Providing the Building Blocks for Organizations to Balance Digital Transformation and Sustainability

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“There must be a better way to make the things we want, a way that doesn’t spoil the sky, or the rain or the land.”

— Paul McCartney

Copyright Statement

The following sections are partly comprised of content taken from the research articles in this thesis. To improve the readability of the text, I have omitted the standard labelling of these citations.

Abstract

Organizations are uniquely positioned to promote sustainability across the environmental, economic, and social pillars due to their capacity for rapid innovation, the creation of spillover effects, and the operation beyond government boundaries. Leveraging this position through Digital Transformation (DT) offers the potential to develop new value propositions and redefine value networks, thereby enabling sustainable development. However, DT can also lead to unintended negative consequences on sustainability, affecting both current and future generations. Thus, a balance must be struck between the promising prospects of DT and its potential adverse effects. In this context, this doctoral thesis examines the challenges arising from the interplay of DT and sustainability. Specifically, it addresses how organizations can enter virtuous cycles, where the success of one project that combines DT and sustainability spurs further similar projects. This is achieved by providing actionable research artifacts, considering sustainability as a concept composed of three pillars (economic, environmental, and social), and leveraging the connections between these pillars. The findings serve as building blocks – i.e., theoretically grounded research artifacts that provide organizations with generalizable yet actionable guidelines – to foster sustainable development by organizations.

Before diving into the exploration of the challenges, Research Article #1 employs a tension lens to investigate the competing demands at the intersection of DT and sustainability. Drawing on these tensions and the results of an interview study, the article introduces three response mechanisms that guide organizations and researchers in understanding and facilitating the integration of DT and sustainability. This approach demonstrates how organizations can actively balance the positive and negative impacts that result from the interaction between DT and sustainability, while treating sustainability as a holistic concept. Building on the first response mechanism (i.e., *Leverage DT to enhance sustainability*), Research Article #2 conducts a multivocal literature review to derive archetypes that use Artificial Intelligence (AI) for sustainability. These archetypes integrate organizational, technical, and sustainability perspectives to enhance the adoption of AI for sustainability in organizations.

Beyond the potentials of DT for sustainability, the second response mechanism *"Exploit sustainability to sharpen digital actions"*, emphasizes how organizations can utilize a sustainability perspective to improve the sustainability of DT projects. Here, Research Article #3 presents design patterns for AI projects to address the negative impacts of AI on the environment and society. Complementary, Research Article #4 focuses on government mechanisms and offers an extension to existing governance frameworks to connect multiple sustainability pillars.

Finally, this doctoral thesis presents two research articles that illustrate the third response mechanism (i.e., *"Integrate DT and sustainability to provide mutual benefits"*) that integrates DT and sustainability by merging the outcome focus of response mechanism one with the process focus of response mechanism two. Research Article #5 employs Automated Machine Learning (AutoML) a technique designed to democratize access to Machine Learning (ML) and facilitates efficient training to compare different feature sets for predicting public transportation punctuality. The results enable public transportation providers to improve service reliability, thereby increasing user attractiveness and promoting a shift toward more sustainable mobility. Concurrently, this research demonstrates how organizations can democratize ML access by showing that AutoML can be used to train sophisticated models. Although fostering a shift towards sustainable mobility, Research Article #6 applies a sustainability lens to enhance information provisioning in intermodal mobility journeys. The resulting model integrates phases, mode combinations, and their interactions, offering organizations an example of blending digital goals (i.e., increasing usability) with sustainability goals (i.e., enhancing sustainable mobility).

In conclusion, this doctoral thesis equips organizations with building blocks for integrating DT and sustainability. By offering actionable practices that consider all three sustainability pillars and connecting values across these pillars, this thesis seeks to engage researchers and practitioners in a dialogue about the powerful interweaving of DT and sustainability.

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1 Introduction

1.1 Motivation

As of today, the Earth has crossed six of the nine planetary boundaries, which serve as measurable limits within which humanity can safely develop and thrive (Richardson et al., 2023; Rockström et al., 2009). With a steep increase from three crossed boundaries in 2009 to six in 2023; there is no denying of the scientifically agreed human-made environmental degradation (Oreskes, 2004; Richardson et al., 2023). However, sustainability extends beyond environmental concerns (Purvis et al., 2019). Sustainable development[1] defined as *"meeting the needs of the present without compromising the ability of future generations to meet their own needs"* (World Commission on Environment and Development, 1987) requires balancing the social, environmental, and economic pillars of sustainability (Elkington, 1997; Purvis et al., 2019). Addressing this multifaceted challenge requires not only individual actions (e.g., adopting vegetarian diets, extending the lifespan of electronic devices) and governmental regulations (e.g., carbon pricing, emission standards) but also significant organizational efforts (Garnett & Balmford, 2022).

The potential of organizations (that is, cooperations, government institutions, and non-governmental institutions) to positively influence sustainable development is undisputed and is increasingly recognized (e.g., Dao et al., 2011; Garnett & Balmford, 2022). Organizations are uniquely positioned to promote sustainability due to their ability to innovate quickly, create spillover effects, and operate beyond government boundaries (Garnett & Balmford, 2022). For example, Cisco used its Digital Transformation (DT) expertise to enable home office settings for schools and other non-profits (Cisco, 2022). Similarly, Ecovadis provides a platform for organizations to assess their own social and environmental sustainability, as well as that of their suppliers, thus promoting sustainable procurement and transparent improvements (Ecovadis, 2024). Although these examples underscore the significant potential of organizations to contribute to sustainable development, it is crucial to recognize that organizations have also played a substantial role in exacerbating environmental and social issues worldwide (Porter & Kramer, 2011; Van Zanten & Van Tulder, 2021). For example, a report by the Customer Data Platform Institute and the Climate Accountability Institute revealed that only 100 companies were responsible for more than 71 % of global industrial greenhouse gas emissions between

[1] In line with Purvis et al. (2019), this doctoral thesis uses the terms sustainability and sustainable development interchangeably.

1988 and 2015 (Griffin, 2017). Therefore, organizations must find a way to leverage their potential to promote sustainable development while also addressing their negative impact on sustainability.

One promising way to achieve sustainable development of organizations is through DT (Ganju et al., 2016; Vassilakopoulou & Hustad, 2023a; Veit & Thatcher, 2023). DT, defined as *"a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies"* (Vial, 2019, p. 121) offers means to promote sustainability (Dao et al., 2011; El Idrissi & Corbett, 2016). For instance, DT can empower villages and regions to develop e-commerce ecosystems that allow them to participate in a global world (Leong et al., 2016), leverage Artificial Intelligence (AI) models for the prediction of urban solid waste (Ayeleru et al., 2021), or facilitate the development of chatbots for the promotion of sexual health among teenagers (Wang et al., 2022). Researchers have explored the positive interplay between DT and sustainability under various terms (e.g., green Information Systems (IS) and IS for sustainability) (Loeser, 2013; Melville, 2010; Vom Brocke et al., 2013). Although many studies primarily focus on environmental sustainability (e.g., Loeser, 2013) or specific pillars of sustainability (e.g., Buck et al., 2023), some research articles investigate the holistic impact of DT on sustainability (e.g., Melville, 2010). The merit of these works is that DT can significantly support sustainable development across the social, environmental, and economic sustainability pillars. Consequently, DT is posited to have the potential to *"make the world a better place"* (Lagna & Ravishankar, 2022, p. 61).

However, this positive view, sometimes even called utopian, on the potentials of DT for sustainability is disputed in the literature (Chatterjee & Sarker, 2024; Pappas et al., 2023; Vial, 2019). Discussed under a magnitude of terms (i.e., *Digitalization as the problem or solution* Veit & Thatcher, 2023, *the dark side of digital [...]* Verbeke & Hutzschenreuter, 2021, and *digital dystopia* Tirole, 2021), the negative impact of DT on sustainability has been acknowledged by several researchers. Examples of this dystopic view include the decline in privacy in today's digital world by the widespread collection of personal data to enhance the quality of data analytics and AI systems (Wieringa et al., 2021), or the negative environmental impact of ever better and larger generative language models (Touvron et al., 2023b, 2023a). The joint claim of this stream of research is that DT besides it benefits can harm sustainable development (Veit & Thatcher, 2023). Research has acknowledged this negative impact of DT on sustainability and developed mitigation strategies to conduct DT while resulting in fewer unintended consequences on the environment (Berthon & Donnellan, 2011). Combined under the term green Information Technology (IT), the IS community analyzed measures and initiatives focused on decreasing the environmental lifecycle footprint of IT equipment and infrastructure (Loeser, 2013). Following a broader definition of sustainability, Pappas et al. (2023) introduce the term responsible DT, which describes the responsible (in terms of social and environmental) DT of organizations.

Both the utopian and the dystopian view on the interplay of DT and sustainability represent two extrema of this polarized discourse. Therefore, to achieve sustainable development for organizations leveraging the intersection, Chatterjee and Sarker (2024) and Veit and Thatcher (2023) argue that researchers and practitioners have to balance the positive and negative impacts of DT on sustainability. Veit and Thatcher (2023) emphasize the need for a balanced approach to harness the benefits of digitalization while mitigating its negative impacts. Chatterjee and Sarker (2024) further propose that simultaneously exploring DT through dystopian and utopian lenses results in a comprehensive understanding that can guide more effective strategies for sustainable development. Hence, the ongoing exploration of both the positive and negative impacts of DT regarding sustainability is crucial to develop holistic strategies that leverage DTs for sustainability and address potential drawbacks. This joint consideration has recently been termed Twin Transformation (TT) on an organizational level and describes the *"value-adding interplay between digital and sustainability transformation 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). Christmann et al. (2024) formalize the concept of TT by identifying two response mechanisms[2]: DT as an enabler for sustainability and sustainability as a guide for DT. In contrast, Crome et al. (2024b) highlight that there is a third response mechanism that combines the positive effects of DT and sustainability, termed integrate DT and sustainability, to provide mutual benefit. Hence, combining the positive effects of DT and sustainability while mitigating the negative effects that might arise from one or the other. Although there are examples of the interplay of DT and sustainability, these research articles predominantly focus on the positive impacts of the interplay (e.g., Crome et al., 2023a; Guandalini, 2022). Hence, current research lacks a balanced perspective that considers the positive and negative impacts that arise through the interplay of DT and sustainability. This perspective should address the inherent tensions that organizations face when simultaneously pursuing DT and sustainable development (Mishra et al., 2022).

[2]The term response mechanisms refers to the wording from Research Article #1 which introduces three response mechanisms which balance tensions arising from the interplay of DT and sustainability.

