economy (CE) instead of a linear one. The primary aim of such circular business models is to minimize resource input through a product design enabling enhanced waste sorting and reusing (Ortega-Gras et al. 2021; Zeiss et al. 2021). For organizations to find partners adhering to sustainable practices (e.g., for supply chains) and for individuals to make conscious (sustainable) purchasing decisions, it is essential to define and compare sustainability value and target achievement (Centobelli et al. 2022; O'Rourke and Ringer 2016). However, to date, the sustainability of products, organizations, or supply chains as a whole has been difficult to measure and compare as it requires transparency, traceability, and accountability (Qorri et al. 2018). Specifically, it is difficult to determine, as the sustainability value rises at different times and can have an impact at the individual, organizational, and societal levels.

On the other hand, DT aims at unlocking new organizational value-creation opportunities that are primarily rooted in emergent digital technologies and often promise to harness novel organizational value (Karnebogen et al. 2021). Thereby, DT enables organizations to change current processes, increasing their operational efficiency and remaining competitive (Vial 2019). However, scholars and practitioners in the Information Systems (IS)1 field have not yet achieved complete conceptual and

[1] While IS refers to the academic discipline focusing on the researching the design, implementation and management of information systems, this thesis refers to information systems (with lowercase) when referring the combination of people, processes and technology that enable the processing of digitalized information (Melville 2010).

empirical clarity regarding DT (Markus and Rowe 2023), leading to the emergence of numerous and varied definitions (e.g., Hanelt et al. 2021; Soluk and Kammerlander 2021; Vial 2019; Wessel et al. 2021). For instance, Vial (2019, p. 121) defines DT as "a process that aims to improve an entity" through the adoption of digital technologies.

Digital technologies encompass a broad range of information, computing, communication, and connectivity technologies (Bharadwaj et al. 2013). According to Vial (2019), adopting digital technologies results in significant changes to the characteristics of the organization, which may include processes, business units, or other organizational elements. Furthermore, some scholars argue that DT extends beyond these changes, as the integration of digital technologies influences value creation and capture, facilitating the emergence of entirely new digital business models (e.g., AlNuaimi et al. 2022; Buck et al. 2022; Wessel et al. 2021). In addition, DT has potential consequences for different organizational actors (i.e., individuals as employees or consumers) and organizational environments (i.e., other organizations or society as a whole), as it fundamentally alters organizational operations, individual interactions, and consumption patterns (Chanias et al. 2019; Kraus et al. 2022). DT thus presents a significant opportunity for organizations to transform their business models' and value chains' sustainably (Kotlarsky et al. 2023). However, DT still challenges organizations, resulting in high failure rates due to setting objectives too optimistically; neglecting the importance of proper execution, including governance and user adoption; and ineffectively managing the change from old to new systems (Bonnet 2022). The reasons for the failure of DT demonstrate that individuals, whether as managers implementing DT or users adopting new digital processes and technologies, are largely responsible for its success rate (Bonnet 2022).

ST may have the potential to mitigate the high failure rates often associated with DT, as the integration of sustainability initiatives can offer organizational employees a purpose that fosters engagement and commitment during DT efforts (Crome et al. 2023). Research has already investigated the intersection of ST and DT, as their convergence presents an opportunity for organizations to enhance efficiency, foster innovation, and reach global sustainability goals, resulting in a possible competitive advantage (Veit and Thatcher 2023; Pappas et al. 2023). Currently, however, such research is predominantly one-sided, primarily focusing on how DT, mainly using digital technologies, can be leveraged to enhance sustainability. Exemplary research streams focusing on how DT enables ST are *Green IS* investigating the use of digital technologies to achieve environmental sustainability goals (e.g., Seidel et al. 2017; Henkel and Kranz 2018; Dao et al. 2011; vom Brocke et al. 2013); *Digital Social Innovation*, exploring how digital technologies can be leveraged to address societal challenges (e.g., Bonina et al. 2021; Buck et al. 2023); and *Artificial Intelligence (AI) for Sustainability*, which focuses on the use of AI for climate or social justice (e.g., van Wynsberghe 2021; Falk and van Wynsberghe 2023).

Digital technologies such as the Internet of Things, blockchain, big data, and AI already enhance traceability and energy management, promote waste reduction, and optimize the utilization of natural resources (e.g., Centobelli et al. 2022; Guandalini 2022). For instance, as organizations are increasingly required to report on their environmental impact, they can utilize the Internet of Things and develop new digital innovations to improve sustainability reporting and ensure compliance (Sjödin et al. 2018). Moreover, digital platforms and networks have the potential to overcome global challenges by connecting different stakeholders; however, they also facilitate competition among them (Nambisan and George 2024).

To sum up, **DT can enable ST,** representing the first part of their interplay, which is examined in this thesis. Nevertheless, DT can have a negative impact on individuals (i.e., social sustainability) and the planet (i.e., environmental sustainability). Possible negative effects on an individual level include increased workloads and difficulties maintaining a work-life balance (Ayyagari et al. 2011). Possible negative effects on environmental sustainability objectives include increased energy consumption, electronic waste, and resource depletion (Murugesan 2008). Hence, it is crucial to consider both the social (e.g., Wolf et al. 2024) and environmental impacts of DT (e.g., Malhotra et al. 2013). Furthermore, as DT can be both a solution and a problem for advancing ST (Veit and Thatcher 2023; Chatterjee and Sarker 2024), research must also examine its negative aspects concerning sustainability. Consequently, it is important to investigate how ST guides the design of DT in order to reduce or avoid possible negative outcomes (Graf-Drasch et al. 2023). Exemplary research streams focusing on how ST guides DT are *Green Information Technology (IT)*, investigating practices of creating environmentally sustainable digital technologies or digital infrastructure (e.g., Berthon and Donnellan 2011; Loeser 2013; Murugesan 2008); and *Sustainable AI*, exploring how AI-based systems should be designed so as not to violate social and environmental objectives (e.g., van Wynsberghe 2021; Leuthe et al. 2024). **ST can guide DT**, representing the second part of their interplay, which is examined in this thesis. Sustainability pressure on the societal and individual levels may reinforce the demand for organizations to use digital technologies for sustainability purposes, that are themselves designed and operated sustainably. Consequently, the complex challenges of DT and ST require integrated solutions, as siloed thinking overlooks the synergistic potential of the interplay between these transformations. The development of new digital and sustainable innovations may create a virtuous circle in which both DT and ST reinforce and drive each other forward. Both single transformations are set to change the interworking of individuals, organizations, and society, ultimately contributing to a more resilient, equitable, and sustainable future (Kotlarsky et al. 2023).

Twin transformation unites these two mechanisms—DT enables ST, and ST guides DT—and thus enables synergies to be leveraged (Balta et al. 2022; Crome et al. 2023; Ollagnier et al. 2021). However, integrating DT and ST on equal footing is challenging and demands specific capabilities and advice to develop and implement them. Thus, this thesis establishes an understanding of twin transformation by

defining twin transformation as "a value-adding interplay between DT and ST efforts that improve an organization by leveraging digital technologies for enabling sustainability and leveraging sustainability for guiding digital progress" (Christmann et al. 2024 p. 7, Research Paper 1). To date, the concept of twin transformation has not been fully developed or firmly anchored in research and practice. For instance, many organizations lack knowledge about the underlying twin transformation mechanisms, required dynamic capabilities for twin transformation, and possible tensions between both single transformations emerging in the interplay of DT and ST (e.g., Mishra et al. 2022; Wong and Ngai 2021; Soluk and Kammerlander 2021). Hence, research must investigate the twin transformation interplay and develop theories to guide organizations in practice. For example, research may help organizations develop specific capabilities to successfully implement twin transformation or understand and mitigate possible tensions between DT and ST. Moreover, research can provide organizations with strategies that support them to successfully accomplish twin transformations and positively influence the sustainability actions of individuals and society at large.

I.2 Research Objectives

Currently, organizations face the challenge of mastering DT and ST simultaneously. DT is often impeded by challenges such as the inertia exhibited by individuals within organizations (e.g., Kaganer et al. 2023). Organizations undergoing ST also face challenges, particularly in effectively tracking and reporting sustainability objectives, which complicates the assessment of progress and accountability (e.g., Sancak 2023). Building on the challenges of DT, ST, and their interplay, this cumulative doctoral thesis aims to contribute to the overarching research question of *how to integrate DT and ST as a twin transformation*. It outlines multiple research objectives, questions, and results, organized into two parts: (1) uncovering and investigating the twin transformation interplay (2) exploring the underlying twin transformation mechanisms in detail. To do so, this thesis examines the twin transformation interplay at the organizational level and, whereas the mechanisms of both single transformations on the respective other transformation are examined by providing exemplary instantiations on both the individual (i.e., DT enables ST) and societal (i.e., ST guides DT) levels. Figure 1 illustrates the twin transformation interplay according to the twin transformation definition outlined above and the assignment of my research papers to different parts of the twin transformation interplay. Providing novel insights into the interplay between DT and ST, this thesis is relevant for researchers and practitioners.

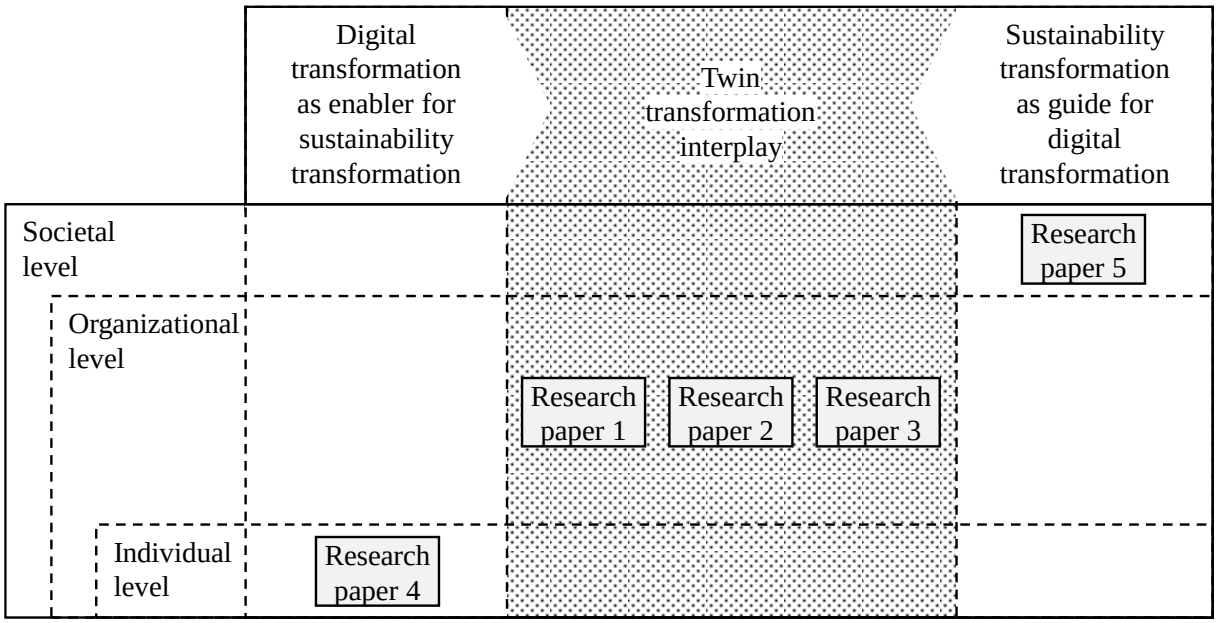

Figure 1: Assignment of my research papers to key research areas of this thesis

This thesis examines the twin transformation interplay at the organizational level, yielding three significant contributions to the discourse on this subject (Section II). It extends the knowledge on twin transformation by developing a foundation for a theory for analysis in Research Paper 1 and a theory for explanation in Research Paper 3, according to Gregor (2006). First, this thesis defines the twin transformation construct and investigates the dynamic capabilities needed for twin transformation. Thereby, Research Paper 1 provides the overarching structure of this thesis, namely the twin transformation interplay. Next, it provides conceptual and empirical clarity on the dynamic capabilities required for organizations to address the goals of DT and ST simultaneously. These are consolidated in a twin transformation capability framework supporting the effective implementation of twin transformation (Section II.1). Second, based on the twin transformation construct and the identified dynamic capabilities, this thesis presents a capability maturity model that demonstrates the twin transformation journey and how organizations can harness their expertise in digitalization and sustainability to support twin transformation (Section II.2). Third, this thesis examines how the interplay between DT and ST affects organizational tensions. It identifies such tensions and proposes three twin transformation response mechanisms to address the organizational tensions (Section II.3). It also explores in detail the enabling mechanism of DT and the guiding mechanism of ST for twin transformation (Section III). At the individual level, this thesis contributes a nascent design theory (level 2; Gregor and Hevner, 2013), outlining design principles (DPs) for information systems to enable improved biowaste and residual waste sorting (Section III.1). At the societal level, it presents a model to assess sustainability value and to leverage that of Smart City solutions (SCSs; Section III.2).