To balance these tensions and allow organizations to integrate DT and sustainability, researchers and organizations must (1) understand sustainability as a holistic concept to mitigate negative impacts (Veit & Thatcher, 2023; Vial, 2019), (2) leverage the connection of multiple sustainability pillars to strengthen support for and comprehension of projects at DTs' and sustainabilities' intersection (Dao et al., 2011; Porter & Kramer, 2011), and (3) identify actionable practices that fuel the balancing (Dennehy et al., 2023; Pappas et al., 2023). Each of the challenges is explored below. First, sustainability is a concept encompassing three pillars that should be treated equally (Elkington, 1997; Purvis et al., 2019; Veit & Thatcher, 2023). Despite the popularity of this definition, current research on the intersection of DT and sustainability focuses primarily on the environmental pillar (Schoormann et al., 2023; Veit & Thatcher, 2023). While there are emerging research streams that address other sustainability pillars, such as fair or responsible DT (e.g., Pappas et al., 2023), these efforts often operate in silos. For example, the research streams of environmental-friendly AI and social-focused AI development have developed independently (Leuthe et al., 2024), resulting in overlapping recommendations and challenges for practitioners trying to comprehensively assess sustainable AI measures (Dennehy et al., 2023; Pappas et al., 2023). Similarly, research on DT for environmental sustainability and the use of DT for social sustainability has developed in different streams (Loeser, 2013). In a practical case study highlighting the importance of treating holistically sustainability, Guo et al. (2019) examined the impact of ride-hailing platforms on car purchases, showing a shift from one group of actors (private car buyers) to another group of actors (drivers purchasing cars commercially), reversing the initial positive impact of reduced car purchases and introducing shifts in social systems by reducing trips from private taxi services and increasing the market share of other ride-hailing services (Veit & Thatcher, 2023). Therefore, the first challenge is to embrace a balanced approach that addresses each sustainability pillar alongside DT (Pappas et al., 2023; Veit & Thatcher, 2023).

Second, while the former challenge highlights the necessity of treating sustainability holistically; previous research has although highlighted the importance of connecting sustainability pillars to increase acceptance within organizations (i.e., connecting environmental and social-oriented actions with economic gains) or reduce negative spillover effects from one pillar to another (Dao et al., 2011; Galaz et al., 2021; Porter & Kramer, 2011). For instance, Maret et al. (2013) highlight based on an example of environmentally friendly bypass systems in long-haul trucking that economic benefits positively influence the use of the system while environmental benefits do not. Hedman and Henningsson (2016) identified the same connection on an organizational level, by presenting the case of an organization that ignited its transformative journey towards integrating DT and sustainability by coupling environmental benefits with economic gains. Porter and Kramer (2011) summarizes the concept under the term shared value which connects economical gains with environmental and social sustainability. However, most previous research articles in the IS research community focused on one pillar, thus failing to recognize the positive effects that arise from an interlinked response (Dao et al., 2011). Therefore, the second challenge focuses on maximizing the connection between economic, social, and environmental sustainability.

Third, research at the intersection of sustainability and DT requires actionable practices that educate organizations on designing DT to foster sustainable development (Dennehy et al., 2023; Pappas et al., 2023). Actionable practices bridge the gap between research and practice by providing artifacts that can be readily employed within real-world scenarios. They can enable individuals to shape the sustainability of an organization (El Idrissi & Corbett, 2016). Furthermore, actionable practices tailored to the intersection of DT and sustainability can facilitate virtuous cycles whereby the accomplishment of a single project that combines DT and sustainability objectives leads to the emergence of additional projects with similar objectives, as evidenced by (Hedman & Henningsson, 2016). This self-reinforcing interplay ignited by successful projects is well established in IS research. For instance, when analyzing the implementation of enterprise resource planning systems, Akkermans and Van Helden (2002) identified a reinforcing loop in which a successful project promotes a spiraling behavior toward the goal of implementing and leveraging an enterprise resource planning system (e.g., Akkermans et al., 2021; Currie et al., 2022). Chatterjee and Sarker (2024) adapted this concept to the interplay of DT and sustainability, calling for more research articles that explore the positive reinforcement mechanism. However, the IS discipline has predominantly focused on building theories and concepts describing this intersection rather than providing practical solution artifacts for specific applications (Gholami et al., 2016; Malhotra et al., 2013). Simultaneously, few research articles provide generalizable examples for the intersection of DT that are applicable in different contexts (e.g., for multiple sectors) (Guandalini, 2022). Therefore, the third challenge is to offer actionable practices of successful projects at the intersection of DT and sustainability that are valid for various application contexts.

In conclusion, this doctoral thesis contributes to the holistic sustainable development of organizations by addressing three challenges that arise from the intersection of DT and sustainability alongside the three response mechanisms. The specific challenges are: (1) Consider the three pillars of sustainability, (2) leverage the connection between the three pillars of sustainability, and (3) provide actionable practices for sustainable development. Hence, this thesis offers organizations building blocks – i.e., theoretically grounded research artifacts that provide organizations with generalizable yet actionable guidelines – to promote sustainability in organizations as a holistic concept (i.e., economic, environmental, social) while integrating multiple sustainability pillars.

1.2 Structure of the Thesis and Overview of Embedded Research Articles

This doctoral thesis is cumulative, consisting of six research articles structured along a two-dimensional grid. The axes of this grid are given by the different types of interplay of DT and sustainability on the y-axis and the three challenges described in section 1.1 on the x-axis. For the y-axis, Research Article #1 in chapter 2 formulates three response mechanisms to balance tensions that arise from the interplay of DT and sustainability. In line with Research Article #1, this thesis defines a response mechanism as a value-adding interplay of DT and sustainability actions blending or balancing the competing demands of tensions rooted in the interplay. The first response mechanism (i.e., *"Leverage DT to enhance sustainability actions"*) describes the use of DT to enhance the sustainability of organizations. Complementary, the second response mechanism (i.e., *"Exploit sustainability to sharpen digital actions"*) focuses on integrating sustainability into the design, development, and deployment of DT projects. Finally, the last response mechanism (i.e., *"Integrate DT and sustainability to provide mutual benefit"*) builds upon the combination of the first and second response mechanisms by focusing on the sustainability of the DT process itself and its outcome (i.e., sustainability impact). The three response mechanisms are vertically intersected with the three challenges identified in section 1.1, resulting in a nine-cell grid. Each cell represents a specific challenge-response combination which is justified by prior research. The structure of this thesis follows this layout (see figure 1.1), outlining the valuable contributions of each research article regarding the challenges across the three response mechanisms.

In this context, section 2.1 which includes Research Article #2 sheds light on the practical potential of DT for advancing sustainability. Research Article #2 analyses use cases of Artificial Intelligence for Sustainability (AI4S) from research and practices based on a newly derived

Research Article #1 | Understanding Tensions That Inhibit and Drive the Twin Transformation

Response mechanisms at the interplay of DT and sustainability

Challenges at the interplay of DT and sustainability

Response mechanism	Research article	Provide actionable practices for sustainable development	Consider the three pillars of sustainability	Leverage the connection between the three pillars of sustainability
Leverage DT to enhance sustainability actions	**Research Article #2** | Navigating AI for Sustainability in Organizations: Untangling Organizational, Sustainable, and Technical Characteristics	X	X	X
Exploit sustainability to sharpen digital actions	**Research Article #3** | Towards Sustainability of AI: Identifying Design Patterns for Sustainable Machine Learning Development	X	X	
	Research Article #4 | Linking Sustainability Dimensions in AI Governance: A Review and Collection of Governance Mechanisms		X	X
Integrate DT and sustainability to provide mutual benefit	**Research Article #5** | Punctuality Predictions in Public Transportation: Quantifying the Effect of External Factors	X		X
	Research Article #6 | Understanding Information Needs for Seamless Intermodal Transportation: Evidence From Germany	X		X

Figure 1.1: Assignment of the research articles to the topics structuring this doctoral thesis

taxonomy that combines the tripartite structure of organizational embedding, sustainability pillars, and technical requirements. The results are reusable AI archetypes that foster the integration of multiple sustainability pillars and integrate organizational and technical characteristics. This approach goes beyond the predominant focus on environmental sustainability (Veit & Thatcher, 2023) and purely technical perspectives (El Idrissi & Corbett, 2016), demonstrating that IS research can achieve a broader impact on sustainability by leveraging the connections between the three pillars (Dao et al., 2011).

Beyond the potential of DT for sustainability outlined in section 2.1, the section 2.2 includes Research Articles #3 and #4 that show how organizations can *Exploit sustainability to sharpen digital actions*. These articles focus specifically on AI, as AI stands out as one of the most promising technologies in the domain of DT for sustainability (Crome et al., 2024a). However, it simultaneously has significant negative consequences that must be carefully managed (Tomaev et al., 2020; van Wynsberghe, 2021). In light of these dual impacts, the following two articles delve into mitigating the unintended negative consequences of AI. Research Article #3 introduces design patterns for the sustainable development of Machine Learning (ML) algorithms, addressing not only each pillar of sustainability, but also providing actionable strategies for organizations (Nishant et al., 2020; Veit & Thatcher, 2023). Research Article #4 examines existing AI governance frameworks and proposes an extension to connect social, environmental, and economic sustainability. This article offers a comprehensive approach to integrate sustainability throughout the AI lifecycle and connects multiple sustainability pillars.

Finally, section 2.3 contains Research Articles #5 and #6, that explores the mutually beneficial interplay between DT and sustainability. Research Article #5 provides a practical application of one of the archetypes identified in section 2.1 by employing the Cross Industry Standard Process for Data Mining (CRISP-DM) research framework to develop ML algorithms that incorporate external factors to predict public transportation punctuality. Specifically, it uses a technique called Automated Machine Learning (AutoML), which reduces the entry barrier for developing ML algorithms and enhances environmental efficiency. The resulting ML algorithm enables transportation providers to create more reliable systems, thus promoting sustainability in urban areas. Reliable public transportation can significantly benefit low-income individuals, who disproportionately rely on it for commuting. In addition, it can improve the economic position of the transportation provider. Research Article #6 presents a practical example of the interplay of DT and sustainability within the context of intermodal mobility. It introduces a novel concept to identify information needs for intermodal journeys, thereby enabling more people to adopt sustainable intermodal mobility solutions. It specifically leverages the concept of sustainability to enhance the provisioning of information in digital applications, while relying on digital technologies to display different information throughout different journey phases. Hence, Research Article #6 leverages a sustainability lens and digital technologies to foster sustainable development.

In summary, each research article with the exemption of Research Article #1 is categorized into one of the response mechanisms to integrate sustainability and DT, as well as one or more of the three challenges. The categorization of each research article is displayed in figure 1.1. By providing a theoretical lens for the interplay of DT with sustainability (see, Research Article #1) and addressing the three challenges for each response mechanism, this thesis provides valuable theoretical and practical contributions for integrating sustainability and DT; ultimately delivering building blocks to foster sustainable development driven by organizations.

Following the research overview, the main body of this doctoral thesis is concluded by chapter 3, which encapsulates the main findings of chapter 2, addresses the limitations of the current study, and outlines prospects for future research. The bibliography follows the chapter. Finally, this thesis concludes with an appendix that includes the list of discussed research articles (see appendix A.1), a detailed account of my contributions (see appendix A.2), and the research articles itself (see appendix A.3 - appendix A.8).

2 Research Overview

Providing a structure for the research articles in this doctoral thesis, Research Article #1 examines how organizations can balance tensions arising from the interplay of DT and sustainability. While the remaining articles focus on DT projects and sustainability, this paper takes a broader perspective, offering a theoretical lens on the interaction between DT and sustainability at an organizational level.