In summary, this thesis contributes to the research question of *how to integrate DT and ST as a twin transformation* by conceptualizing and exemplifying the twin transformation interplay. Methodologically, this thesis employs qualitative approaches, following either the grounded theory

(Gioia et al. 2013) to explore emerging phenomena such as twin transformation or the design science research (DSR) paradigm to develop design knowledge (Hevner et al. 2004; Tuunanen et al. 2024). Doing so, this thesis applies different theoretical lenses (i.e., dynamic capabilities, organizational tensions, and the Theory of Planned Behavior [TPB]) to examine the twin transformation interplay from different perspectives including the individual, organizational, and societal levels.

I.3 Structure of the Thesis and Embedding of the Research Papers

This thesis comprises five research papers contributing to the research objectives above. Table 1 provides an overview of the overall thesis structure and the embedded research papers.

The thesis is structured as follows: Section I introduces the research gaps addressed in this work and defines the research objectives. Section II presents the concept of twin transformation as a new construct in research. The three associated research papers lay the foundation for twin transformation research by defining this concept, identifying and categorizing the necessary dynamic capabilities, and presenting mechanisms for managing tensions between DT and ST. Section III explores how individuals and societies can leverage synergies between DT and ST, including two papers that demonstrate how digital technologies can be used to achieve better waste sorting and present an assessment for the sustainability value of SCS. Section IV presents a summary of the findings and limitations of this thesis, while also highlighting potential directions for future research. Finally, Section V lists the references, while the appendix in Section VI includes an index of the research papers, a summary of my individual contributions, and (extended) abstracts of the research papers

Table 1. Structure of this thesis and embedding of the research papers

I	**Introduction**
II	**Uncovering and Investigating Twin Transformation on an Organizational Level**
	Research Paper 1 The Twin Transformation Butterfly – Capabilities for an Integrated Digital and Sustainability Transformation Christmann, AS., Crome, C, Graf-Drasch, V, Oberländer, AM., Schmidt, L
	Research Paper 2 Dynamic Capabilities for the Twin Transformation Climb: A Capability Maturity Model Breiter, K, Crome, C, Oberländer, AM., Schnaak, F
	Research Paper 3 Navigating the Twin Transformation Frontier: Resolving Tensions between Digital and Sustainability Transformations Crome, C, Kreuzer, T, Meyer-Hollatz, T, Oberländer, AM.
III	**Individual and Societal Level Considerations of Twin Transformation**
	Research Paper 4 Circular Economy Is Key! Designing a Digital Artifact to Foster Smarter Household Biowaste Sorting Crome, C, Graf-Drasch, V, Hawlitschek, F, Zinsbacher D
	Research Paper 5 Smart Cities, Sustainable Futures: Uncovering the Sustainability Value of Smart City Solutions Abdipour, R, Crome, C, Michaelis, A, Oberländer, AM, Steinkopf, J, Jonas, C
IV	**Conclusion**
V	**References**
VI	**Appendix**

II Uncovering and Investigating Twin Transformation on an Organizational Level

As outlined in Section I, IS researchers and practitioners must understand the twin transformation interplay as both DT and ST affect and challenge organizations. Thus, this thesis conceptualizes twin transformation and presents relevant dynamic capabilities (Section II.1, Research Paper 1). Building on this, it offers a capability maturity model for twin transformation and points to three different pathways to twin transformation maturity: digitalization expert, sustainability expert, and twin transformation newcomer (Section II.2, Research Paper 2). Next, this thesis investigates possible organizational tensions between DT and ST that may affect the achievement of digital and sustainability objectives and presents response mechanisms that address potential tensions affected by DT and ST (Section II.3, Research Paper 3).

II.1 Conceptualizing Twin Transformation

To fully harness the synergetic relationship between DT and ST, IS research must establish a unified understanding of the twin transformation construct. Following this, it is crucial to delineate the capabilities required for effective twin transformation. Capabilities refer to repeatable action patterns that utilize resources to create and deliver products or services (O'Reilly and Tushman 2008; Teece et al. 1997; Wade and Hulland 2004), serving as foundational elements for both research and practical implementation of twin transformation. Organizations need ordinary capabilities to organize recurring processes or perform efficiently in the market (Teece 2014). Additionally, they require dynamic capabilities to build, conjoin, and configure ordinary capabilities and assets when exploring new markets or products, for instance, during the creation of digital innovations (O'Reilly and Tushman 2013; Teece et al. 1997; Winter 2003; Piccoli and Ives 2005). Once identified, dynamic capabilities can offer benefits by enhancing an organization's potential to (1) identify new opportunities, (2) make timely and market-oriented decisions, and (3) systematically solve problems (Barreto 2010; Teece 2007). Such dynamic capabilities are essential for effective organizational transformations, as they initiate change to ensure a competitive advantage (Teece 2007, 2014). Following existing IS research, Research Paper 1 refers to dynamic capabilities as the organizational ability to (1) scan the environment regarding opportunities and threats, (2) make decisions based on identified opportunities, and (3) transform ordinary capabilities and assets to realize the identified opportunities withstanding rapidly changing environments (Steininger et al. 2022; Teece et al. 1997; Teece 2007). Against this backdrop, Research Paper 1 investigates the following research questions: *What constitutes twin transformation, and which capabilities are needed for organizations to twin transform?*

In response to the research questions, Research Paper 1 integrates the perspectives of DT and ST, thereby (1) defining and establishing the twin transformation construct while delimiting related concepts (Podsakoff et al. 2016; Suddaby 2010). Furthermore, it investigates the dynamic capabilities pertinent

to twin transformation through the lens of dynamic capability theory (Teece et al. 1997), (2) resulting in the development of a twin transformation capability framework. Employing a qualitative research approach, Research Paper 1 leverages empirical data from 20 semi-structured exploratory interviews with key informants recognized for their DT, ST, and twin transformation knowledge. Qualitative methods are particularly effective for exploring nascent research areas (Miles and Huberman 1994). The reasoning employed in Research Paper 1 was inductive, treating the gathered data as representative information to construct a framework grounded in empirical evidence (Bhattacherjee 2012; Sarker et al. 2018). The analysis was guided by a grounded theory approach, incorporating open, axial, and selective coding techniques (Gioia et al. 2013).

As a result, Research Paper 1 develops a definition of twin transformation, splitting it into two mechanisms: namely, DT enables ST, and ST guides DT. As illustrated in Figure 2, the twin transformation interplay is rooted in a holistic, transformational, and deeply synergetic approach, which is disregarded when focusing on both transformations in isolation. Twin transformation is a multi- and interdisciplinary construct that is not only the responsibility of and driven by the entire top management but also requires the cooperation of all organizational departments (Dyllick and Muff 2016; Wessel et al. 2021). Twin transformation balances the efforts and rewards of both single transformations by considering them on an equal footing, with the potential to lead to a reinvention of the organization, thus impacting the organization's identity as well as creating value far greater than the sum of each transformation. Consequently, twin transformation extends prior hybrid constructs at the interplay between DT and ST.

Serving as a foundation for future twin transformation research and this thesis in general, as well as the development of twin transformation capabilities in particular, Research Paper 1 presents the following definition of the twin transformation construct: *A twin transformation refers to a value-adding interplay between DT and ST efforts that improve an organization by leveraging digital technologies for enabling sustainability and leveraging sustainability for guiding digital progress.*

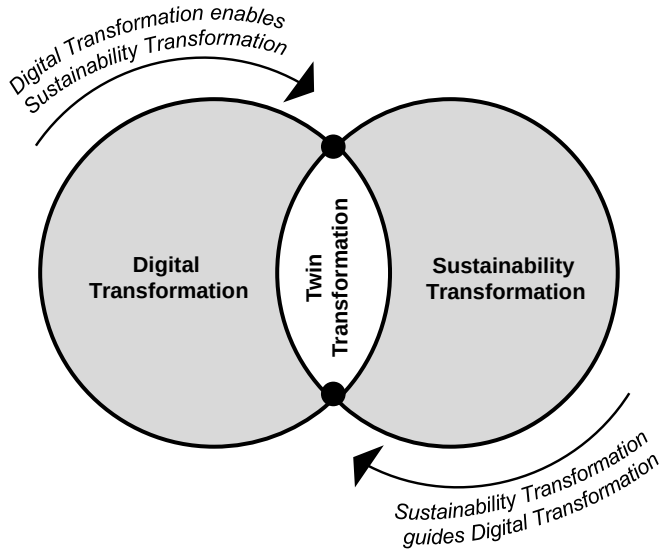

Figure 2: Twin transformation conjuncts the synergies of digital and sustainability transformation

Moreover, Research Paper 1 develops a twin transformation capability framework (Figure 3). Drawing on Baiyere et al.'s (2020) symbolic perspective of organizational transformations, the twin transformation process is analogized to the metamorphosis of a larva into a butterfly. Just as a butterfly's body supports its wings, enabling flight, organizations can only achieve successful twin transformation by developing and implementing relevant dynamic capabilities across four capability categories: make DT sustainable, make ST digital, and build outside-in and inside-out capabilities. This holistic approach is essential for organizations to effectively "take off" in their twin transformation journey.

Twin transformation capabilities allow for integrating sustainability and digitalization perspectives into organizations on an equal footing. The presented twin transformation butterfly encompasses dynamic twin transformation capabilities, as they are directed toward organizational change processes (Teece 2007, 2014; Piccoli and Ives 2005) and are needed to initiate twin transformation. Starting from the butterfly's body, Research Paper 1 distinguishes between primary and support capabilities (Huber et al. 2022; Porter 1985). The left and right sides of the butterfly work in conjunction with one another, as both "wings" enable each other. Proceeding with the wings, the first two wings are primary capabilities that directly influence the organization's value creation by shaping the supply of new products or services. They encompass spanning capabilities that aim for an integrated approach to twin transformation, merging aspects from inside and outside the organization. Making DT sustainable presents ST as a guide to DT. The category captures the dynamic twin transformation capabilities by harnessing DT to attain sustainability targets. In contrast, making ST digital refers to DT as an enabler of ST. The category includes dynamic twin transformation capabilities that accelerate digital technology integration to an end of leveraging sustainability-focused practices.

The other two categories relate to support capabilities that indirectly influence the organization's value creation by increasing the primary capabilities' effectiveness. Support capabilities encompass inside-

out capabilities, deployed from inside the organization, and outside-in capabilities, which are externally oriented. *Build inside-out capabilities,* therefore, describes the ability to respond to market requirements and opportunities. *Build outside-in capabilities* refers to anticipating market requirements through external partnerships. Support capabilities also encompass relevant change management practices such as "enhance joint innovation and strong community networks."

In establishing a general understanding of twin transformation and revealing a range of dynamic twin transformation capabilities that are critical yet overdue, Research Paper 1 presents three overarching implications. First, it provides an opportunity for the IS discipline to take a natural and decisive next step in advancing DT and ST knowledge, thus creating a foundation for further theorizing on twin transformation. Second, Research Paper 1 arrives at insights relating to the DT realm, emphasizing sustainability in future endeavors. Third, it mobilizes ST research efforts by underscoring the need to consider DT as an enabler. In addition, it highlights the practical value of recognizing and understanding relevant dynamic capabilities to initiate twin transformations in organizations. In the overall context of this thesis, Research Paper 1 forms the basis for further research on the twin transformation construct and presents the DT and ST interplay as the overarching structuring element of this thesis.

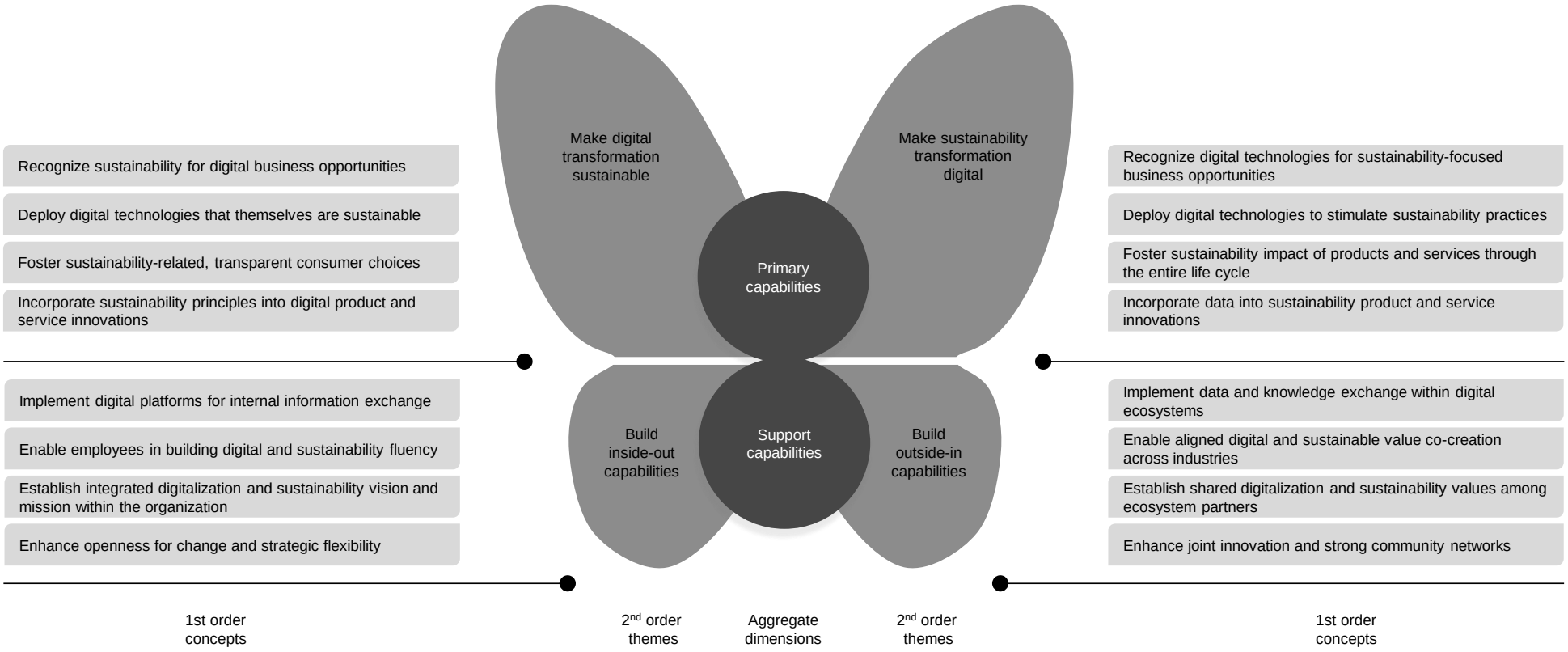

Figure 3: Twin transformation capability framework

II.2 Revealing Different Pathways to Twin Transformation Maturity

While the twin transformation construct is conceptually convincing, its realization is not trivial. As with almost any transformation, organizations require dynamic capabilities to adapt their existing business models to address rapidly changing environments and ensure long-term growth and survival (Teece et al. 1997; Teece 2014). To effectively master twin transformation, it is essential to understand, develop, sustain, and continuously monitor integrated dynamic capabilities to assess progress and leverage the mutual benefits of DTs and STs within a twin transformation. Researchers have investigated and structured the capabilities required for mastering DT through maturity models (e.g., Aguiar et al.; Ellström et al. 2022; Gökalp and Martinez 2021). Additionally, an increasing number of studies are examining the capabilities required for ST (e.g., Amui et al. 2017; Shang et al. 2020; van de Wetering et al. 2017) and developing roadmaps toward sustainability maturity (e.g., Uhrenholt et al. 2022; Vásquez et al. 2021). Research Paper 2 draws on the knowledge of the twin transformability framework presented in Research Paper 1.

Current research uses maturity models to explore DT or ST capabilities independently. However, there is a lack of a structured overview of integrated dynamic capabilities; specifically, a twin transformation maturity model is missing. It is insufficient to consider DT and ST separately and rely on individual maturity models. An integrated perspective enhances efficiency between both transformations, saving time and resources. Developing integrated dynamic capabilities, namely twin transformation capabilities, organizations require straightforward guidance to use their experiences and current expertise effectively, as DT and ST capabilities are the basis for integrated capability development. Furthermore, especially multidimensional maturity models offer a holistic overview of organizations, which is advantageous in the given context, as twin transformation affects "all organizational layers inside and outside an organization" (Graf-Drasch et al. 2023 p. 11).

Research Paper 2 focuses on the structured development of dynamic capabilities for twin transformation, enabling organizations to assess their twin transformation maturity and ensure sustainable long-term relevance. Therefore, Research Paper 2 poses the following research question: *What are twin transformation maturity stages and corresponding dynamic capabilities?*

To address this research question, Research Paper 2 develops, evaluates, and demonstrates the twin transformation capability maturity model (TTCMM), following Becker et al.'s (2009) procedure model for maturity model development using the DSR paradigm provided by Peffers et al. (2007). The methodological steps comprised a structured literature review (Leidner 2018; vom Brocke et al. 2015), 13 expert interviews (following Myers and Newman 2007), and a case demonstration with a subsidiary of a DAX 40 (Deutscher Aktienindex [in English, German stock index]) company, which is one of the 40 largest German stock corporations.

To address the lack of investigations into dynamic capabilities and maturity stages for twin transformation, design objectives (DOs) were formulated to develop a capability maturity model. These objectives guided the development of an artifact to systematically foster dynamic capabilities for twin transformation, enabling organizations to assess their maturity (Peffers et al. 2007). The DOs read as follows:

DO.1 TTCMM must include DT and ST capabilities for holistic organizational assessment.

DO.2 TTCMM must consider DT and ST as equally important.

DO.3 TTCMM must consider the different starting points of organizations.

During the development of the TTCMM, it was recognized that twin transformation capability development differs from other dynamic capabilities, which typically follow a linear maturity progression. Given the dual focus of twin transformation, organizations begin their twin transformation journey from various starting points, not only in terms of general maturity but also based on their prior experience and expertise in DT or ST. Organizations may already be very mature regarding dynamic DT capabilities but lack the sustainability equivalents and vice versa. To account for such different starting points, the TTCMM outlines three pathways to becoming a *true twin transformer* (stage #4): pursuing twin transformation as a *DT expert*, an *ST expert*, or a *twin transformation newcomer*. The pathways are illustrated in Figure 4, which sketches a climb up the twin transformation mountain. Organizations that are already *DT experts* (i.e., having a high maturity of DT capabilities) may save themselves a bit of a climb to the top as they start their twin transformation journey from stage #2. This also applies to *ST experts* with a high maturity of ST capabilities. To reach twin transformation maturity stage #2, DT and ST capabilities are required but suffice in isolation. From twin transformation maturity stage #2, DT and ST capabilities must be integrated, thought of together, and brought together on equal footing. For all twin transformation pathways, the capability dimensions are the building blocks of the twin transformation mountain to be considered by organizations. In summary, DT experts possess DT-related capabilities. Hence, they develop ST-related and integrated capabilities during their twin transformation journey. The reverse applies to ST experts.

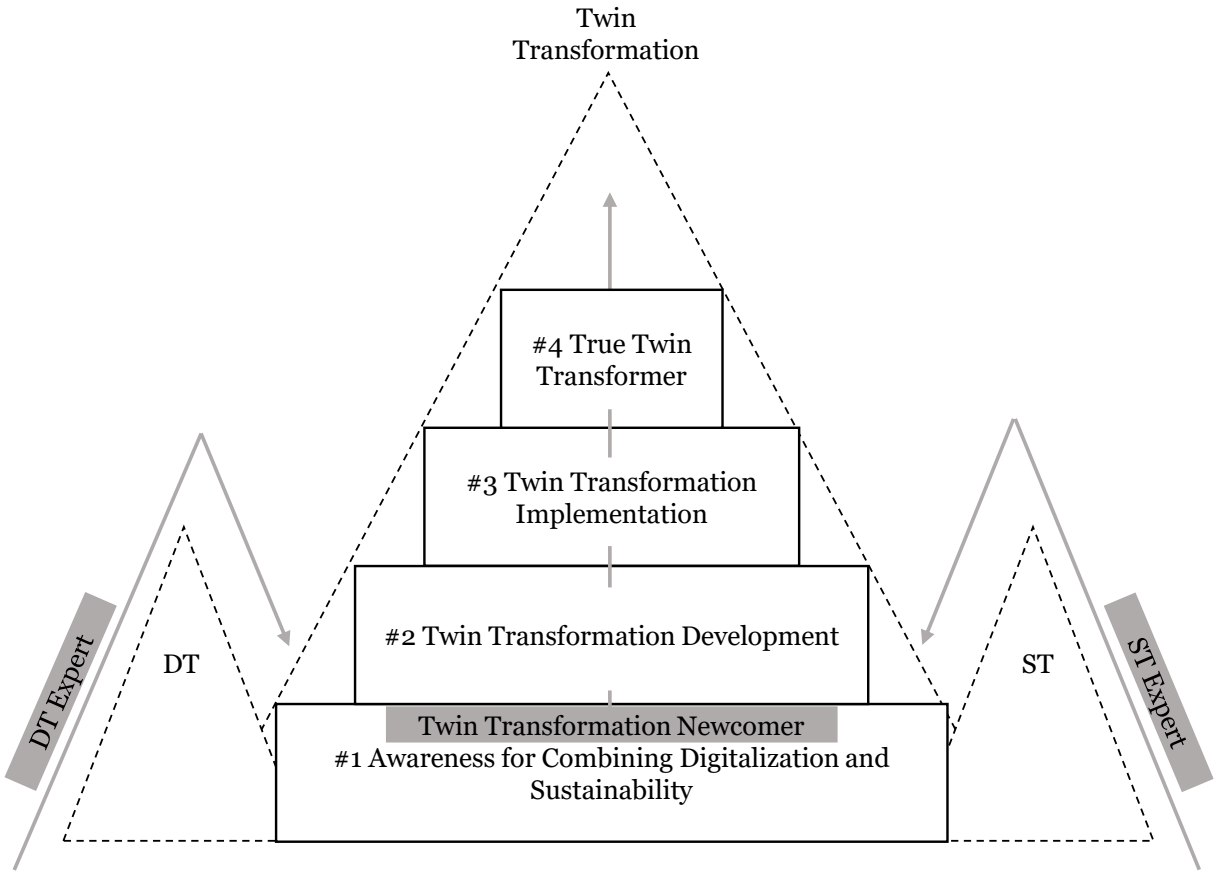

Figure 4: Three pathways toward twin transformation maturity

During their twin transformation climb, organizations must understand this concept as a holistic transformation that affects the entire organization (Graf-Drasch et al. 2023). This holistic nature is evident in the TTCMM, where the interdependence of different capabilities increases with higher maturity stages. Organizations are considered to have reached a particular stage when they fulfill all capabilities within one dimension that aligns with their business model, known as their solution space. It is possible for organizations to achieve different maturity stages across various capability dimensions. At stage #1, DT- and ST-related capabilities exist independently. In subsequent stages, these capabilities become increasingly intertwined. Research Paper 2 introduces the TTCMM, which is the foundation for the outlined twin transformation stages and pathways. The TTCMM comprises six capability dimensions, organizing a total of 45 capabilities (Table 2).

Table 2: Twin transformation capability maturity model

Capability dimension	Maturity stage				
	#1 Awareness of combining digitalization and sustainability		#2 Twin transformation development	#3 Twin transformation implementation	#4 True twin transformer
	DT-related capabilities	ST-related capabilities	← Integrated DT and ST-related capabilities →		
Strategy and leadership	– Understand the economic potential of DT – Foster the use of digital technologies	– Understand sustainability as a must-do – Foster the performance of a life-cycle analysis	– Develop a twin transformation strategy and derive measurable digitalization and sustainability objectives that are not mutually exclusive – Strengthen digitalization and sustainability investments – Establish digitalization and sustainability key performance indicators – Foster twin transformation development through (top) management commitment	– Foster twin transformation implementation through the (top) management – Integrate investments in twin transformation innovations – Allow integrated digital and sustainability-related changes to the value proposition and organizational identity	– Evaluate activities regarding twin transformation objectives[2] – Develop twin transformation business models
Culture and employees	– Develop human capital regarding digital skills	– Develop human capital regarding sustainability skills	– Enable creativity and self-realization to foster digital and sustainability innovation – Introduce values underlining the vision of a digital and sustainable organization	– Establish twin transformation training for employees – Enable new digital and self-determined work	– Integrate twin transformation key performance indicators in reward systems of employees and (top) management
Ecosystem and partnerships	– Enhance transparency in supply chains using digital technologies	– Foster dialogue with partners	– Reconfigure relationships with partners based on the results of data analytics enhancing the sustainability of products/services	– Integrate partners' twin transformation knowledge and competencies acquired thanks to established dialogue	– Influence legislators on twin transformation standards
Products and services	– Foster the development of digital services	– Foster the collection of environmental and social sustainability data on products/services	– Reconfigure product development teams to include sustainability and digital specialists	– Redesign or develop products and services as per twin transformation objectives[1] – Establish data analytics to enhance the sustainability of products/services	– Focus on cradle-to-cradle approaches
Operations	– Foster integrated information, communication, and operation systems	– Foster the introduction of criteria to digitally evaluate the sustainability performance of operations	– Establish data-based (sustainability) monitoring – Establish cross-departmental collaboration	– Reconfigure layouts, manufactural and logistical processes for sustainability effectiveness	– Establish data analytics to continuously improve the twin transformation performance of operations
Technology	– Establish data governance mechanisms to enhance the data and information sovereignty	– Build awareness for sustainability within the technology stack (Green/Effective IT) – Implement environmental, social, and governance (ESG) controlling	– Establish the usage of sustainable internal processes and technical infrastructure (Green/Effective IT)	– Facilitate cross-organizational cooperation by providing an organization-wide data management tool – Foster advanced analytics in management dashboards to monitor twin transformation objectives[1]	– Exploit the sustainability potential of emerging digital technologies – Establish a cross-ecosystem data management tool facilitating twin transformation

[2]Twin transformation objectives are balancing digitalization and sustainability goals

To validate the TTCMM, it was applied with a case demonstration company, an IT service subsidiary of a DAX 40 group with approximately 10,000 employees worldwide. The senior sustainability manager utilized the model to assess ongoing initiatives, establish target maturity levels for twin transformation capabilities, and identify challenges and pathways toward achieving twin transformation maturity (Becker et al. 2009).