Research Article #1: Examining TT to Balance Digital Transformation and Sustainability Transformation Tensions

DT and Sustainability Transformation (ST) bring about profound changes in society and industries, but are often considered separate processes due to their differing key characteristics. On the one hand, DT refers to the adoption and use of digital technologies through which an organization redefines its value creation, value proposition, and identity (Hanelt et al., 2021; Vial, 2019; Wessel et al., 2021). On the other hand, ST focuses on the development and exploitation of processes, products, and services that promote the sustainable development of organizations (Dorninger et al., 2020; Sancak, 2023). Although its interplay is often analyzed from a positive point of view, it has been shown that the simultaneous realization of DT and ST creates tensions in organizations (e.g., Mishra et al., 2022), which are defined as contradictory yet interrelated elements that exist simultaneously and persist over time (Smith & Lewis, 2011, p. 382). Broadly speaking, this tension arises because (1) DT is primarily economically driven, whereas ST follows environmental and social goals (Chatterjee & Sarker, 2024), and (2) digital technologies can potentially cause environmental and social problems (van Wynsberghe, 2021; Veit & Thatcher, 2023).

Against this background, the recently emerging concept of TT offers a potential solution by combining digital and sustainability efforts on equal footing, thereby yielding synergies and exploiting economic advantages (Christmann et al., 2024). To better understand how TT can balance the tensions at the interplay of DT and ST, Research Article #1 first delves into a deeper understanding of the underlying tensions. This approach bridges the well-known DT tensions (e.g., Danneels & Viaene, 2022; Soh et al., 2023; Wimelius et al., 2021) with the relatively unexplored ST tensions. Second, while TT can be pivotal for exploiting synergies between DT and ST, little is known about response strategies to manage tensions. With this in mind, Research Article #1 formulates the following research question: *Which tensions occur due to the interplay of DT and ST in organizations?*

To identify tensions at the interplay of DT and ST, Research Article #1 employs a structured literature review methodology (Wolfswinkel et al., 2013) and analyzes the results using paradoxical tension theory (Smith & Lewis, 2011). To support the theory-based findings, 24 interviews with subject-matter experts were conducted, providing insights into managing different DT and ST demands to balance possible tensions. The results reveal three relevant TT response mechanisms.

Research Article #1 has three major artifacts. First, it summarizes existing academic research on the interplay of DT and ST in three waves. Figure 2.1 displays said interaction. The figure highlights the development in the academic discourse from isolated streams at the beginning (e.g., Matt et al., 2015) to occasional interactions (e.g., Loeser, 2013), and finally to the complete integration as postulated in more recent research endeavors (e.g., Christmann et al., 2024).

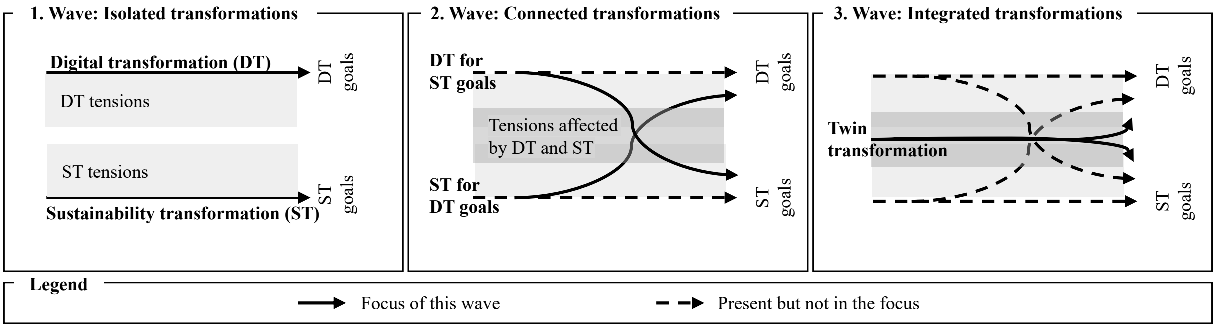

Figure 2.1: Interplay of Digital and Sustainability Transformation in Different Waves of Academic Research

Furthermore, figure 2.1 highlights the scope of this research article, focusing on tensions that are affected or induced by DT and ST. Based on the results of the structured literature review, the research article provides an overview of the resulting tensions as its second artifact. The tensions are further classified by three effects: arise, shift, and reinforce. Arising tensions are newly created through the interaction of DT and ST. For instance, if one transformation introduces a new demand that competes with an existing demand in another transformation, the tension arises. In contrast, shifting tensions change their focal points but are already present in both single transformations. The focal point changes 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 as a result of the integration. Reinforcing tensions are already present in DT and ST but are intensified by the interplay between the transformations. Table 2.1 shows the identified tensions with descriptions.

Finally, to facilitate the management of tensions in organizations, Research Article #1 investi-

Table 2.1: Digital Transformation and Sustainability Transformation Tensions

Tension according to Smith and Lewis (2011)	Tension is affected by the interplay of DT and ST	Description
Performing tensions	Societal value vs. organizational performance	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. *Tension exists in ST and* ***arises*** *due to the competing demands between DT and ST.*
	Radical innovation vs. incremental innovation	Balancing the need for both transformations to introduce groundbreaking technological or sustainability-oriented changes with gradual and continuous improvements reaching short-term goals. *Tension exists in DT and ST and* ***is reinforced*** *due to the competing demands between DT and ST.*
Organizing tension	Competition vs. collaboration	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. *Tension exists in DT and ST and* ***is reinforced*** *due to the competing demands between DT and ST.*
Belonging tension	Personal employee identity vs. organizational identity	Balancing sustainability and digitalization values and beliefs of employees with organizational values. *Tension exists in DT and ST and* ***shifts*** *due to the competing demands between DT and ST.*
Learning tension	Depth of competence vs. breadth of competence	Balancing the specific in-depth capabilities of both transformations with wide-ranging sustainability and digital knowledge. *Tension exists in DT and ST and* ***shifts*** *due to the competing demands between DT and ST.*

gates possible responses in the realm of TT, which involves the conscious integration of DT and ST as means and ends on equal footing. Applying TT helps to find integrated DT and ST responses to balance competing demands in virtuous organizational cycles. The responses are aggregated into TT response mechanisms, describing the value-adding interplay that blends digitalization and sustainability to balance tensions affected by DT and ST. Each response mechanism was derived from interviews with subject-matter experts.

The first TT response mechanism, namely leveraging digitalization to enhance sustainability actions, is characterized by the empowering effect of data and digital technologies in facilitating sustainability efforts. This response mechanism relies on existing knowledge from research areas such as green IS (e.g., Melville, 2010) to consciously use digital technologies to uncover new value paths focusing on sustainability. Thus, organizations leverage DT (e.g., using blockchain technologies to track the supply chain) to positively impact ST actions (e.g., identifying and subsequently reducing the emissions of scope three). An example of this response mechanism is the implementation of organizational-wide, centralized, and automated reporting tools to enhance transparency in current sustainability initiatives, thereby balancing the tension between societal value and organizational performance.

The second TT response mechanism, namely exploiting sustainability actions to sharpen digitalization, is characterized by the strengthening effect of purpose and stakeholder engagement in leveraging the implementation of digital initiatives. In this approach, organizations' ST goals (e.g., improving employees' mental health) balance and influence DT actions (e.g., introducing measures against techno-stress when new collaboration software is introduced). An example of this response mechanism is the integration of sustainable development patterns in DT projects, as described in Research Articles #3 and #4. This approach can balance the tension between societal value and organizational performance, as most environmental or social patterns also influence economic performance (see Research Article #3).

Finally, the last TT response mechanism, namely establishing integrated digital sustainability, stands out due to the integration of digital and sustainability changes in value creation (e.g., internal processes) and resources (e.g., IT infrastructure or employees). This response mechanism builds upon existing knowledge from TT research (e.g., Breiter et al., 2024; Christmann et al., 2024). Organizations blend DT with ST actions by integrating the goals of both transformations, thereby developing and addressing new TT goals, such as increasing the penetration of sustainable information technology infrastructure (Breiter et al., 2024). While digital technologies can enhance an organization's sustainability performance, it is essential to consider the sustainability of these digital technologies themselves to balance the tension between societal value and organizational performance (van Wynsberghe, 2021). An example of this response mechanism is leveraging managers as TT role models to support widespread adoption within the organization, thereby balancing the tension between personal identity and organizational identity.

Hence, by applying a tension lens to investigate which conflicting demands exist between DT and ST, Research Article #1 provides response mechanisms for how organizations can balance the resulting tensions within TT. The uncovered tensions facilitate the understanding of each individual transformation (i.e., DT or ST) in the context of the other transformation, as well as the interplay of both, setting the foundation for exploring integrated tension management. Furthermore, the article follows the call for further research by Vial (2019) investigating how organizations can balance the tension between organizational performance and ethics. Unlike Vial (2019), this article treats sustainability as a holistic concept encompassing social, environmental, and economic pillars. Hence, it demonstrates how organizations can actively balance the positive and negative impacts of the interplay between DT and sustainability while treating sustainability as a holistic concept.

2.1 Leveraging DT to Enhance Sustainability Actions

The positive impact of DT on sustainability is evidenced by numerous examples (Loeser, 2013; Melville, 2010). In particular, one of its prominent technologies, AI, offers significant potential (Schoormann et al., 2023; Vinuesa et al., 2020). However, to harness this potential, organizations must address several challenges, two of which are examined in this section. First, previous research on the positive interplay of AI and sustainability has primarily focused on the technical perspective. Yet, to integrate AI4S effectively within organizations, it is essential to understand the tripartite structure that includes organizational embedding, technical capabilities, and sustainability outcomes (Di Vaio et al., 2020; Nishant et al., 2020). Second, organizations require specific examples that integrate multiple sustainability pillars. Research Article #2 presented in this section provides solutions to address these challenges, thereby leveraging DT for sustainability.

Research Article #2: Navigating AI for Sustainability in Organizations: Untangling Organizational, Technical, and Sustainable Characteristics

In the pursuit of the Sustainable Development Goals (SDGs), the role of digital technologies, particularly AI, has become increasingly crucial (Kar et al., 2022; Tseng & Lin, 2024). Organizations leveraging AI to contribute to the SDGs are expected to accelerate and broaden the impact on sustainability (Kopka & Grashof, 2022). AI has the potential to mitigate 5-10% of global greenhouse gas emissions by 2030 (Forum, 2024), and its positive impact on reducing inequality is expected to continue to grow between 2021 and 2030 (Nahar, 2024). AI is thus positioned as a key enabler of economic, environmental, and social sustainability, encapsulated in the concept of AI4S (Frank, 2021; Vinuesa et al., 2020). To achieve the SDGs, it is essential to understand and disseminate organizational adoption patterns and technical value-generating mechanisms (Enholm et al., 2022). Hence, there is a need for academia to analyze the triad of organizational embedding, sustainability and technology. However, previous research primarily focuses on the combination of technical characteristics (e.g., algorithms and data sources) and SDGs, thus excluding an organizational perspective that limits the needed adaptability for organizations (e.g., Cowls et al., 2023; Vinuesa et al., 2020). Leaving a use case-driven examination of the connection between a technical, organizational, and sustainable perspective remains understudied (Di Vaio et al., 2020; Nishant et al., 2020). Therefore, Research Article #2 of this doctoral thesis poses the research question: *How can AI-based use cases be structured and conceptualized to integrate organizational, technological, and sustainability perspectives to achieve sustainable development?*

To address this question, a four-step process was employed. Initially, a detailed introduction and review of a sample of the multivocal literature was conducted according to Garousi et al. (2019). Subsequently, the AI4S taxonomy was developed, comprising three layers, ten pillars, and 47 characteristics Nickerson et al. (2013). Subsequently, the literature sample was clustered using the AI4S taxonomy through hierarchical and partitioning-based clustering methods, resulting in the identification of seven AI4S archetypes. Lastly, these seven archetypes were synthesized into a complexity positioning roadmap Hunke et al. (2022), which encapsulates the tripartite structure of the taxonomy and underscores the complexity of various archetypes within an organizational context.