Research Paper 2 makes significant theoretical contributions by structuring the twin transformation maturity journey through various capability dimensions and maturity stages, identifying three distinct pathways: (1) twin transformation newcomers integrating both transformations from scratch, (2) DT experts making DT sustainable, and (3) ST experts making ST digital. These pathways are designed to help organizations leverage their existing knowledge in the complex twin transformation process. Additionally, Research Paper 2 identifies the dynamic capabilities required to master different twin transformation stages, expanding existing DT and ST capability research. Regarding practical implications, the TTCMM aids organizations of all sizes in assessing their twin transformation journey and developing the necessary capabilities, considering their prior transformation experience and expertise. In the overall context of this thesis, Research Paper 2 highlights three pathways for organizations to become true twin transformers and expands the dynamic capabilities for twin transformation outlined in Research Paper 1 by providing a capability maturity model for twin transformation.

II.3 Applying Twin Transformation to Address Tensions between Digital and Sustainability Transformation

Despite the optimistic outlook on the potential of intersecting DT and ST, a growing body of research is beginning to challenge this positivistic depiction (Tirole 2021; Verbeke and Hutzschenreuter 2021; Chatterjee and Sarker 2024). Studies have shown that the interconnected realization of DT and ST creates tensions within organizations (e.g., Mishra et al. 2022), characterized by “contradictory yet interrelated elements that exist simultaneously and persist over time” (Smith and Lewis 2011 p. 382). Broadly speaking, this is due to (1) DT being primarily economically driven, while ST follows environmental and social goals (Chatterjee and Sarker 2024), and (2) potential environmental and social issues related to digital technologies (Berthon and Donnellan 2011; van Wynsberghe 2021; Veit and Thatcher 2023).

Against this background, twin transformation offers a potential solution approach. It suggests that the conscious combination of digital and sustainability efforts on equal footing yields synergies and exploits economic advantages (e.g., Crome et al. 2023; Ollagnier et al. 2021). The distinction between an integrated twin transformation and the connected pursuit of DT and ST lies in the conscious use of digital and sustainability actions for mutual benefit in the former, whereas the latter involves isolated efforts with occasional interactions. Research Paper 3 addresses two key research gaps within the current body

of knowledge on the interplay of DT and ST (i.e., an integrated twin transformation or partly connected DT and ST): First, there is a need to better understand and specify the underlying tensions between DT and ST (Smith and Lewis 2011; Gaim et al. 2018). While DT tensions in isolation are well-documented in IS research (e.g., Wimelius et al. 2020; Danneels and Viaene 2022; Soh et al. 2023), the tensions related to ST and their interrelation with DT tensions remain relatively unexplored. Understanding these specific tensions is crucial for effective tension management and identifying appropriate organizational responses (Smith and Lewis 2011). Second, while twin transformation is essential for exploiting synergies between DT and ST, little is known about response strategies to manage these tensions. Such knowledge would be particularly beneficial for practitioners who are currently facing challenges in integrating their DT and ST efforts to maximize the benefits of combined digital and sustainability actions while navigating potential tensions. Therefore, Research Paper 3 poses the following research question: *Which tensions are affected by the interplay of DT and ST in organizations?*

In addressing the research question, Research Paper 3 presents a systematic literature review focused on the tensions between DT and ST. Using the paradoxical tensions theory (Smith and Lewis 2011), Research Paper 3 explores these tensions in depth. The theoretical insights are supported by 24 interviews with subject-matter experts, who provided strategies for managing the conflicting demands of DT and ST. This approach enabled the identification and mapping of relevant responses to twin transformation challenges.

As the core of its investigation, Research Paper 3 reveals five relevant tensions affected by DT and ST, as well as three twin transformation response mechanisms. Twin transformation enables organizations to seek solutions that address the competing demands of DT and ST, leveraging the strengths of one transformation to benefit the other. The resulting twin transformation responses are integration strategies (Soh et al. 2023) designed to mitigate negative effects on tensions that arise or are influenced by the connections between DT and ST. Research Paper 3 identifies three effects on these tensions due to the interplay of DT and ST: arise, shift, and reinforce. Arising tensions are newly created through the interaction of DT and ST; for example, tension arises if one transformation introduces a new demand that competes with an existing demand in another transformation. Shifting tensions, on the other hand, change their focal points but have already been present in both single transformations. This shift occurs because the integration of the two transformations causes the sub-goals, namely DT and ST goals, to be adjusted and/or the competing demands to change because of the integration. Reinforcing tensions are already present in DT and ST but are intensified by the interplay between them. Table 3 shows the identified tensions with descriptions of and details on the references.

Table 3: Digital transformation and sustainability transformation

Tension affected by the interplay of DT and ST	Effect	Description	References to existing literature		
			DT	Interplay of DT/ST	ST
Societal value vs. organizational performance	Tension **arises** due to the competing demands between DT and ST.	*Balancing DTs' focus on new value creation – often leveraged for economic value creation - with STs' focus on societal value – is predominantly considered as opposition to economic value.*		van Wynsberghe 2021; Veit and Thatcher 2023; Mishra et al. 2022	Haffar and Searcy 2017; Luo et al. 2020; Palakshappa et al. 2024; Román et al. 2022; Wannags and Gold 2020; Glinik et al. 2024
Radical innovation vs. incremental innovation	Tension **is reinforced** due to the competing demands between DT and ST.	*Balancing the need for both transformations to introduce groundbreaking technological or sustainability-oriented changes with gradual and continuous improvements reaching short-term goals*	Soh et al. 2019; Soh et al. 2023; Johansson et al. 2022; Wimelius et al. 2020; Toutaoui et al. 2022; Gregory et al. 2015	Mishra et al. 2022	Hahn et al. 2015; Glinik et al. 2024
Competition vs. collaboration	Tension **is reinforced** due to the competing demands between DT and ST.	*Balancing the drive for digital and sustainability innovation and a related competitive advantage based on internal knowledge with the necessity for cooperation, collective actions, and digital sustainability knowledge sharing.*	Wimelius et al. 2020; Tóth et al. 2022; Koukouvinou et al. 2023; Svahn et al. 2017	Mishra et al. 2022	
Personal employee identity vs. organizational identity	Tension **shifts** due to the competing demands between DT and ST.	*Balancing sustainability and digital values and beliefs of employees with organizational values.*	Johansson et al. 2022; Wareham et al. 2014; Tóth et al. 2022; Soh et al. 2019; Toutaoui et al. 2022	Mishra et al. 2022	Palakshappa et al. 2024; Luo et al. 2020; Wannags and Gold 2020; Glinik et al. 2024; Hahn et al. 2015
Depth of competence vs. breadth of competence	Tension **shifts** due to the competing demands between DT and ST.	*Balancing the specific in-depth capabilities of both transformations with wide-ranging sustainability and digital knowledge.*	Johansson et al. 2022; Danneels and Viaene 2022; Svahn et al. 2017; Toutaoui et al. 2022; Tóth et al. 2022; Smith and Beretta 2021	Mishra et al. 2022	Luo et al. 2020

To elucidate the intricate dynamics of tensions between DT and ST, Research Paper 3 identifies five key tensions and their effects during the interplay of both transformations. First, the performing tension of *societal value vs. organizational performance* **arises** between DT and ST due to conflicting demands between economic goals (e.g., shareholder value) and sustainability goals (e.g., employee work-life balance). Second, the performing tension between *radical innovation vs. incremental innovation* is **reinforced** due to conflicting demands between DT and ST. DT and ST both require radical changes at the business model level, while organizations are confronted with limited financial resources (El Hilali et al. 2020). Third, during DT and ST, the organizing tension between *competition vs. collaboration* is **reinforced** due to the competing demands between DT and ST. This tension is present in DT and ST. While DT enables sharing across organizational boundaries with customers and other organizations by reducing transaction costs (Vial 2019), ST leverages digital technologies to use the effect of low transaction costs for collaboration. Fourth, the belonging tension of *personal employee identity vs. organizational identity* exists in DT and ST and **shifts** due to the competing demands between DT and ST in organizations. On the one hand, personal employee identity changes due to present global crises such as the climate crisis (Hug and Zhang 2024). Fifth, the learning tension between *depth of competence vs. breadth of competence* exists in both single transformations and **shifts** due to the competing demands between DT and ST, as both transformations simultaneously demand broad sustainability and digital competencies and experts with in-depth knowledge.

To facilitate the management of such tensions in organizations, Research Paper 3 investigates possible responses in the realm of twin transformation. Leveraging twin transformation helps to find responses to address the competing demands of DT and ST in virtuous organizational cycles. Research Paper 3 presents three twin transformation response mechanisms and underlying twin transformation responses. The three twin transformation response mechanisms are split into two balancing and one blending response mechanism (Gregory et al. 2015). The balancing response mechanisms use either (1) digital actions or (2) sustainability actions to facilitate the achievement of the other transformation's demands. For example, digital technologies can be used to track the sustainability performance of suppliers, thereby supporting an organizational twin transformation. In contrast, the blending response mechanism (3) integrates digital and sustainability actions to simultaneously address the demands of both transformations, such as developing a digital sustainable product.

The first supporting twin transformation response mechanism, leveraging digital actions to enhance sustainability, utilizes data and digital technologies to facilitate sustainability initiatives. Drawing from areas such as green IS (e.g., Melville 2010), this mechanism employs digital technologies like blockchain to achieve positive sustainability impacts, such as reducing scope three emissions. By using digital actions to balance competing demands between DT and ST, this mechanism is classified as a balancing response mechanism (Gregory et al. 2015).

The second supporting twin transformation response mechanism, exploiting sustainability actions to sharpen digitalization, focuses on using social and environmental requirements to enhance digital processes. This mechanism ensures that sustainability goals, such as improving employee mental health, positively influence the DT process, like reducing technostress from new software introductions. By implementing, for instance, sustainable IT infrastructure and resource efficiency, this balancing response mechanism helps organizations manage tensions between DT and ST (Gregory et al. 2015).

The third executing twin transformation response mechanism, integrating digital and sustainability actions to provide mutual benefit, combines the goals of both DT and ST for enhanced value creation and resource management. Building on twin transformation research (e.g., Research Papers 1 and 2), this mechanism yields new twin transformation goals, such as digitally measurable sustainability performance indicators. By addressing societal value and organizational performance tensions, this blending response mechanism offers integrated solutions for both DT and ST demands (Gregory et al. 2015). Figure 5 summarizes the proposed connection of the tension affected by DT and ST and three identified twin transformation response mechanisms.

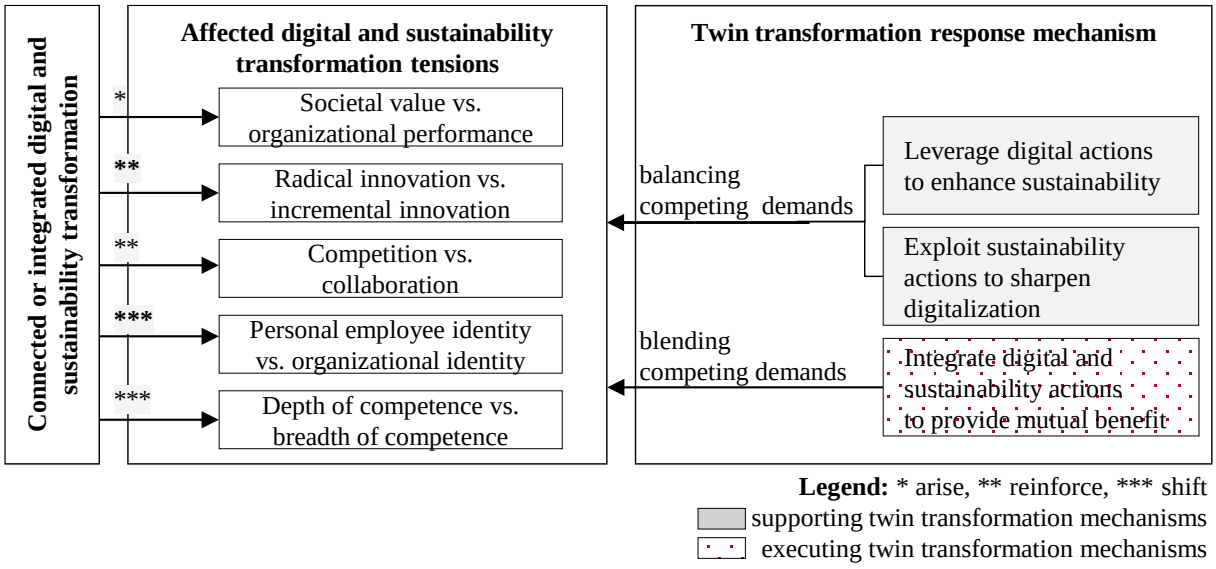

Figure 5: Connection of digital and sustainability transformation tensions and twin transformation response mechanisms

Research Paper 3 makes two significant contributions to both researchers and practitioners. First, by analyzing the interplay between DT and ST tensions, it provides a deeper understanding of each transformation within the context of the other. This extends existing research by providing a perspective on the tensions between DT and ST, which fosters further theorizing and mitigates emerging management challenges. Second, Research Paper 3 contributes by offering twin transformation response mechanisms that facilitate the management of both transformations on equal footing, addressing possible tensions. In the overall context of this thesis, Research Paper 3 employs a tension lens to

examine the interplay between DT and ST, demonstrating that while twin transformation cannot entirely eliminate existing tensions, it can effectively manage and address them.

This section establishes a foundation for research by conceptualizing twin transformation at the organizational level and applying explorative research methods. The interplay of twin transformation comprises two interrelated mechanisms: DT enables ST, while ST guides DT. Research Paper 1 defines twin transformation and identifies the dynamic capabilities critical for its successful implementation. Research Paper 2 introduces the TTCMM, outlining three pathways to achieve twin transformation maturity in organizations. To enhance the understanding of the interplay between both single transformations, Research Paper 3 examines the tensions that emerge from their interplay and proposes response mechanisms for effectively managing them.

III Individual- and Societal-Level Considerations of Twin Transformation

As outlined in Section II, the twin transformation interplay consists of two mechanisms: the enabling mechanism of DT on ST and the guiding mechanism of ST on DT. Both DT and ST involve individuals, organizations, and society. While Section II refers to the interplay of both transformations in organizations, this Section details both mechanisms of the interplay on the individual and societal levels. To understand how the two mechanisms of twin transformation unfold in detail, this thesis develops design knowledge for both mechanisms. First, it advances a CE by providing design knowledge for information systems to improve waste sorting, emphasizing awareness, transparency, social influence, education, and incentives. This guidance aids practitioners in leveraging digitalization to enhance household waste sorting and achieve sustainability goals (Section III.3., Research Paper 4). Second, it contributes by providing a comprehensive model for the sustainability value assessment of SCS. The model supports the development and implementation of sustainable SCSs and thus supports reaching sustainability for all stakeholders of a Smart City, namely individuals (who are referred to as "people" in Research Paper 5), organizations, and society at large (Section III.4, Research Paper 5).

III.1 Digital Transformation Enabling Sustainability Transformation

Global annual waste generation is expected to double by 2050 due to population growth and urbanization (Kaza et al. 2018). The CE concept, which aims to transform the current linear take-make-dispose model into a circular one, is seen as a promising solution. CE seeks to narrow, slow, and close material loops and decouple economic growth from resource use (Bocken et al. 2016; Ghisellini et al. 2016; Zeiss et al. 2021). However, most global waste today is not recovered but sent to landfills and incineration, increasing resource and energy demands and exacerbating climate change and biosphere degradation (Murray et al. 2017; Ellen MacArthur Foundation 2021a, 2021b). In high-income countries with well-established waste management systems, nearly 100% of waste is collected, yet a significant portion is incinerated rather than recycled (Kaza et al. 2018). For example, in Germany, 65% of incinerated residual waste includes valuable materials like biowaste, paper, plastics, and metals, with biowaste accounting for almost 40% (Hawlitschek 2021; German Environment Agency 2020). Biowaste, which includes inedible food byproducts and green waste, cannot be eliminated but can be converted into valuable products like biogas, organic fertilizers, and bioplastics if properly sorted (Fricke et al. 2018; Vea et al. 2018). The importance of locally produced biogas as a renewable energy source is especially apparent during energy and gas shortages in Europe and other regions. Digitalization and digital technologies are often viewed as opportunities to enhance biowaste sorting and promote circular resource flows (Aceleanu et al. 2019; Antikainen et al. 2018; Zeiss et al. 2021).

However, research on digital solutions for waste management is still in its early stages. Some studies suggest using nondigital feedback systems or gamification to improve household waste sorting (Lim et al. 2021; Soma et al. 2020; Soomro et al. 2022; Hoffmann and Pfeiffer 2021). Nonetheless, more

empirical and experimental studies are needed to explore how digital applications can enhance biowaste-sorting quality in households (González-Briones et al. 2020; Pedersen and Manhice 2020; van der Werff and Lee 2021). IS research has the potential to contribute significantly to this issue but has so far made limited contributions to CE, particularly in empowering citizens to improve biowaste quality (Zeiss et al. 2021). Mismanaged biowaste that is incinerated as residual waste exacerbates the climate crisis, highlighting the need for simple but effective solutions to change individual behavior to meet the Sustainable Development Goals (SDGs) by 2030. This study aims to provide an IS perspective on changing household biowaste-sorting behavior, focusing on citizen engagement. Therefore, Research Paper 4 addresses the research question of *how to design an information system that contributes to improved biowaste sorting in households, promoting the urban circular economy (CE).*

To address this research question, Research Paper 4 develops design knowledge for an information system that promotes household waste sorting based on existing literature and 23 interviews. A DSR approach is applied, following the methodological guidelines of Peffers et al. (2007) and Gregor et al. (2020). The resulting digital design artifact is evaluated through a prototypical instantiation in the German city of Frankfurt am Main.

First, Research Paper 4 derives three DOs based on the current challenges and expectations mentioned in semi-structured interviews by waste management experts. The DOs read as follow:

DO.1 The artifact leads to higher separately collected biowaste quantities.

DO.2 The artifact promotes users' understanding of the CE.

DO.3 The artifact raises users' awareness of the importance of biowaste quality.

Second, DPs are derived from the interviews and structured using the TPB as an informing theory. The TPB of Ajzen (1991) is a well-established framework for predicting individual behavior or behavioral change, incorporating various motivational factors. According to the TPB, intention—defined as the motivational factors influencing effort to perform a specific behavior—can be predicted based on three determinants: (1) attitude—favorable or unfavorable appraisal of a behavior, (2) subjective norm—perceived social pressure to perform a behavior, and (3) perceived behavioral control—perception of how easy or difficult a behavior is to perform. Intention and perceived behavioral control together influence actual behavior. The DPs are derived by clustering the wishes, expectations, and statements from interviews with potential users, gamification and nudging experts, and information systems designers. Table 4 summarizes these DPs and structures them alongside the established DP dimensions of Gregor et al. (2020).

Table 4: Design principles, their dimensions as proposed by Gregor et al. (2020), and the relationship to the Theory of Planned Behavior

Design Principles	Aim (design objectives), implementer, user	Application context	Mechanism	Rationale	Relation to the TPB
Awareness and Transparency	To promote the user's favorable appraisal of the waste sorting behavior (DO.1; DO.2; DO.3)	Regional waste management systems in developed countries Adaption based on the regional systems	Provide transparent information about waste management processes and the positive impact of each user	Transparent information and awareness allow users to understand and trust the positive impacts of waste sorting and can increase the favorable appraisal of waste sorting behavior	Attitude toward the behavior
Social Influence	To increase the user's perceived social pressure to sort their waste through descriptive and injunctive norms (DO.1)	Monitoring and displaying the waste of individual households	Monitor and display the quantities of separately collected biowaste, compare it to neighbors or the average, and show that others of approving waste sorting	Social influence shows users if others sort waste by themselves or approve of waste sorting behavior leading to perceived social pressure	Subjective norm
Education	To promote the user's perception that waste sorting is easy to perform (DO.1; DO.2; DO.3)	Agreement of households that their data is shown Regional waste management systems in developed countries	Provide information about correct waste sorting and waste reduction	Education on correctly sorting and reducing waste can strengthen user's control beliefs that one possesses resources and fewer obstacles to waste sorting	Perceived behavior control
Confirmation and Incentive	To change the user's behavior, control beliefs, and influence future waste sorting intentions positively (DO.1)	Adaption based on the regional systems Monitoring and displaying the waste of individual households	Monitor and display the quantities of separately collected biowaste, show the progress of the user, and provide incentives for good waste sorting behavior	Feedback can strengthen the user's control beliefs by recognizing that they have control over their outcome. Incentives can foster the user's behavioral beliefs that waste sorting leads to a desirable outcome for themselves.	Feedback effects

Third, Research Paper 4 instantiates the design knowledge developed with the DPs through a field study in the German city of Frankfurt am Main, developing and evaluating the digital artifact *TrennMonitor* (in English, *SortingMonitor*) for smarter household waste sorting. Frankfurt, being the fifth largest city in Germany with a growing population and low biowaste-sorting rates, presents a significant opportunity for improving waste management and bioenergy production. The city's commitment to zero-waste and smart city initiatives, along with the local waste management company's transition to resource management, makes it an ideal environment for implementing and testing digital artifacts.

Fourth, following agile development principles, the *SortingMonitor* prototype was continuously revised based on feedback from interviews, and a suitable district in Frankfurt was selected for a field study, resulting in seven participating households from 100 households contacted. The field study qualitatively evaluated the *SortingMonitor* prototype against the three DOs. First, users reported that the artifact had a positive influence on their waste-sorting behavior, potentially leading to higher biowaste quantities. Second, feedback indicated that the application promoted a better understanding of the CE, and third, it raised awareness about the importance of biowaste quality. Additionally, the artifact demonstrated resource efficiency and a positive environmental impact by increasing biowaste collection, producing biogas and compost, and fostering sustainable user behavior.

Table 5: Evaluation of the prototype (based on March and Smith, 1995)

Criteria	Objectives	Evaluation
Effectiveness (regarding DOs)	Higher biowaste quantities	(✓)
	A better understanding of CE	✓
	Higher awareness of biowaste quality	✓
Efficiency	Low use of resources	(✓)
Impact on the environment and the user	Positive environmental impact (through higher quantities of biowaste) and better users' understanding of CE	✓
	Positive impact on interested users through getting feedback about waste generation, seeing the personal contribution to solving environmental challenges, and getting compost	✓

While the evaluation confirms that the instantiated design knowledge contributes to fulfilling the DOs, further development options were identified through evaluation interviews and the literature (Table 5). Three suggested expansions for smart waste management applications in cities include measuring biowaste quality, integrating multifamily houses, and enhancing the acceptance and usage of the artifact. These expansions involve incorporating quality measurement technology, fostering competition among multifamily houses (Popova and Sproge 2021; Abrahamse and Steg 2013), and making the artifact more interactive and comprehensible to appeal to a broader range of users (Abrahamse and Steg 2013).

The generalized design knowledge based on the well-known TPB can be transferred to other waste fractions and cities by adjusting the artifact's aim, adapting to regional sorting rules and cultural

differences, and ensuring infrastructure requirements and cooperation with waste management entities. Once these adaptations are implemented, the artifact can operate with minimal effort.

Research Paper 4 significantly contributes to advancing the transition toward a CE. Specifically, the design knowledge to design information systems for improved waste sorting is classified as a level two theory, namely a nascent design theory, as defined by Gregor and Hevner (2013). DPs derived include the importance of awareness and transparency, social influence, education and confirmation, and incentives. The developed digital artifact facilitates correct biowaste sorting by elucidating the importance of proper waste management and explaining the principles of CE. This design knowledge provides actionable guidance for practitioners, including waste management companies, municipal enterprises, and city administrations, on enhancing individual waste sorting and leveraging digitalization for operational improvements and reaching sustainability goals. In the overall context of this thesis, Research Paper 4 contributes by demonstrating how DT can enhance the sustainability of individual behavior through design knowledge on developing information systems for improved waste sorting.

III.2 Sustainability Transformation Guiding Digital Transformation

The convergence of organizations and individuals within cities further amplifies the need for DT and ST within cities, particularly for designing future-proof businesses and their processes (Baldassarre et al. 2020). Consequently, both transformations are increasingly on the agenda of cities, driven by growing urbanization and resource scarcity (Abu-Rayash and Dincer 2021). Thus, cities and their stakeholders face the dual pressures of managing digitalization and implementing sustainability measures. Smart Cities offer solutions to facilitate or even address the challenges of urbanization, integrating sustainability into urban living (Fernandez-Anez et al. 2018).

Smart Cities deploy digital technologies and technology-based applications, creating opportunities for sustainable development and tracking the impact of sustainability measures (Bohnsack et al. 2022). The term SCS refers to individual technology-based applications within a Smart City, acting as enablers for the concept and implementation of the Smart City (Jonas et al. 2023). First, smart cities offer benefits to citizens by enhancing quality of life, well-being, inclusion and participation, environmental development, and economic growth (Dameri 2013; Toli and Murtagh 2020). Second, the administration and operations of a smart city involve multiple stakeholders (Toli and Murtagh 2020). Third, smart cities utilize digital technologies to facilitate effective performance across various dimensions, including economy, people, governance, mobility, environment, and living (Dameri 2013; Giffinger and Haindlmaier 2010).

However, determining the value of SCS and its effectiveness toward sustainability is challenging but crucial. These applications often involve multiple stakeholders—individuals and organizations—who benefit directly or indirectly. Since sustainability value often materializes in the future, relying solely on

quantitative sustainability key performance indicators is insufficient to capture sustainability value creation (Agostinho et al. 2022). An example of an SCS is smart street lighting. This application primarily involves stakeholders such as the city administration and the installation organization, but it also provides direct and indirect value to other stakeholders, including citizens. To accurately gauge the overall sustainability value of this SCS, one must consider its economic, ecological, and social impacts. This holistic approach captures the sustainability value, highlighting the need for a systematic and comprehensive evaluation to guide investment decisions and enhance sustainability measures. Therefore, Research Paper 5 aims to answer the following research question:

How can the sustainability value of smart city solutions (SCSs) be assessed?

In response to the research question, Research Paper 5 presents a model to assess the sustainability value of digital solutions, developed in line with the DSR paradigm (Hevner et al. 2004; Peffers et al. 2007), specifically the DSR process following Peffers et al. (2007). Drawing on 15 expert interviews and a structured literature review (Sonnenberg and vom Brocke 2012; Webster and Watson 2002), this model evaluates the sustainability value of specific SCSs. It illustrates the complex interrelationships within a smart city and delineates both the direct and indirect values of an SCS.