Following the methodology described, this article derived three main results. First, the AI4S taxonomy which structures the research space along three pillars (i.e., technology, organization, and sustainability) adopted from the well-established Technology-Organization-Environment (TOE) framework. While the TOE-framework is commonly used to interpret the adoption of technologies and innovations from a socio-environmental and technical context (Chatterjee et al., 2021), recent works have moved to substitute the conventional view on environmental factors with a holistic sustainability definition (Dadhich & Hiran, 2022).

In line with the adapted TOE framework, Research Article #1 describes the three pillars of technology, organization, and sustainability as separate pillars that interact in the adaptation of AI4S within organizations.

Based on the classification and analysis of 158 AI4S use cases, the article presents seven AI4S archetypes that outline AI4S mechanisms. Each archetype represents a distinct set of technical, organizational, and sustainable characteristics and is described by two exemplary AI4S use cases. Hence, the archetypes form a predominant compilation of characteristics for the design of future or the evaluation of existing AI4S use cases. The complete list of archetypes is presented in table 2.2.

Table 2.2: Overview of the AI4S Archetypes

Archetype	Description	Defining Characteristics	Reference case
1 ∣ Understand and Verify Sustainability Claims	Use of NLP to extract, aggregate, and validate sustainability claims from corporate reports and regulatory guidelines, enhancing corporate efficiency and regulatory enforcement.	Technical: *{unsupervised; NLP}* Organizational: *{Support Functions}* Sustainability: *{Environmental; SDG 9; SDG 12; SDG 13}*	Extraction of corporate sustainability efforts from ESG reports for sustainability auditing (Schimanski et al., 2023).
2 ∣ Acquire and Determine Structured Sustainability Data	Application of advanced technologies such as computer vision to transform complex and unstructured data (e.g., satellite images) into structured sustainability insights.	Technical: *{unstructured data; supervised}* Organizational: *{external; front-end}* Sustainability: *{Environmental; SDG 11; SDG 15}*	Early-stage detection of wildfires in Australia through the analysis of hyperspectral images (Thangavel et al., 2023).
3 ∣ Provide Individual Advice for Social Impact	Use of NLP and generative AI to provide personalized social impact strategies to companies and direct, individualized advice to consumers, fostering enhanced social responsibility.	Technical: *{unstructured; prescriptive}* Organizational: *{AI-Performed; front-end}* Sustainability: *{Economic; Social; SDG 10}*	Extraction of relevant data from customer emails and automatic formulation of an individual response (Olujimi & Ade-Ibijola, 2023).
4 ∣ Predict Impact on Sustainability	Utilization of ML on tabular data to accurately predict the sustainability impact of firm operations, offering impact analysis on previous inaccessible data.	Technical: *{Tabular ML; predictive}* Organizational: *{AI-Supported; back-end}* Sustainability: *{Environmental; SDG 11; SDG 12}*	Quantitative prediction of municipality solid waste for more efficient planning of waste management in Johannesburg (Ayeleru et al., 2021).
5 ∣ Provide Optimization Recommendations for Sustainability in Operations	Use of tabular ML to provide optimizations for the sustainability impact of operations to enhance the overall sustainability performance incrementally.	Technical: *{supervised; Tabular ML}* Organizational: *{AI-Supported; front-end}* Sustainability: *{Environmental; SDG 11}*	Decision model for economically and environmentally optimized logistics (Jeberg et al., 2021).
6 ∣ Generate Sustainability Process, Product, and Service Alternatives	Employment of generative AI models to design and propose sustainable alternatives for processes, products, and services.	Technical: *{unstructured; generative AI}* Organizational: *{AI-augmented}* Sustainability: *{Economic; Environmental; SDG 12}*	Integration of AI-proposed product and model designs for a more efficient automotive design process at Toyota Research (Mast, 2023).
7 ∣ Evaluate and Automate Sustainability Actions	Application of tabular ML to autonomously evaluate the sustainability impact of process redesign options and selecting and implementing the optimal policy.	Technical: *{Tabular ML; Prescriptive}* Organizational: *{Front-end}* Sustainability: *{Economic; Environmental}*	Analytical and mathematical models for sustainability assessment and improvement of supply chains (Vivas et al., 2020).

The distinct features of each archetype (e.g., data, algorithm, or business function) and numerous examples from the literature sample provide a valuable link to practice and can drive discussions with practitioners. However, to develop a more detailed understanding of how the seven archetypes relate to each other, this article developed a complexity positioning roadmap following the example of Hunke et al. (2022). The positioning in one artifact synthesizes the tripartite structure of the layers, thus aggregating the results in an accessible form (see Figure 2.2).

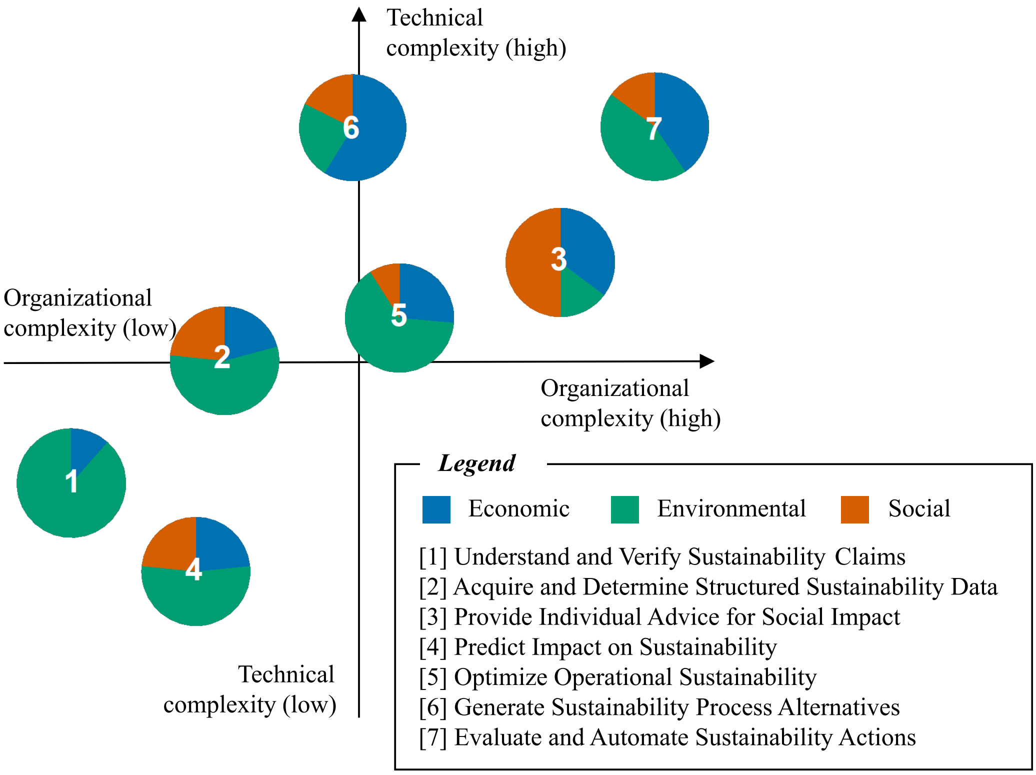

Figure 2.2: The AI4S Complexity Map

Overall, Research Article #2 provides the missing link between organizational adoption patterns, technical characteristics, and sustainability impact, by providing the AI4S taxonomy, a tripartite framework (i.e., organizational, technical, and sustainability perspective) that helps practitioners understand and differentiate AI4S use cases, AI4S archetypes, and the complexity map. Thereby providing researchers and practitioners with a novel overview and a systematic understanding of AI4S in an organizational context.

2.2 Exploit Sustainability to Sharpen Digital Actions

Organizations must not only navigate the challenges of leveraging DT for sustainable development, but also address the complexities of integrating a sustainability perspective into the design, development, and implementation of DT projects. Although this integration has the potential to enable a sustainable future (Pappas et al., 2023), it also presents significant challenges for organizations (Veit & Thatcher, 2023). This is particularly pertinent for AI, as the examination of its negative implications is still in its early stages (van Wynsberghe, 2021), revealing conflicting mechanisms (Leuthe et al., 2024). Consequently, the two research articles in this section focus on the integration of sustainability within the AI lifecycle, addressing two specific challenges. First, organizations must understand how to integrate sustainable practices in each pillar of sustainability (Dennehy et al., 2023; Shneiderman, 2021). Second, given their limited capacities, organizations must implement mechanisms that foster virtuous cycles (Hedman & Henningsson, 2016).

Research Article #3: Towards Sustainability of ML – Identifying Design Patterns for Sustainable Machine Learning Development

Research Article #3 focus goes beyond the positive impacts of DT on sustainability by actively offering design patterns to improve the sustainability of ML development projects. ML as one specific technology of DT can create value in various domains such as education, finance, and manufacturing (Enholm et al., 2022; Kim et al., 2022). While there are ever-increasing efforts to apply AI and ML for sustainable use, i.e., early detection of wildfires (Wanner et al., 2020) or cancer (Schoormann et al., 2023), AI's negative impacts on resource consumption, social injustice, or even human rights cannot be neglected anymore (Cowls et al., 2023; Dennehy et al., 2023; Koniakou, 2023). Hence, the dark side of AI has become more apparent (Mikalef et al., 2022), leading to calls for reserach on sustainable AI (SAI) (Schoormann et al., 2023; Schwartz et al., 2020; Tornede et al., 2022). Analogous to the research streams green IS and green IT (Veit & Thatcher, 2023), SAI describes the sustainable design, development, and use of AI throughout its entire life cycle (van Wynsberghe, 2021).