Based on the first round of four interviews, DOs were derived to lay the foundation for subsequent model development. Smart City experts were asked about current problems in the sustainability value assessment of SCSs and model requirements. The conceptual schema proposed by Gregor et al. (2020) inspired the development of these DOs.

The model aims to provide a structure and approach to address sustainability value assessments in SCSs (Hilty et al. 2014). It should also help users deepen their understanding of SCSs and facilitate communication of SCS value potentials to a less knowledgeable audience. Therefore, the first DO is:

> **DO.1** Sustainability value assessment: The model should help SCS stakeholders assess the sustainability value of SCSs by applying the model.

Experts highlighted the difficulty of identifying all possible sustainability drivers and the complexity of including them in a single model. Thus, the second DO is:

> **DO.2** Value levers: The model should assist SCS stakeholders in identifying relevant value levers by considering the economic, ecological, and social dimensions of SCS.

Experts also noted the interconnectedness of SCSs with multiple stakeholders and how the value generated varies by stakeholder objectives. The third DO is:

> **DO.3** Stakeholders: The model should help SCS stakeholders identify and consider multiple stakeholders in the smart city context beyond themselves.

Finally, experts emphasized the need for the model's general applicability across different complexities,

use cases, and phases of SCS development. The fourth DO is:

> **DO.4** Generalizability: The model should assist SCS stakeholders in acknowledging and applying the model to different types and phases of SCS.

With the DOs in mind, Research Paper 5 presents the development of a model for assessing sustainability value. The model consists of two components: the value framework (Figure 6), which conceptualizes sustainability value generation for different stakeholders, and the value levers (Table 6), which identify specific values generated.

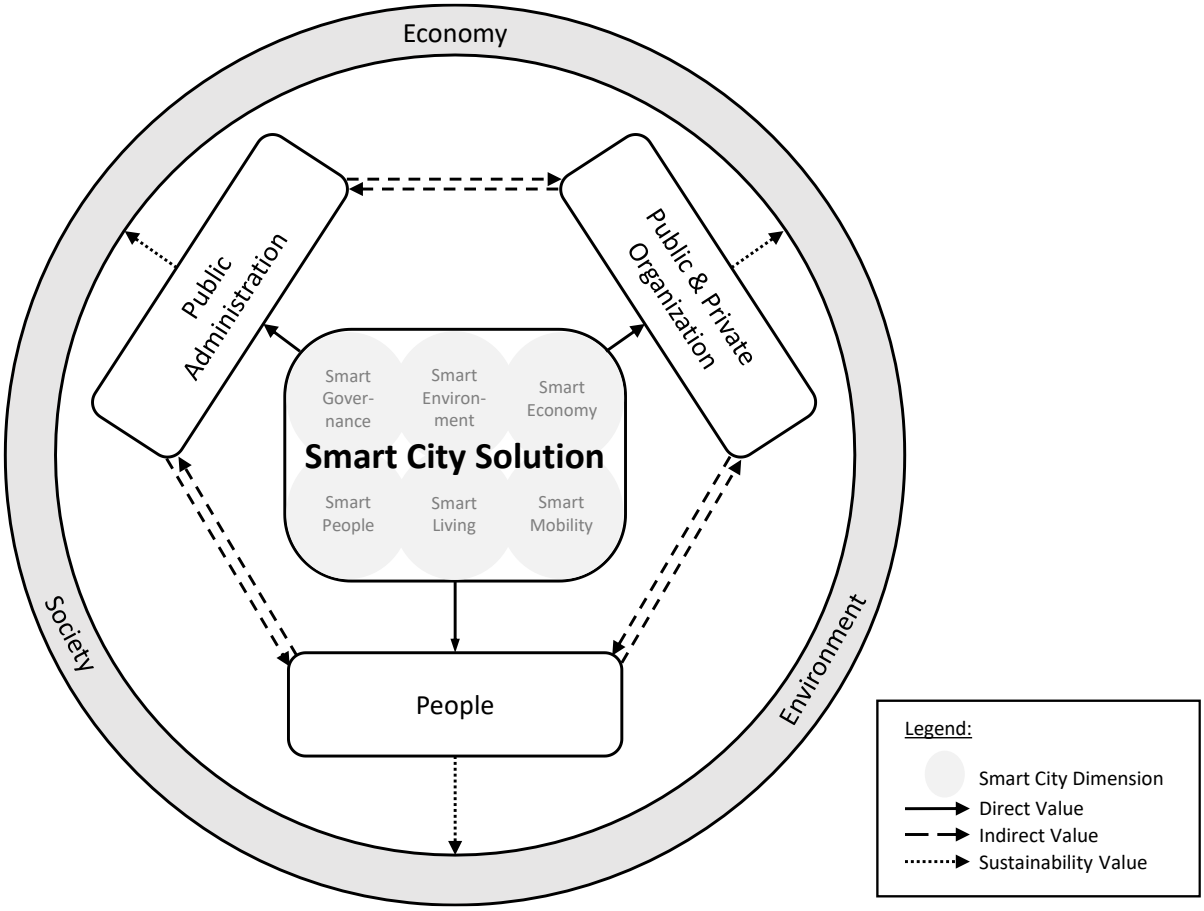

Figure 6: Smart City solution sustainability value framework

The SCS value framework depicts the relevant stakeholders, their relationships, and the SCS in the center with the smart city dimensions based on Giffinger and Haindlmaier (2010). These Smart City dimensions are elaborated in more detail in the second part of the model on value levers. Within the framework, the SCS is purposely not specified in more detail since the aim is to provide a model applicable to different kinds of SCSs. The three stakeholders, namely public administration, people, and public and private organizations, relevant to the smart city context are arranged around the SCS.

The sustainability value encompasses three dimensions—society, environment, and economy—aiming for their long-term preservation (Ahvenniemi et al. 2017; International Telecommunications-Union

2016). Arrows connecting stakeholders represent value relationships, indicating value creation between stakeholder groups and the SCS. The direction of the arrows denotes the flow of value and the ultimate value recipient. The SCS generates direct value for one or more stakeholders, while indirect value emerges in subsequent steps from either direct or indirect value. The final link in this value chain is sustainability value, a type of indirect value that enhances one of the sustainability dimensions, thus contributing to the long-term preservation of society, the environment, or the economy.

To enhance the model's practical applicability and facilitate value assessment, SCS-related value levers were inductively inferred and classified from the structured literature review (third level in Table 6). These value levers were then clustered into general themes (second level) and assigned to the smart city dimensions (first level) according to Giffinger and Haindlmaier (2010). This thematic structuring simplifies the handling of the value levers within the smart city context. The smart city dimensions, as outlined by Giffinger and Haindlmaier (2010), encompass multiple facets crucial for urban development and sustainability: The **smart economy** dimension emphasizes a city's competitiveness through overall economic strength, company profitability, and labor market conditions. **Smart people** focuses on enhancing social and human capital by fostering social life, public participation, and comprehensive education. The **smart mobility** dimension addresses advancements in transportation and information communication technology (ICT) to ensure environmentally friendly, safe, and comfortable transit options alongside improved digital connectivity. **Smart governance** highlights effective city administration, robust civilian participation, transparent decision-making, and efficient resource management. The **smart environment** dimension prioritizes environmental protection, emissions control, and sustainable energy use to conserve natural resources and reduce carbon footprints. Lastly, **smart living** aims to elevate the overall quality of life by ensuring high living standards, accessible health care, and robust safety measures for citizens.

Table 6: Excerpt of the Smart City dimensions and value levers

1st level	2nd level	3rd level	1st level	2nd level	3rd level
Smart Economy	↑ Overall Economy	↑ Innovation	Smart Governance	↑ Administration	↓ Maintenance Time and Effort
		↑ Business Opportunities			↓ Time & Effort for Administrative Procedures
		↑ Gross Domestic Product (GDP)			↑ Information about Administrative Procedures
		…			…
	↑ Company Profitability and Performance	↑ Motivation and Quality of Workforce		↑ Relationship to Citizens	↑ Trust
		↑ Productivity & Processes			↑ Transparency in Decision Making
		↓ Costs			↑ Data Privacy
		…			…
	↑ Labor Market	↑ Income / Income Equality		↑ Resource Availability	↑ Availability of Financial Resources
		↓ Unemployment			↑ Resource Management
		…			…
	…	…		…	…
Smart People	↑Social Life	↑ Culture	Smart Environment	↑ Energy Supply and Usage	↓ Energy Cost
		↑ Social Cohesion			↑ Energy Efficiency
		↑ Social Equity			↑ Renewables
		…			…
	↑ Public Participation	↑ Participation in Political Events		↑ Environmental Protection	↑ Green Areas
		↑ Participation in Social Events			↑ Biodiversity
		…			…
	↑ Education of Individuals	↑ Quality of Education		↑ Emission Control	↑ Emission Monitoring
		↑ Digital Skills			↓ Carbon Emissions
		…			…
	…	…		…	…
Smart Mobility	↑ Transportation Possibilities	↑ Public Transport Opportunities	Smart Living	↑ Overall Living Standards	↑ Living Comfort
		↑ Public Transport Convenience and Preference			↑ Security of Supply
		…			…
	↑ Traffic Management	↑ Traffic Optimization and Forecasting		↑ Citizen Safety	↑ Individual Safety
		↑ Mobility Strategy			↓ Crime
		…			…
	↑ ICT Access	↑ Network Availability		↑ Citizen Health	↑ Access to Healthcare Services
		↑ Cyber Security			↑ Usage of Healthcare Devices
		…			…
	…	…		…	…

In line with DSR, the model was demonstrated using the real-world case of smart street lighting, which includes functionalities such as smart control of light based on passersby and movement data analysis. The value framework categorized smart street lighting into smart governance, smart environment, smart living, and smart economy dimensions, thereby identifying public administrations, private organizations, and people as key stakeholders. The next step involved examining direct value levers, such as increased energy efficiency and business opportunities, and indirect sustainability value levers, like resource conservation and reduced crime, associated with smart street lighting. These value levers demonstrate that multiple stakeholders, including public administrations, public and private organizations, and individuals, can benefit both directly and indirectly, enhancing long-term sustainability in social and environmental aspects.

The model presented in Research Paper 5 extends current literature by providing a comprehensive approach and structure for sustainability value assessment for individual SCSs while also offering practical benefits for SCS stakeholders using the model to examine and further develop their SCS. In doing so, Research Paper 5 offers a comprehensive way for cities and their stakeholders to find a structure and possible solution within the obscure tunnel of digitalization and sustainability. Most of the literature on smart cities focuses on quantitative, indicator-based approaches (e.g., Abu-Rayash and Dincer 2021; Angelakoglou et al. 2020; Benites and Simões 2021), but the presented model extends these by dividing sustainability value assessment into two steps and addressing the research gaps in systemic analysis and stakeholder relationships of current assessment of SCSs (Agostinho et al. 2022; Hilty et al. 2014; Kotlarsky et al. 2023; Patrão et al. 2020). The model systematically categorizes stakeholder relationships into three groups and incorporates sustainability value levers, which is simple and flexible. The design enhances its applicability across various stages of SCS development and implementation. Additionally, the model functions as an effective communication tool for justifying decisions and promoting sustainability value, thereby establishing a foundation for future monetization strategies supporting the implementation of SCSs. In the overall context of this thesis, Research Paper 5 contributes by demonstrating how ST at the societal level can contribute to the targeted use of digital technologies and their design for a sustainable future. In addition, it offers a way of systematically assessing the sustainability value of digital solutions instantiated as SCSs.

Recognizing that the twin transformation concept extends the organizational level, this section explores the underlying mechanisms of twin transformation at both the individual and societal levels by developing design knowledge following the DSR paradigm. At the individual level, Research Paper 4 demonstrates how DT enables ST by presenting DPs for information systems that enhance waste-sorting behavior, thereby supporting a circular economy. Furthermore, at the societal level, Research Paper 5 illustrates how ST guides DT by introducing a model for assessing the sustainability value of digital solutions, namely SCSs.

IV Conclusion

IV.1 Summary

The urgency for enhancing global sustainability is more critical than ever. Currently, six out of nine planetary boundaries, which are the limits essential for maintaining the environment's stability and human progress, have been exceeded (Richardson et al. 2023). Respecting these planetary boundaries is not only an environmental concern but also a significant social issue, as exceeding them impacts where and how individuals can live meaningful lives (e.g., floods or heat waves; Rockström et al. 2009). In general, organizations have a substantial role in achieving global sustainability objectives, while individuals can influence the actions of these organizations through their consumption choices (El Geneidy et al. 2021; Garnett and Balmford 2022). In particular, digital technologies are crucial in reaching global sustainability objectives as they facilitate improving efficiency and create transparency (e.g., Pappas et al. 2023; Centobelli et al. 2022; El Hilali et al. 2020). Thus, it is essential to take a holistic view of individuals, organizations, and society in the context of DT and ST.

This thesis, along with its research papers, aims to help individuals, organizations, and societies secure a sustainable future by exploring twin transformation as a potential solution for digitalization- and sustainability-related challenges. Twin transformation leverages the synergies between DT and ST, aiming to achieve the objectives of both transformations simultaneously. This thesis includes five research papers that explore the interplay and the underlying mechanisms of twin transformation in detail.

First, this thesis explicitly addressed the organizational perspective of the twin transformation interplay. It began with conceptualizing and defining twin transformation, laying the foundation for understanding its underlying mechanisms and significance. Following this, the thesis introduced the twin transformation capability framework, which forms the foundation for the TTCMM that outlines three pathways to achieve twin transformation maturity. Additionally, the thesis employed a tension lens to explore conflicting demands between DT and ST, proposing three twin transformation response mechanisms to effectively address tensions affected by the interplay between DT and ST.

Second, regarding the underlying mechanisms of the twin transformation interplay, the thesis detailed two instantiations of these mechanisms on each, namely, the individual and societal levels. On the individual level, it examined how DT can enable ST by providing design knowledge for creating information systems that facilitate more thoughtful waste-sorting practices. On the societal level, this thesis investigated how ST can guide DT by developing a model to assess the sustainability value of digital solutions, namely SCSs. This comprehensive approach provides actionable insights for leveraging the synergies between DT and ST to achieve global digital and sustainability objectives.

Overall, this thesis makes significant contributions to the existing literature by providing both descriptive and explanatory knowledge on the interplay of DT and ST. On the one hand, descriptive knowledge lays the groundwork for a theory for analysis (type I theory according to Gregor, 2006) by systematically conceptualizing the twin transformation interplay at an organizational level and enhances the understanding of different pathways to twin transformation maturity. On the other hand, this thesis provides explanatory knowledge, which forms the basis for a theory for explanation (theory type II according to Gregor, 2006) by advancing the understanding of the twin transformation interplay and elucidating the underlying mechanisms and tensions between DT and ST. Furthermore, this thesis presents design knowledge for designing digital artifacts to enhance individual sustainability behavior and demonstrates a model for assessing the sustainability value of SCSs. The presented results provide insights for research and practice, guiding future researchers in investigating and shaping the twin transformation interplay (see Section IV.3) as well as practitioners in advancing integrated sustainability and digital actions in practice. In doing so, the contributions of this thesis not only enhance the theoretical understanding of the twin transformation interplay and underlying mechanisms but also offer tangible benefits for individuals to facilitate sustainable practices, organizations to reach twin transformation maturity, and societies to implement sustainable SCSs.

IV.2 Limitations

The research findings presented in this thesis should be interpreted with consideration of their overall limitations, which are summarized below. These extend beyond the specific limitations of each individual research paper, which are detailed in the respective research paper (see Sections VI.3–VI.7). Instead, this Section identifies broader constraints of this thesis.

First, the conceptualization of twin transformation in this thesis operates at a high level of abstraction by identifying the two underlying mechanisms, namely DT enables ST, and ST guides DT. However, a twin transformation in and across different, specific organizational departments is necessary to realize these mechanisms, which is not the focus of this thesis. Furthermore, this thesis recognizes the pivotal roles of individuals, organizations, and societal factors in determining the success of twin transformation. Nonetheless, the interactions among these three levels have not been systematically investigated, thus creating a critical gap in understanding their collective impact on the successful integration of DT and ST as twin transformation.

Second, a limitation of this thesis stems from the rapidly evolving landscape of DT and ST, which necessitates qualitative input data, particularly expert interviews, to effectively explore this emerging research field. However, the rapid evolution of both individual transformations and the integrated twin transformation compromises the generalizability of the findings. For instance, dynamic twin transformation capabilities (see Research Papers 1 and 2) and sustainability value levers for SCSs (see Research Paper 5) are still evolving in practice. Furthermore, the scarcity of organizations recognized

as real twin transformers also limits the generalizability of the findings, as the pool of qualified interview subjects possessing expertise in twin transformation, and not only DT and/or ST, was relatively small.

Third, the findings of this thesis are constrained by the context-specific effectiveness of the proposed artifacts. For instance, the TTCMM (see Research Paper 2) and the sustainability value assessment model (see Research Paper 5) may not hold equal relevance across all organizations or for assessing the sustainability value of digital solutions beyond smart cities. The context-specificness raises questions regarding the universal applicability of these artifacts, as their effectiveness could be influenced by factors such as industry dynamics and specific (technological) contexts.

IV.3 Future Research

Both the presented contributions and limitations of this thesis highlight potential starting points for future research.

First, future research would benefit from a comprehensive exploration of the twin transformation interplay, considering interconnections at the individual, organizational, and societal levels. Given the complex and multilevel nature of twin transformation, employing a multilevel IS research approach may facilitate the examination of the interrelationships among technology usage, individuals, and groups within organizational and societal contexts (Bélanger et al. 2014). Specifically, research focused on the usage of sustainable digital technologies as well as knowledge management, sharing, and collaboration could greatly benefit from structured multilevel research approaches (Bélanger et al. 2014). For instance, future research could utilize a multilevel research approach and apply a system theory lens to examine feedback loops between individual sustainability behavior (e.g., customers' consumption behavior) and organizational sustainability practices (e.g., sustainability reporting) and the effect of digital technologies on both. Thereby, future research could analyze how individual consumption behavior affects organizational sustainability practices and how organizational sustainability reporting influences individual consumption behavior. In doing so, further studies could uncover feedback loops between individual sustainability behavior and organizational sustainability practices, which may be facilitated or hindered by the use of digital technologies. Multilevel research approaches can enhance the understanding of the underlying mechanisms of twin transformation (i.e., DT enables ST, and ST guides DT) across individuals, organizations, and broader societal contexts. An integrated perspective encompassing these three levels would more accurately reflect the inherent complexity and interdependencies in both DT and ST.

Second, future research could focus on the operationalization of twin transformation by investigating its interplay across various organizational departments, such as human resources and operations, and within diverse industries, including automotive and pharmaceuticals. Gholami et al. (2016) stress the need for solution-oriented IS research to address grand societal sustainability challenges. To facilitate practical implementations of twin transformation and deepen the scholarly discourse, it is essential for future

researchers to adopt appropriate research methods. On the one hand, related research could conduct case studies (Yin 2012) to gain deep insights into the dynamics of twin transformation in specific contexts. In doing so, it could also refine the proposed artifacts of this thesis (e.g., develop a TTCMM for specific industries or an assessment method for the twin transformation based on the TTCMM; Research Paper 5). Guandalini (2022) advocates comparative research across industries to leverage industry-specific synergies between DT and ST. On the other hand, employing action design research (Sein et al. 2011) could enable future researchers to simultaneously innovate twin transformation artifacts while refining theoretical constructs that address grand societal issues. This duality enhances both practical twin transformation applications and theoretical advancements in digital sustainability research.

Third, in alignment with the call by Kotlarsky et al. (2023), future research could investigate digital sustainability ecosystems and the role of individuals, organizations, and society within them. To create value for the common good, organizations must engage in collaborative efforts, adopting an outside-in perspective that prioritizes societal sustainability challenges (Dyllick and Muff 2016). This necessitates an examination of the interrelations between digital sustainability ecosystems and the three levels discussed in this thesis: individuals, organizations, and society. Investigating these relationships can show how various stakeholders interact within digital sustainability ecosystems, potentially revealing mechanisms for enhanced collaboration and knowledge sharing. Furthermore, future research could delve into how these ecosystems influence the emergence and successful diffusion of digital sustainable business models, particularly those aligned with CE principles (Zeiss et al. 2021). Additionally, a focus on the dynamics of individual behavior (e.g., stakeholder engagement) within digital sustainability ecosystems could provide insights into the factors that facilitate or hinder collaborative efforts in organizations and society. This might include exploring the roles of leadership or organizational culture in fostering effective partnerships. By examining these elements, future researchers could contribute to a more comprehensive understanding of how digital sustainability ecosystems' function and how they can be leveraged to promote twin transformation practices.

In conclusion, this thesis aspires to provide valuable insights and practical guidance for both researchers and practitioners, thereby facilitating the effective integration of DT and ST as twin transformation in organizations with a positive impact regarding digital and sustainable objectives for individuals and society at large. By advancing the understanding and application of the interplay between the two transformations, I aim to contribute to developing a resilient, sustainable, and digital future, ensuring that the world remains a viable and flourishing environment for future generations.

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VI Appendix

VI.1 Index of Research Articles

Table 7. Index of research articles

Research Paper 1	**The Twin Transformation Butterfly – Capabilities for an Integrated Digital and Sustainability Transformation** Christmann, AS, **Crome, C**, Graf-Drasch, V, Oberländer, AM, Schmidt, L (2024). The Twin Transformation Butterfly. Bus Inf Syst Eng. https://doi.org/10.1007/s12599-023-00847-2. (VHB-24[3]: B, VHB-JQ3[4]: B, IF[5]: 7,4)
Research Paper 2	**Dynamic Capabilities for the Twin Transformation Climb: A Capability Maturity Model** Breiter, K, **Crome, C**, Oberländer, AM, Schnaak, F (2024)**.** Dynamic Capabilities for the Twin Transformation Climb: A Capability Maturity Model. Inf Syst Front. https://doi.org/10.1007/s10796-024-10520-y. (VHB-24: B, VHB-JQ3: B, IF: 6,9)
Research Paper 3	**Navigating the Twin Transformation Frontier: Resolving Tensions between Digital and Sustainability Transformations** **Crome, C**, Kreuzer, T, Meyer-Hollatz, T, Oberländer, AM (2024). Examining Twin Transformation to Balance Digital Transformation and Sustainability Transformation Tensions. *Outlet hidden due to the double-blind review process.*
Research Paper 4	**Circular Economy Is Key! Designing a Digital Artifact to Foster Smarter Household Biowaste Sorting** **Crome, C**, Graf-Drasch, V, Hawlitschek, F, Zinsbacher D (2023). Circular Economy Is Key! Designing a Digital Artifact to Foster Smarter Household Biowaste Sorting, Journal of Cleaner Production. https://doi.org/10.1016/j.jclepro.2023.138613. (VHB-24: B, VHB-JQ3: B, IF: 9,7)
Research Paper 5	**Smart Cities, Sustainable Futures: Uncovering the Sustainability Value of Smart City Solutions** Abdipour, R, **Crome, C,** Michaelis, A, Oberländer, AM, Steinkopf, J, Jonas, C (2024). Smart Cities, Sustainable Futures: Conceptualizing the Sustainability Value Assessment of Smart City Solutions. *Outlet hidden due to the double-blind review process.* Earlier version published in ECIS 2024 Proceedings. https://aisel.aisnet.org/ecis2024/track17_greenis/track17_greenis/30 (VHB-24: A (Proceedings), VHB-JQ3: B)

[3] VHB-24: VHB Publication Media Rating 2024
[4] VHB-JQ3: VHB-JOURQUAL3
[5] Impact Factor

Further, I also co-authored the following research papers. These papers are not part of this dissertation.

Table 8. Further research articles

From Synergy to Value - An ESG Perspective on Twin Transformation Auweiler, S, **Crome, C**, Kneissel, K, Kreuzer, T, Müller, M (2024). From Synergy to Value - An ESG Perspective on Twin Transformation. *Outlet hidden due to the double-blind review process.*
Agentic Information Systems in Smart Homes: A Pathway to Psychological Well-Being and Climate Change Mitigation Bonenberger, L, Breiter, K, **Crome, C,** Gimpel H (2024). Agentic Information Systems in Smart Homes: A Pathway to Psychological Well-Being and Climate Change Mitigation. *Outlet hidden due to the double-blind review process.*
Evaluating Digital Sustainability-Oriented Innovations: Criteria for the Frontend of Innovation Wormeck, L, **Crome, C**, Meyer-Hollatz, T, Hinsen, S, Wasserman, ME (2024). Evaluating Digital Sustainability-Oriented Innovations: Criteria for the Frontend of Innovation. ECIS 2024 Proceedings. 13. https://aisel.aisnet.org/ecis2024/track02_general/track02_general/13 (VHB-24: A (Proceedings), VHB-JQ3: B)
Building a Digital and Sustainable Future – How Companies Can Pioneer Twin Transformation Bitzer, M, **Crome, C**, Graf-Drasch, V, Hinsen, S, Huber, F, Pantzer, J, Meyer-Hollatz, T, Oberländer, AM, Schleich, E, Urbach, N, Wilkens, H (2023). Building a Digital and Sustainable Future – How Companies Can Pioneer Twin Transformation. https://www.fit.fraunhofer.de/en/business-areas/digital-business/study-building-a-digital-and-sustainable-future.html
Integrating Digital and Sustainability Transformation Through Artificial Intelligence: A Framework for AI-enabled Twin Transformation **Crome, C,** Graf-Drasch, V, Oberländer, AM, Seidel, S (2024). Integrating Digital and Sustainability Transformation Through Artificial Intelligence: A Framework for AI-enabled Twin Transformation. In: Lynn, T., Rosati, P., Kreps, D., Conboy, K. (eds) Digital Sustainability. Palgrave Studies in Digital Business & Enabling Technologies. Palgrave Macmillan, Cham. https://doi.org/10.1007/978-3-031-61749-2_3

VI.2 Individual Contributions to Research Papers

This dissertation is cumulative and includes five research papers, all written in teams with multiple co-authors. This section outlines the settings and describes my contributions to the five research papers. The descriptions follow the contributor roles taxonomy (CRediT) by Allen et al. (2019).[6]

Research Paper 1 entitled "*The Twin Transformation Butterfly – Capabilities for an Integrated Digital and Sustainability Transformation*" (Christmann et al. 2024; Section VI.3), was written by a team of five authors. I overtook the project administration and contributed significantly to reviewing and editing the entire manuscript during the revision process. As a team, the other members and I agreed that all contributed to this research paper in equal parts.