The previous work can be classified into three streams. First, a majority of the articles have focused on solutions to reduce the energy consumption of AI development and ML models and, therefore, the environmental impacts (e.g., Patterson et al., 2022; Veit & Thatcher, 2023; Verdecchia et al., 2023). Second, recent publications have focused on social and ethical aspects of ML as well as increasing fairness during ML development to foster responsible ML (e.g., Dennehy et al., 2023; Ferrara, 2023; Mikalef et al., 2022). Third, an increasing number of papers are focusing on the challenges that ML poses from a governance perspective (Koniakou, 2023; Papagiannidis et al., 2023; Verdecchia et al., 2023). In general, previous work is fragmented across several streams, leading to overlapping recommendations and difficulties, especially for practitioners, to comprehensively assess possible measures toward more sustainable ML. At the same time, there is an increasing demand as well as calls for research to shift from pure principles to comprehensive design approaches and implementable best practices for sustainable AI (e.g., Dennehy et al., 2023; Pappas et al., 2023; Shneiderman, 2021). Thus, this article seeks to answer the following research question: *What are design patterns that ML development stakeholders can incorporate to increase the sustainability of the ML development process?*

Therefore, this article applies the Design Science Research (DSR) paradigm to develop the Sustainable Machine Learning Design Pattern Matrix (SML-DPM) in close alignment with four key requirements based in the literature (Hevner et al., 2004; Peffers et al., 2007). First, a set of Design Patterns (DPs) was derived from 41 multivocal references. To evaluate and iterate on these DPs, the article used the criteria developed by Sonnenberg and vom Brocke (2012). Thus, the applicability and usefulness of the artifact was evaluated through focus groups and semi-structured interviews with subject-matter experts. Finally, a developed web-based prototype was leveraged to evaluate the intentions of users to apply the SML-DPM in three real-world ML projects.

The result of the described methodology is the SML-DPM which is depicted in figure 2.3. To promote the applicability of the SML-DPM in practical environments, the artifact was built on two research streams. First, the y-axis is oriented along the Environmental, Social, and Governance (ESG) concept. Second, the x-axis represents the ML life cycle, anchored in the four distinct phases of ML development. The results are 35 DPs are divided into the environmental dimension which encompasses 14 DPs, the social dimension 12 DPs, and the governmental dimension 9 DPs. Each DP is based on the principle of providing tangible proven solutions to recurring problems to ensure the sustainability of ML.

Moreover, based on a demonstration in three case studies, the SML-DPM's ease-of-use, usefulness, and behavioral intention in line with the Technology Acceptance Model (TAM) were evaluated. Within the case study, the participants were asked to use the SML-DPM to identify areas of improvement for the of their current ML projects. The feedback on the SML-DPM was predominantly positive across all three metrics. Participants in the case study were particularly favorable to the statements relating to changes in behavioral intentions. The results in the behavioral intention category underlined the articles' idea that a set of comprehensible and actionable DPs can lead to a shift towards more sustainable ML development. Overall, the number of DPs that the teams plan to incorporate in the development process was 1.8 higher than

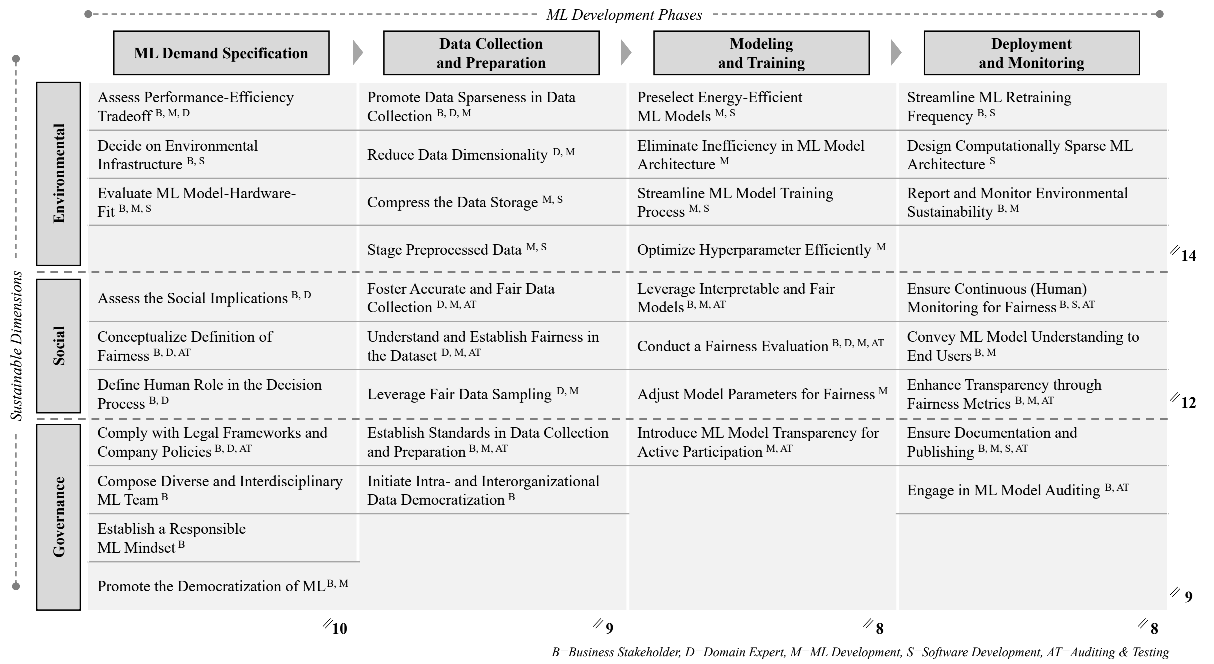

Figure 2.3: The Sustainable Machine Learning Design Pattern Matrix

the number of employed DPs. In conjunction with the strong evaluation of the participants' behavioral intention to continue using the artifact and to focus on ML development projects' sustainability, confirmed that the SML-DPM is applicable in real-world environments.

In total, Research Article #3 contributes to previous research by bridging the gap between the ESG sustainability concept and the end-to-end ML development process, unifying environmental, social, and governance aspects into a single artifact. The artifact provides 35 DPs with justificatory knowledge from expert insights, tailored to specific ML development phases and stakeholders, and validated through naturalistic evaluations. These DPs offer standardized, actionable solutions to recurring problems in SAI, addressing algorithmic biases and promoting responsible digital transformation. Extensive naturalistic insights from a web-based prototype and three ML case studies highlight the importance of covering all sustainability pillars, development phases, and stakeholders, and stimulate discussions on sustainable practices within ML teams. The web-based prototype aids researchers and practitioners to integrate sustainable practices, aligning with calls for actionable research in the field.

Research Article #4: Linking Sustainability Dimensions in AI Governance: A Review and Collection of Governance Mechanisms

Research Article #4 also addresses the sustainability of AI, but shifts the unit of analysis from design patterns and the development process to governance mechanisms and the entire AI lifecycle.

AI applications offer organizations numerous opportunities to refine their business models, enhance products, optimize processes, access new markets, and increase revenue (Corporation, 2022; Maslej et al., 2024). Yet as described in the previous Research Article, AI can also impact the social, environmental, and economic sustainability of organizations and the society (De Vries, 2023; Maslej et al., 2024; Sokalski et al., 2019). In response, various actors have issued AI principles to guide the design, development, deployment, and operation of AI systems (Mäntymäki et al., 2023). However, these principles are often abstract and lack actionable guidance, making implementation challenging for organizations (e.g., Georgieva et al., 2022; Mäntymäki et al., 2022b). To address this issue, AI Governance (AIG) frameworks, consisting of governance mechanisms (i.e., rules, practices, processes, and tools), ensure an organization's AI use aligns with its strategies and sustainability principles (Mäntymäki et al., 2022a).

While every governance framework addresses sustainability to some extent, the definition and scope of sustainability varies significantly (Galaz et al., 2021). The most prominent research stream on AIG focuses on the two objectives of trustworthy and responsible AI development (Kaur et al., 2023; Lu et al., 2023). Both terms predominantly emphasize social sustainability (i.e., fairness, explainability, transparency) and sometimes include either environmental (i.e., environmental well-being) or economic (i.e., organizational efficiency) sustainability (OECD, 2019; Owe & Baum, 2021). The NIST (2023) and OECD (2023) frameworks both extend their focus toward a holistic sustainability scope that includes social, environmental, and economic sustainability.

Despite the progress of these frameworks, they often neglect the interdependencies among the three sustainability pillars (Galaz et al., 2021; Owe & Baum, 2021). For example, optimizing AIs' infrastructure costs (economic sustainability) might lead an organization to switch to a cloud provider with higher greenhouse gas emissions per computing hour, thereby compromising environmental sustainability. Conversely, this interdependency can also yield positive outcomes. For example, reducing the volume of data to protect individual privacy (social sustainability) simultaneously enhances environmental and economic sustainability by decreasing computational requirements. Neglecting these interconnections can lead to additional sustainability risks or missed synergies between the three pillars of sustainability (Hedman & Henningsson, 2016; Rohde et al., 2024).

Against this backdrop, Research Article #4 seeks to conduct a thorough review of existing governance frameworks through a sustainability lens and identifies governance mechanisms that integrate multiple sustainability pillars. This leads to the following research question: *How can AIG integrate and balance social, environmental, and economic sustainability throughout the AI lifecycle?*

To address this research question, Research Article #4 conducts two Multivocal Literature Reviews (MLRs). The first MLR identified AIG frameworks by encompassing a wide range of sources, including blogs, white papers and websites, thus capturing current practices and practical perspectives that have been often overlooked (Garousi et al., 2019). These results were then analyzed through a sustainability lens. The second MLR, conducted according to Webster and Watson (2002), Kitchenham (2004), and Garousi et al. (2019), focuses on articles describing governance mechanisms targeted at least one sustainability dimension. The articles were analyzed using open, axial, and selective coding (Corbin & Strauss, 2008; Gioia et al., 2013) to derive the final set of governance mechanisms for the Sustainable AI Governance Framework Extension (SAIG-FE).

As explained previously, the results of this Research Article are twofold. The first part focuses on the review of existing AIG frameworks through a sustainability lens, and the second introduces the SAIG-FE. For the first part, the Research Article structures the trustworthy and responsible AI requirements frequently leveraged in contemporary AIG research along the three pillars of sustainability. This review yields three key insights into the state-of-the-art of AIG frameworks.

First, the sustainability focus of AIG frameworks varies significantly, with most addressing social sustainability, but few integrating economic and environmental dimensions. Only NIST (2023) and OECD (2023) include all three sustainability pillars, yet they mainly focus on social sustainability, leaving economic and environmental aspects often under-researched (Galaz et al., 2021; Owe & Baum, 2021). Second, ambiguity often surrounds which sustainability pillars or AI lifecycle phases the mechanisms within AIG frameworks are intended to address. While some frameworks emphasize monitoring SAI metrics during the deployment phase, the scope and sustainability impact of these metrics are often unclear. Only OECD (2023) integrates both lifecycle phases and risk categories into their governance approach. Finally, some analyzed AIG frameworks address multiple sustainability pillars, but predominantly treat them as separate goals (e.g., Microsoft, 2022; NIST, 2023; Singapore, 2020). While frameworks like NIST (2023) and OECD (2023) recognize the interactions among sustainability pillars, they lack specific guidance on resolving tensions between them. An integration which preliminary information systems research has highlighted as impactful to mitigate negative spillover-effects and leverage positive synergies (Dao et al., 2011; Hedman & Henningsson, 2016; Porter & Kramer, 2011).

Second, the Research Article #4 presents the SAIG-FE an extension to existing governance frameworks that includes AIG mechanisms that integrate multiple sustainability pillars in one governance mechanism. Each governance mechanism is structured along the governance dimensions of information technology by Peterson (2004), the governance levels by Shneiderman (2020), the three pillars of sustainability (Elkington, 1997; Purvis et al., 2019) and the adopted AI lifecycle phases according to the (OECD, 2019). The results are displayed in table 2.3.