Research Paper 2, "*Dynamic Capabilities for the Twin Transformation Climb: A Capability Maturity Model*" (Breiter et al. 2024; Section VI.4), was written by a team of four authors. I contributed to the conceptualization, investigation, and methodology of the manuscript. In addition, I mainly contributed to the visualization. Furthermore, I was responsible for writing parts of the original draft and was involved in reviewing and editing the manuscript during the revision process. The team agreed that all members contributed equally to this research paper.

Research Paper 3 entitled "*Navigating the Twin Transformation Frontier: Resolving Tensions between Digital and Sustainability Transformations*" (Crome et al. 2024; Section VI.5), was written by a team of four authors. As the lead author, I held a crucial role in all parts and administered this research project. I contributed significantly to the conceptualization, methodology, investigation, and data curation for this research paper. I was also responsible for writing the original draft and for visualization. I acted as lead author, while the other three co-authors acted as subordinate authors.

Research Paper 4 entitled "*Circular Economy Is Key! Designing a Digital Artifact to Foster Smarter Household Biowaste Sorting*" (Crome et al. 2023; Section VI.6), was written by a team of four authors. I contributed to the methodology and investigation of the paper. Furthermore, I contributed significantly to the writing of the original draft and was mainly responsible for reviewing and editing the entire paper. The team agreed that all members contributed to this research paper in equal parts.

Research Paper 5 entitled "*Smart Cities, Sustainable Futures: Uncovering the Sustainability Value of Smart City Solutions*" (Abdipur et al. 2024; Section VI.7), was written by a team of six authors. I contributed significantly to the conceptualization and methodology of the paper and was involved in reviewing and editing it in entirety. Although I fulfilled a supervision role, the team members all contributed to this research paper in equal parts.

[6] Allen, L., O'Connell, A., & Kiermer, V. (2019). How can we ensure visibility and diversity in research contributions? How the Contributor Role Taxonomy (CRediT) is helping the shift from authorship to contributorship. Learned Publishing, 32(1), 71-74.

VI.3 Research Paper 1: The Twin Transformation Butterfly – Capabilities for an Integrated Digital and Sustainability Transformation

Authors:

Anne-Sophie Christmann, Carlotta Crome, Valerie Graf-Drasch, Anna Maria Oberländer and Leonie Schmidt

Published in:

Bus Inf Syst Eng 66, 489-505 (2024). DOI: 10.1007/s12599-023-00847-2

Abstract:

Complex digitalization and sustainability challenges shape today's management agendas. To date, the dedication of Information Systems research to both challenges has not been equal in terms of effort and reward. Building capabilities to leverage the synergetic potential of digital and sustainability transformation may enhance organizational performance and imply new value creation for the common good. To uncover such synergetic potential, this work conceptualizes the "twin transformation" construct as a value-adding reinforcing interplay between digital transformation and sustainability transformation efforts that improve an organization by leveraging digital technologies to enable sustainability and to guide digital progress by leveraging sustainability. The twin transformation conceptualization is complemented with a capability framework for twin transformation drawing from dynamic capability theory. This work contributes to descriptive knowledge of the interplay between digital transformation and sustainability transformation, setting a foundation for further theorizing on twin transformation and enabling organizations to twin transform.

Keywords:

Twin transformation, Digital transformation, Sustainability transformation, Dynamic capabilities

VI.4 Research Paper 2: Dynamic Capabilities for the Twin Transformation Climb: A Capability -Maturity Model

Authors:

Katharina Breiter, Carlotta Crome, Anna Maria Oberländer and Feline Schnaak

Published in:

Inf Syst Front (2024). DOI: 10.1007/s10796-024-10520-y

Abstract:

Digital transformation and sustainability transformation are at the top of organizations' agendas to remain competitive. While guidance on both transformations exists separately, even more research on integrating digital and sustainability transformation, namely twin transformation, is required. Specifically, deeper knowledge about relevant twin transformation capabilities and progress is needed for effective implementation. To enhance the understanding and provide corresponding guidance, we developed a twin transformation capability maturity model focusing on dynamic capabilities required to realize twin transformation based on a structured literature review and interviews with 13 experts. Further, we demonstrated its use with a technology service provider. Our contribution is twofold: First, accounting for organizations' twin transformation starting points in terms of their digitalization and sustainability experience and expertise, we reveal three pathways to becoming a twin transformer. Second, our work provides an overview of 45 relevant twin transformation capabilities structured along six capability dimensions and four maturity stages. Our work also provides relevant practical implications supporting organizations in assessing their twin transformation maturity, building the foundation for targeted capability development.

Keywords:

Digital transformation, Sustainability transformation, Maturity model, Design science research, Twin Transformation, Dynamic capabilities

VI.5 Research Paper 3: Navigating the Twin Transformation Frontier: Resolving Tensions between Digital and Sustainability Transformations

Authors:

Carlotta Crome, Tim Meyer-Hollatz, Thomas Kreuzer and Anna Maria Oberländer

Submitted to:

Outlet hidden due to the double-blind review process

Extended Abstract:

At present, organizations are undergoing significant changes driven by two critical transformations: Digital transformation (DT) and sustainability transformation (ST). Both transformations are perceived as separate, primarily due to their specific characteristics (e.g., Dorninger et al., 2020; Vial, 2019). While DT in general and digital technologies, in particular, facilitate adopting new digital value-creation processes, ST fosters social and environmental practices in organizations. Hence, both transformations lead to business model changes and affect tensions that may hinder such organizational change (Chatterjee & Sarker, 2024; Mishra et al., 2022). These tensions can be attributed to (1) DT's economic motivations contrasted with ST's focus on environmental and social objectives (Chatterjee & Sarker, 2024) and (2) the environmental and social challenges associated with digital technologies (Veit & Thatcher, 2023). Nevertheless, both transformations are vital for long-term organizational viability and societal well-being. DT facilitates organizational adaptation to technological changes, thereby enhancing competitiveness, while ST ensures the preservation of environmental and human resources for future generations (Sancak, 2023).

In this context, twin transformation, namely the integration of DT and ST on equal footing, presents a promising approach to mitigate the tensions arising from their interaction (Christmann et al., 2024). However, to advance twin transformation research, a thorough understanding of the tensions at the interplay of DT and ST and the mechanisms for reconciling them is imperative. This paper aims to investigate the tensions affected by the integrated implementation of DT and ST within organizations, focusing on how organizations can effectively navigate these tensions through twin transformation.

To examine and address such tensions, this work follows a sequential, multi-method research strategy (Mingers, 2001). First, a systematic literature review is performed to synthesize existing knowledge on the tensions associated with DT and ST (Wolfswinkel et al., 2013). Second, 24 semi-structured interviews with subject-matter experts are conducted to derive strategies for balancing the identified tensions (Gioia et al., 2013; Myers & Newman, 2007). The literature review identifies five primary tensions influenced by the interplay of DT and ST: *societal value versus organizational performance, radical innovation versus incremental innovation, competition versus collaboration, personal employee*

identity versus organizational identity, and depth of competence versus breadth of competence. These tensions are categorized utilizing the established tension framework proposed by Smith and Lewis (2011). The empirical data from the interviews reveal three response mechanisms for twin transformation aimed at addressing these tensions: *leveraging digitalization to foster sustainability efforts, utilizing sustainability initiatives to enhance digitalization, and integrating digital and sustainability practices for mutual benefit.* These mechanisms offer a structured approach for practitioners to manage and reconcile the competing demands of DT and ST, thereby facilitating the implementation of an effective twin transformation.

This work contributes to research and practice in two significant ways: First, it enhances understanding of the tensions affected by the interplay of DT and ST, laying the groundwork for integrated tension management. Second, it provides actionable twin transformation response mechanisms that bridge the gap between theoretical insights and practical application. These findings not only support practitioners in successfully implementing effective twin transformations but also provide researchers with a structured approach to investigate such tensions and connect the emerging field of twin transformation research to established streams of Information Systems research.

Keywords:

Twin Transformation, Digital Transformation, Sustainability Transformation, Tensions, Systematic Literature Review, Interview Study

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VI.6 Research Paper 4: Circular Economy is Key! Designing a Digital Artifact to Foster Smarter Household Biowaste Sorting

Authors:

Carlotta Crome, Valerie Graf-Drasch, Florian Hawlitschek and Daniela Zinsbacher

Published in:

Journal of Cleaner Production (2023). DOI: 10.1016/j.jclepro.2023.138613.

Abstract:

Waste volumes are rising. This is a problem, as they worsen environmental challenges such as climate change. At the same time, however, waste bears valuable resources – yet untapped. The concept of a circular economy bears the potential to unleash these resources. In the short run, only changing the waste sorting behavior of citizens can effectively contribute to circular resource flows, as waste management companies cannot ensure the purity of waste by purely technical means. Aligned with the digital realm, this work focuses on designing a digital artifact that contributes to improved household waste sorting. Using a design science research approach, we develop the artifact's design with input from theory, 23 interviews with potential users and practitioners, and evaluate a prototypical instantiation in a large German city. We contribute to literature and theory by generating design knowledge on information systems for improved biowaste and residual waste sorting by individuals. We derive as key design principles the importance of awareness and transparency, social influence, education and confirmation, and incentives. Our solution embracing those principles enhances the awareness of circular economy processes and the relevance of correct waste sorting. At the same time, our solution is relevant to solving waste management companies' current challenges such as the incineration of valuable biowaste as part of residual waste.

Keywords:

Household waste sorting, Circular economy, Design science research, Zero waste, Biowaste

VI.7 Research Paper 5: Smart Cities, Sustainable Futures: Uncovering the Sustainability Value of Smart City Solutions

Authors:

Rojin Abdipour, Carlotta Crome, Claudius Jonas, Anne Michaelis, Anna Maria Oberländer and Jana Steinkopf

Submitted to:

Outlet hidden due to the double-blind review process

Earlier version published in ECIS 2024 Proceedings, https://aisel.aisnet.org/ecis2024/track17_greenis/track17_greenis/30.

Extended Abstract:

Sustainability and digitalization are increasingly crucial for individuals, organizations, and society (Guandalini, 2022). Both phenomena shape organizational processes (Baldassarre et al., 2020) and influence everyday life through digital technologies that promote more efficient energy consumption (Berger et al., 2022). As urbanization escalates and resource constraints become more pressing, city administrations are prioritizing both digital and sustainability transformations (Abu-Rayash & Dincer, 2021). Digital transformation is essential for cities, enhancing operational efficiency, improving service delivery, and fostering innovation to meet the needs of growing populations (Anthony Jnr, 2021). Likewise, sustainability transformation ensures responsible resource use, mitigates environmental impacts, and enhances residents' quality of life, contributing to the long-term viability of urban ecosystems.

To evaluate sustainability advancements, the Sustainable Development Goals represent a universal framework addressing global challenges like poverty, inequality, and climate change (United Nations, 2010). Sustainability advancements can be assessed across social, environmental, and economic dimensions (Santoyo-Castelazo & Azapagic, 2014). However, urban stakeholders encounter the challenge of managing the complexities of digitalization and implementing effective sustainability initiatives. Smart Cities, in general, and Smart City solutions, in particular, are an approach to integrate sustainability into urban life through digital technologies (Fernandez-Anez et al., 2018), yet assessing the value of Smart City solutions remains challenging. Current value assessment approaches lack standardized methods for evaluating sustainability value (Gasparatos & Scolobig, 2012; Ramos, 2019; Warren-Myers, 2013) and often fail to capture the complexities and indirect values associated with implementing Smart City solutions (Hilty et al., 2014).

This work aims to develop a model for qualitatively assessing the sustainability value of Smart City solutions. The development of the model aligns with the design science research paradigm (Hevner et

al., 2004; Peffers et al., 2007) and combines a structured literature review with expert interviews (Sonnenberg & vom Brocke, 2012; Webster & Watson, 2002) to depict interrelationships within a Smart City. It provides a comprehensive approach for assessing the sustainability value of individual Smart City Solutions, facilitating the navigation of the complexities at the intersection of digitalization and sustainability. The resulting model, consisting of a framework to assess the sustainability value of Smart City solutions and specific value levers, offers a structured framework for stakeholders to manage and evaluate the sustainability value of specific Smart City solutions. In doing so, the model splits sustainability value into direct, indirect, and sustainability-specific values. The results highlight the necessity for a systematic approach to capture these solutions' economic, environmental, and social impacts. This work contributes significantly to Information Systems research and practice by enhancing understanding of sustainability value in Smart Cities and providing actionable insights for practitioners. The model is a vital tool for urban stakeholders, facilitating informed decision-making regarding sustainability investments and supporting the goal of advancing smart sustainable cities.

Keywords:

Smart City solution, Sustainability, Value assessment, Design Science Research, Smart sustainable city

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