Table 2.3: The SAIG-FE

Governance Dimension	Governance Level	ID	Governance Mechanism	AI Development Lifecycle[1]						
				0	1	2	3	4	5	6
Structural	Organization	SO1	Establish SAI Oversight Committee	x						
	Organization	SO2	Define SAI Enablers and Advisors	x						
	Team	ST1	Assign SAI Roles and Responsibilities		x					
	Team	ST2	Establish Human Oversight in Operations		x					x
Relational	Organization	RO1	Develop AI and SAI Literacy	x						
	Organization	RO2	Reduce the Barriers to Data Access and AI Development	x						
	Organization	RO3	Promote SAI Development through Leadership Commitment and Culture	x						
	Organization	RO4	Collaborate with the SAI Community to Leverage External Expertise	x						
	Team	RT1	Publish Sustainability Reports and Technical Artifact Descriptions				x			x
	Team	RT2	Assemble Diverse Teams		x					
	Team	RT3	Integrate Affected Stakeholder in the AI Development Process		x	x	x	x	x	x

Continued on next page

Table 2.3: The SAIG-FE (Continued)

Governance Dimension	Governance Level	ID	Governance Mechanism	AI Development Lifecycle[1]						
				0	1	2	3	4	5	6
Procedural	Organization	PO1	Develop a Strategy for SAI development	x						
	Organization	PO2	Create Common Terms and Consistent Documentation	x	x	x	x	x	x	x
	Organization	PO3	Establish Tooling and Infrastructure for SAI Practices	x	x	x	x	x	x	x
	Organization	PO4	Analyze and Optimize Infrastructure for AI Development and Inference	x		x	x	x		
	Organization	PO5	Develop a Standardized Set of Sustainability Definitions and KPIs	x						
	Organization	PO6	Establish Continuous Sustainability Monitoring	x	x	x	x	x	x	x
	Organization	PO7	Review and Audit AI Systems	x				x		x
	Team	PT1	Assess Sustainability Impact of AI Systems		x	x	x	x		
	Team	PT2	Derive Tangible Sustainability Requirements		x					
	Team	PT3	Pre-Select AI Models Based on Sustainability Impact				x			
	Team	PT4	Optimize Data Collection and Usage for Sustainability			x				
	Team	PT5	Optimize AI Models For Sustainability				x	x	x	
	Team	PT6	Utilize Explainable AI in Development				x			
	Team	PT7	Integrate Transparency and Explainability in AI System User Interfaces						x	x
	Team	PT8	Implement Feedback Mechanism for AI System Users	x			x		x	
	Team	PT9	Ensure Sustainability within the AI Supply Chain			x	x	x	x	x

[1] 0 – Organizational Embedding; 1 – Planning and Design; 2 – Data Collection and Processing; 3 – Model Building and Interpretation; 4 – Verification and Validation; 5 – Deployment; 6 – Operation and Monitoring

This Research Article makes two significant contributions. First, it analyzes the sustainability orientation of multiple AIG frameworks, revealing that most frameworks focus on a single dimension or link social sustainability with either environmental or economic aspects, with OECD (2023) and NIST (2023) being notable exceptions. However, these frameworks fail to address the interconnections between sustainability dimensions, underscoring the need for a unified framework extension. Second, it offers a comprehensive review of AIG mechanisms that impact multiple dimensions of sustainability, culminating in the SAIG-FE. This framework integrates mechanisms across the AI lifecycle, IT governance dimensions, and AI governance levels, providing practitioners with a structured approach to incorporating sustainability into AIG efforts. By emphasizing the interconnections between sustainability dimensions, this approach aims to mitigate negative spillover effects and leverage mutual reinforcement. Unlike Research Article #3, which focuses on design patterns for the development process, this article extends the scope to include governance mechanisms that span the entire AI lifecycle. It encompasses measures targeting the organization, as well as those preceding and succeeding the development process. Additionally, rather than treating each sustainability pillar separately, this Research Article emphasizes the connections between multiple pillars.

2.3 Integrate DT and Sustainability to Provide Mutual Benefits

The third response mechanism discussed in this section builds upon the combination of the first (see section 2.1) and second response mechanisms (section 2.2) by focusing on both the sustainability of the DT process itself and its outcomes (i.e., sustainability impact). This approach integrates DT actions with sustainability goals, fostering the development of new values. In this line, Research Articles #5 and #6 of this doctoral thesis offer practical examples of how DT and sustainability can be integrated to provide mutual benefits. Both research articles focus on decarbonizing road transportation by improving mobility reliability.

Research Article #5: Punctuality Predictions in Public Transportation: Quantifying the Effect of External Factors

Research Article #5 of this doctoral thesis examines the application of DT within the realm of public transportation. Specifically, it operationalizes archetype 5, "Provide Optimization Recommendations for Sustainability in Operations," as identified in Research Article #2. By applying the mechanisms discussed to the public transportation context, Research Article #5 offers a practical illustration of how DT can be utilized to promote sustainability in urban environments.

Urban regions face increasing challenges in providing efficient and sustainable public transportation services. The growing urban population and the demand for mobility services contribute to congestion, accidents, and pollution. Consequently, Batterbury (2003) and Liotta et al. (2023) and others have concluded that sustainable urban development in terms of social welfare and economic growth is incompatible with the continuous increase in the use of private vehicles. As a result, cities worldwide are advocating more sustainable transportation alternatives (Simlett & Atalla, 2019). To address these challenges, public transportation services must be optimized to offer efficient, reliable, and sustainable mobility solutions. Local public transportation, in particular, can significantly reduce emissions, prevent accidents, and democratize mobility (TorreBastida et al., 2018; Yang et al., 2015). Previous research underscores the importance of punctuality and arrival predictions in encouraging potential passengers to switch to public transportation and enabling transportation providers to develop more reliable systems (Ibrahim & Borhan, 2020; Olsson & Haugland, 2004).

Although numerous studies have investigated the effects of external factors, such as weather and holidays, on public transportation (Liu et al., 2017; Oneto et al., 2018; Zakeri & Olsson, 2018), the applicability of these findings to tram-based mobility remains unclear. Mesbah et al. (2015) and Zychowski et al. (2018) provide preliminary evidence but focus on either small datasets or limited time periods. Consequently, a comprehensive analysis of a complete tram network over multiple time frames and years has not yet been conducted. Furthermore, Research Article #5 increases the granularity beyond daily or weekly weather aggregations for weather features (Chen et al., 2004; Zakeri & Olsson, 2018) and addresses the call for further research on the effect of holidays (Laifa et al., 2021). In summary, Research Article #5 aims to quantify the impact of external factors on punctuality predictions in public transportation services by answering the research question: *How does enriching historical datasets with external factors influence the performance quality of punctuality predictions in public tram transportation?*

Research Article #5 addresses this research question by employing the CRISP-DM methodological approach as delineated in Wirth and Hipp (2000). Utilizing this methodology, four state-of-the-art ML models were implemented on different combinations of features aggregated from historical train movements, weather, and holiday data to predict expected departure delays with a time horizon of a few days, considering the limitations of small-scale weather projections (Bauer et al., 2015; Jung et al., 2010). The article compares their performance in an empirical case study to assess the impact of augmenting historical train movement data with additional features. The historical punctuality dataset comprises real-world data from a medium-sized German city over three consecutive years, encompassing 1.4 million trips across 222 stations.

Figure 2.4 shows an excerpt from the final historic-train movements dataset. The plot on the left-hand side illustrates the distribution of the departure delay across the considered data points. Most data records exhibit low and positive departure delays, indicating that trams tend to leave stations belated rather than too early, which aligns with the policy of tram providers. The remaining plots highlight increased departure delays during usual working hours compared to evening hours and the effect of different geolocations of tram stations regarding departure delay.

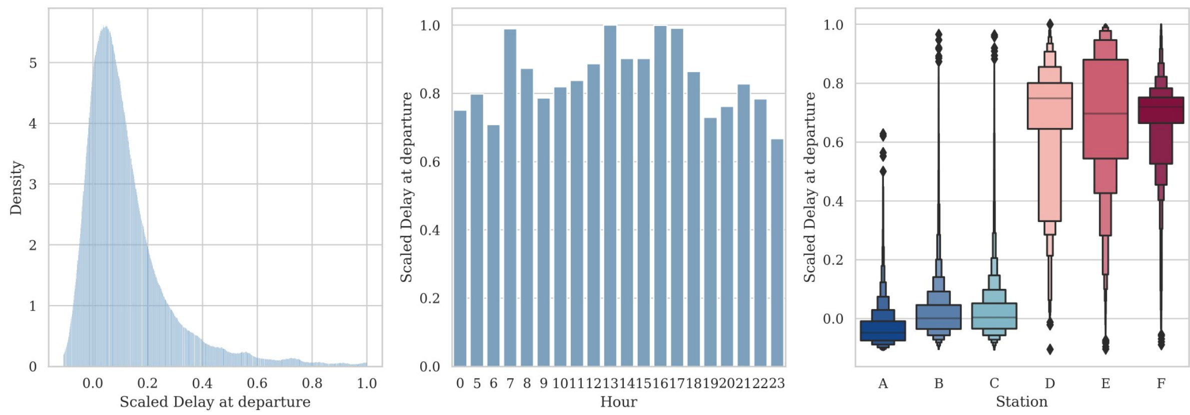

Figure 2.4: Summary plots for the historic train movements

After preprocessing the dataset, the final dataset contained 14 million punctuality records. Based on a literature review and multiple explorative data analysis, 16 features were divided into three feature sets. The first set contained features describing the historic tram movements and time data. The remaining two sets of features described external influences on tram movements, namely categorical values describing the weather at the current station (i.e., temperature, snow height, wind speed, and precipitation) and binary data that describe whether the current day is a working day (that is, school holidays, public holidays, and long weekends). Based on an analysis of various ML models suitable for punctuality prediction with reasonable optimization runtime and scalability for the datasets, four models (i.e., Random Forest Regressor (RF), K-Nearest Neighbors (KNN), Extreme Gradient Boosting (XGBoost), Light Gradient Boosting Machines (LGBM)) were selected. Additionally, this article offers a solution to a common problem in punctuality prediction, which is that historic punctuality data underlies strict regulations in terms of publishing, which is the result of a direct relation between ML evaluation functions and the volatility in the test data set which allows the inference of other metrics. Therefore, the article introduces a novel evaluation metric, the Quality Metric (QM), which allows the evaluation of the model performance without the need for actual punctuality data. The QM compares the mean of the differences between the planned departure times according to the timetable and the historic departure times ($MAE(DED_{timetable})$) and the mean of the predicted departure delay of the model ($MAE(DED_{predicted})$). The ratio between these two mean absolute errors, as defined in equation (2.1), acts as a QM for the result that is independent of the granularity of the baseline values

$$QM = 1 - \frac{MAE(DED_{predicted})}{MAE(DED_{timetable})} = 1 - \frac{MAE_{model}}{MAE_{baseline}} \tag{2.1}$$

All models were trained on permutations of the large-scale exogenous datasets to study performance for each category, as well as individual features to rule out secondary effects. To enhance applicability and comprehension of the results, this article leverages AutoML. AutoML summarizes solutions that aim to improve the availability of ML functionalities, reduce training costs, and improve reproducibility while maintaining high accuracy (Truong et al., 2019). Using this approach, the best overall model, LGBM, yields an Mean Absoulte Error (MAE) of 51.08s or 43.76 % QM when trained on historic train movement data enriched with four weather and three holiday features. Taking into account both evaluation metrics (i.e., QM and the Residual Mean Square Error (RMSE) improvement compared to the train schedule as baseline), all models tend to improve performance when trained on enriched datasets. XGBoost exhibits the most significant relative improvements of 17.33 % comparing historical data and the complete feature set. While the relative percentage might vary between models, the general trend prevails: the larger the set of uncorrelated features, the better the quality metric. Figure 2.5 illustrates the performance of the models compared to the two benchmarks.

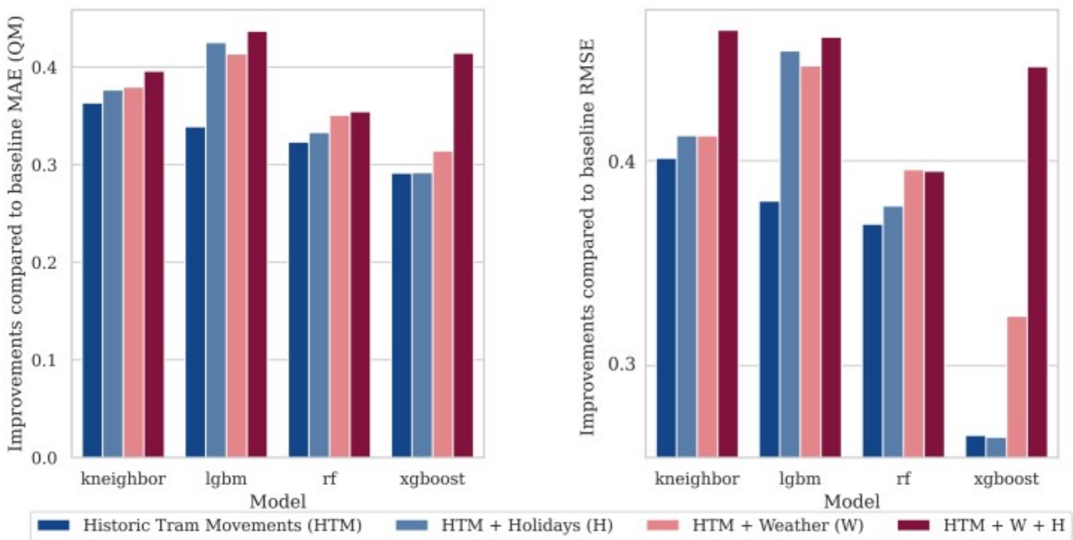

Figure 2.5: Performance evaluation of the models benchmarked against the deviations in the train schedule

Research Article #5 offers several managerial and academic implications. Academically, it introduces a method to quantify the results of the punctuality prediction using a quality metric, facilitating the comparison of findings across different datasets. Additionally, it verifies previous findings for urban tram networks and quantifies the impact of enriching historical train movement data with exogenous factors, while controlling for secondary effects across an entire transportation network with multiple stations and lines. This contrasts with previous research that focused primarily on single lines or stations. By analyzing the effects of exogenous data (e.g., holidays and weather) over an extended period with finer granularity, the study enhances the prediction of public transportation punctuality. These insights enable transportation providers to develop more reliable systems, thus promoting sustainable urban development. In alignment with the goals of this doctoral thesis, this article leverages AutoML to provide organizations with actionable recommendations that can improve sustainability holistically.

Research Article #6: Understanding Information Needs for Seamless Intermodal Transportation: Evidence from Germany

In today's discussion of decarbonizing road transportation, the switch from combustion engine vehicles that burn fossil fuels toward alternatives such as electric vehicles or fuel cell electric vehicles is dominating (Reul et al., 2021; Yu et al., 2023). What is often neglected, but is largely responsible for urban air pollution and the decrease in available urban space, is the continued increase in individual transportation and the land use of private cars in cities (Arnott & Inci, 2006; Barth & Boriboonsomsin, 2008). Therefore, there is a growing interest in intermodal mobility as a solution that combines the strengths of different transportation modes, offering reduced environmental impacts and healthier transportation (Dacko & Spalteholz, 2014; Gebhardt et al., 2016; Oostendorp & Gebhardt, 2018). For instance, combining public transportation and walking can create seamless door-to-door trips, encouraging a shift away from the dependency on cars (Gebhardt et al., 2016).

Nonetheless, as of 2023, intermodal mobility still represents the minority of trips (Goletz et al., 2020). To strongly promote intermodal mobility, and to stimulate an intentional and sustainable long-term shift in urban mobility behaviors, individual attitudinal aspects toward intermodality are crucial (Javid et al., 2016). Following De Vos et al. (2022), travel satisfaction and, therefore, the choice of a mobility mode is influenced by a magnitude of factors (e.g., travel time, costs). Due to the number of factors, combined with the increasing flexibility arising from new transportation systems and mobility-as-a-service (MaaS) concepts in intermodal trips, travelers face very complex and interrelated mode choice decisions (Feneri et al., 2022). To support this decision-making process, a plurality of information is required throughout the intermodal trip (Jochem et al., 2021).

Although research on travel satisfaction factors, the quality of transportation services, and customer experiences in unimodal mobility or multimodal mobility is dense (e.g., De Vos et al., 2016, 2022), intermodal mobility and holistic research on information requirements for intermodal trips have rarely been analyzed (Susilo & Cats, 2014), especially regarding the interactions between information, mode chains, and phases. Therefore, Research Article #6 aims to answer the following research question: *What are the key information requirements for creating seamless intermodal mobility solutions, depending on modes and travel phases in urban environments?*

To examine and practical validate the information required to conduct an intermodal mobility trip, the article follows the methodology of Berger et al. (2022) and leverages a sequential mixed-method approach. Mixed-method approaches are well-known research methodologies (McKim, 2017) that focus on increasing the practical validity of the theoretically obtained findings and that simultaneously help to create new concepts (McKim, 2017; Venkatesh & Brown, 2013). Within the broad spectrum of mixed-method research (see Venkatesh & Brown, 2013; Venkatesh et al., 2016), the article follows a sequential and dependent research process. First, a systematic literature review was conducted to gain a holistic overview of passenger information for selected means of urban mobility, which was then validated using a questionnaire with 500 participants.

The main results of Research Article #6 are a detailed analysis of the current literature on information needs in intermodal transportation and three propositions, which form the final artifact of the article. The first and second proposition focus on the individual influence of phases (Proposition I: The information requirements to facilitate intermodal mobility trips vary depending on the phase of the trip) and mode chains on information needs (Proposition II: Each mode combination for an intermodal mobility chain requires different information). Based on two previous propositions, one would assume, that based on evaluating the phase's influence and mode chain's influence independent of one another, the most important information for one trip would be known. However, as derived from the questionnaire, the information needs can only be determined when considering the mode chain and the current phase simultaneously. Hence, leading to the final proposition, which focuses on the interaction of mode chains, phases, and information: Information cannot be viewed from a single perspective that focuses on either mode chains or phases; it should be viewed from a perspective that focuses on the interactions between both (Proposition III).

Drawing on these insights, Research Article #6 developed a preliminary concept that encompasses mode chains, phases, and their interactions, providing a comprehensive picture of information needs in intermodal mobility trips. Figure 2.6 illustrates said interaction.

This concept has the potential to improve customer satisfaction by having mobility services

[1]RI = Relative Importance

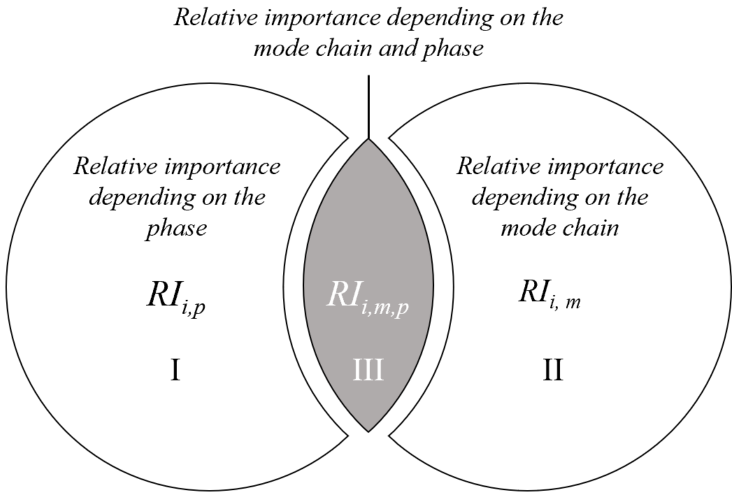

Figure 2.6: The Interaction between Information (i), Mode Chains (m), and Phases (p)[1]

providers deliver relevant information timeously. By tailoring information provision to the specific requirements of diverse intermodal mode chains, the concept can contribute to the formulation of more effective strategies, ultimately enhancing passengers' overall travel satisfaction. In turn, this can lead to less congestion and less air pollution by allowing more users to switch from private vehicles to intermodal mobility chains consisting of sustainable mobility modes. Hence, Research Article #6 provides an example of how DT - i.e., the provision of information in traveler apps and sustainability i.e., the need for more sustainable mobility can be integrated to provide mutual benefits. In this case, the need for more sustainable mobility led to the development of a concept that can enhance customer satisfaction by requiring mobility services providers to deliver relevant information in a timely manner.

3 Conclusion

3.1 Summary

Organizations are at the forefront of contributing to sustainable development (Porter & Kramer, 2011; Van Zanten & Van Tulder, 2021). Leveraging their strong innovation capabilities and operation outside of governmental boundaries, they have the potential to create positive sustainability impacts beyond their direct influence (Garnett & Balmford, 2022). To achieve these positive impacts, DT is recognized as one of the key levers (Vassilakopoulou & Hustad, 2023b; Veit & Thatcher, 2023). However, research is still trying to balance the positive results DT can facilitate for sustainable development with the unintended negative outcomes (Chatterjee & Sarker, 2024; Veit & Thatcher, 2023). Therefore, Research Article #1, driven by the desire to understand the challenge of mastering both DT and sustainability, applies a tension lens to investigate the conflicting demands between DT and sustainability and how organizations may balance the resulting tensions. The results are the three response mechanisms that structure this work and facilitate the understanding of the interplay on an organizational level. Each represents one avenue for organizations and researchers to leverage the value-adding interplay of DT and sustainability. Orthogonal to these response mechanisms (i.e., *"Leverage DT to enhance sustainability actions"*, *"Exploit sustainability to sharpen digital actions"*, *"Integrate DT and sustainability to provide mutual benefit"*), organizations face multiple challenges which are recurring for each response mechanisms. The combination of response mechanisms and challenges provides the outline for this doctoral thesis. Along this structure, this thesis offers several contributions that have implications for both practitioners and academics.

First, in relation to the response mechanism *leverage DT to enhance sustainability actions*, section 2.1 offers actionable practices for organizations to embrace and connect the three pillars of sustainability. In this vein, Research Article #2 developed the AI4S taxonomy, a tripartite framework (i.e., organizational, technical, and sustainability perspective) that helps practitioners understand and differentiate AI4S use cases. Based on the taxonomy and the analysis of 158 AI4S use cases, the article describes the predominant features of AI4S use cases and how they manifest themselves in the technical (i.e., focus on specific data, algorithms, and AI-skills), organizational (i.e., especially the distribution along business functions), and sustainability (i.e., a clear focus towards certain SDGs) dimensions; resulting in seven archetypes that support organizations and researchers to develop effective solutions for their sustainability challenges and encourage the design of DT projects that connect multiple sustainability pillars.

On the second response mechanism (*Exploit sustainability to sharpen digital actions*), section 2.2 describes patterns and mechanisms to reduce the negative impacts of DT on sustainability. Specifically, it focuses on one prominent subset of digital technologies, namely AI. Despite the rapid adoption of AI, the recognition of their associated sustainability risks has been gradual (Cowls et al., 2023). Yet, as more and more AI systems are deployed, giving them an ever-greater influence, it is important to do so with a focus on sustainability (van Wynsberghe, 2021). Therefore, Research Article #3 presents the SML-DPM, a holistic framework providing research and practice with application-context independent DPs to develop sustainable AI systems. The framework structures the DPs along the entire AI development process and the ESG dimensions. Thereby providing practitioners and researchers with actionable practices that enhance the sustainability of the AI development process. Research Article #4 goes beyond the separate treatment of each sustainability pillar, by deriving governance mechanisms that integrate multiple sustainability pillars, resulting in an extension framework for existing governance Frameworks.

Regarding the final response mechanism (*Integrate DT and sustainability to provide mutual benefit*), section 2.3 presents two cases that exemplify the mutually beneficial relationship between DT and sustainability. Both Research Articles #5 and #6 address the challenge of reducing the environmental impact of urban mobility. Following one of the archetypes identified in section 2.1, Research Article #5 provides a specific implementation example leveraging AI, particularly its prominent subset ML, to compare different feature sets for predicting the punctuality of tram-based public transportation networks. The article utilized AutoML – a technique to efficiently compare and train different ML algorithms while lowering the entry hurdle for users – to train punctuality prediction models. The results indicate that AutoML can train sophisticated ML models within a reasonable computational time, and thus enable more employees to leverage ML. Additionally, the enhancement of prediction quality by 54% confirms previous findings that external factors (e.g., weather and holidays) significantly affect prediction quality. The improved models can help public transportation providers to improve short-term planning, make transportation more reliable, and encourage the use of sustainable mobility alternatives. In comparison, Research Article #6 introduces the concept of mode chain- and phase-sensitive information, which aids in better understanding passengers information needs during intermodal trips. By integrating a sustainability perspective into the development process, Research Article #6 increases the accessibility of the resulting digital product for various user groups and thus presents an example of the mutual benefiting interplay of DT and sustainability.

3.2 Limitations and Future Research

This doctoral thesis has certain limitations that pave the way for future research opportunities. This part summarizes these limitations, suggesting new directions for researchers at the intersection of DT and sustainability. Furthermore, each research article offers an in-depth look at these limitations and their potential to inspire further studies (see appendix A.3 - appendix A.8).

First, Research Articles #2 and #4 have shown the potential to enhance the understanding of a specific response mechanism (c.f., section 2.1 and section 2.2). Both articles share a common methodological approach by conducting multivocal literature reviews to develop archetypes or governance mechanisms. Although the selection of the literature was carried out with care, the presence of biases in the literature or the exclusion of important research articles cannot be entirely eliminated. Further research could adopt a deductive approach grounded in empirical investigations to validate the results and provide insight into adoption patterns. For example, extending Research Article #4 through longitudinal case studies could yield practical insights into the real-world application of governance mechanisms and offer detailed implementation guidelines. Similarly, extending Research Article #2 by conducting case studies in different sectors could identify whether archetypes manifest differently and examine the detailed influence of leveraging AI4S archetypes. This is in line with the call by Guandalini (2022) for more cross-sector and cross-geographical research, which is currently underrepresented at the intersection of DT and sustainability.

Second, Research Articles #5 and #6 provide compelling illustrations of how the interplay of DT and sustainability can harmonize DT and sustainability goals. While both research articles illustrate how organizations can leverage the integration of DT and sustainability, they fail to address each sustainability pillar comprehensively. As Veit and Thatcher (2023) highlights, a clear sustainability definition that addresses each pillar is necessary to reduce the potential for unintended side effects. Therefore, further research should aim to identify actionable practices that integrate digital and sustainability actions, to provide mutual benefits while incorporating a holistic definition of sustainability. One potential approach for IS research with a practical orientation may lie in incorporating the design patterns identified in Research Article #3 or the governance mechanisms identified in Research Article #4 to holistically address sustainability in the design, development, and deployment of AI.

Third, Research Articles #2, #3, and #4 present compelling cases illustrating how the interplay of DT and sustainability can generate positive sustainability impacts or reduce the unintended negative impacts. For instance, Research Article #1 offers archetypes that bridge technical, organizational, and sustainability dimensions, underscoring the potential of DT for advancing sustainability. Although the artifacts presented in these research articles focus on sustainability impacts, they do not quantify the impact of each artifact on sustainability. Further research could leverage these findings and fortify the results by quantifying the sustainability impact along the product lifecycle. In this context, the methodological approach by Schneider et al. (2023) and the definition of metrics by Rohde et al. (2024) can serve as a point of departure for the quantification of actions.

In summary, this doctoral thesis highlights the significant potential that arises from the integration of DT and sustainability to address grand societal challenges. By offering actionable practices that consider all three sustainability pillars and examine the connection of multiple pillars, this thesis aims to engage researchers and practitioners in a dialogue about the impactful combination of DT and sustainability. I sincerely believe that it is this powerful combination that can facilitate sustainable development for organizations.

4 Bibliography

Akkermans, H., & Van Helden, K. (2002). Vicious and virtuous cycles in ERP implementation: A case study of interrelations between critical success factors. *European Journal of Information Systems*, *11*(1), 35–46. https://doi.org/10.1057/palgrave.ejis.3000418

Akkermans, H., Van Oppen, W., Vos, B., & X. J. Ou, C. (2021). Reversing a relationship spiral: From vicious to virtuous cycles in IT outsourcing. *Information Systems Journal*, *31*(2), 231–267. https://doi.org/10.1111/isj.12309

Allen, L., OConnell, 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. https://doi.org/10.1002/leap.1210

Arnott, R., & Inci, E. (2006). An integrated model of downtown parking and traffic congestion. *Journal of Urban Economics*, *60*(3), 418–442. https://doi.org/10.1016/j.jue.2006.04.004

Ayeleru, O., Fajimi, L., Oboirien, B., & Olubambi, P. (2021). Forecasting municipal solid waste quantity using artificial neural network and supported vector machine techniques. *Journal of Cleaner Production*, *289*. https://doi.org/10.1016/j.jclepro.2020.125671

Barth, M., & Boriboonsomsin, K. (2008). Real-World Carbon Dioxide Impacts of Traffic Congestion. *Transportation Research Record: Journal of the Transportation Research Board*, *2058*(1), 163–171. https://doi.org/10.3141/2058-20

Batterbury, S. (2003). Environmental Activism and Social Networks: Campaigning for Bicycles and Alternative Transport in West London. *The ANNALS of the American Academy of Political and Social Science*, *590*(1), 150–169. https://doi.org/10.1177/0002716203256903

Bauer, P., Thorpe, A., & Brunet, G. (2015). The quiet revolution of numerical weather prediction. *Nature*, *525*(7567), 47–55. https://doi.org/10.1038/nature14956

Berger, M., Lange, T., & Stahl, B. (2022). A digital push with real impact Mapping effective digital nudging elements to contexts to promote environmentally sustainable behavior. *Journal of Cleaner Production*, *380*, 134716. https://doi.org/10.1016/j.jclepro.2022.134716

Berthon, P., & Donnellan, B. (2011). The greening of IT: Paradox or promise? *The Journal of Strategic Information Systems*, *20*(1), 3–5. https://doi.org/10.1016/j.jsis.2011.02.001

Breiter, K., Crome, C., Oberländer, A. M., & Schnaak, F. (2024). Dynamic capabilities for the twin transformation climb: A capability maturity model. *Information Systems Frontiers*. https://doi.org/10.1007/s10796-024-10520-y

Buck, C., Krombacher, A., Röglinger, M., & Körner-Wyrtki, K. (2023). Doing good by going digital: A taxonomy of digital social innovation in the context of incumbents. *The Journal of Strategic Information Systems*, *32*(4), 101806. https://doi.org/10.1016/j.jsis.2023.101806

Chatterjee, S., Rana, N. P., Dwivedi, Y. K., & Baabdullah, A. M. (2021). Understanding AI adoption in manufacturing and production firms using an integrated TAM-TOE model. *Technological Forecasting and Social Change*, *170*, 120880. https://doi.org/10.1016/j.techfore.2021.120880

Chatterjee, S., & Sarker, S. (2024). Toward a better digital future: Balancing the utopic and dystopic ramifications of digitalization. *The Journal of Strategic Information Systems*, *33*(2), 101834. https://doi.org/10.1016/j.jsis.2024.101834

Chen, M., Liu, X., Xia, J., & Chien, S. I. (2004). A Dynamic Bus-Arrival Time Prediction Model Based on APC Data. *Computer-Aided Civil and Infrastructure Engineering*, *19*(5), 364–376. https://doi.org/10.1111/j.1467-8667.2004.00363.x

Christmann, A.-S., Crome, C., Graf-Drasch, V., Oberländer, A. M., & Schmidt, L. (2024). The twin transformation butterfly: Capabilities for an integrated digital and sustainability transformation. *Business & Information Systems Engineering*. https://doi.org/10.1007/s12599-023-00847-2

Cisco. (2022). Turning COVID challenges into hybrid-learning success.

Corbin, J., & Strauss, A. (2008). *Basics of qualitative research (3rd ed.): Techniques and procedures for developing grounded theory*. SAGE Publications, Inc. https://doi.org/10.4135/9781452230153

Corporation, I. (2022). *IBM Global AI Adoption Index 2022* (tech. rep.). IBM Corporation. Armonk, NY.

Cowls, J., Tsamados, A., Taddeo, M., & Floridi, L. (2023). The AI gambit: Leveraging artificial intelligence to combat climate changeopportunities, challenges, and recommendations. *AI & SOCIETY*, *38*(1), 283–307. https://doi.org/10.1007/s00146-021-01294-x

Crome, C., Graf-Drasch, V., Oberländer, A. M., & Seidel, S. (2024a). Integrating Digital and Sustainability Transformation Through Artificial Intelligence: A Framework for AI-enabled Twin Transformation. In T. Lynn, P. Rosati, D. Kreps, & K. Conboy (Eds.), *Digital Sustainability* (pp. 49–62). Springer Nature Switzerland. https://doi.org/10.1007/978-3-031-61749-2_3

Crome, C., Hinsen, S., Huber, F., Pantzer, J., Schleich, E., Wilkens, H., Graf-Drasch, V., Oberländer, A. M., Meyer-Hollatz, T., & Urbach, N. (2023a). Digital und nachhaltig die zukunft sichern: Wie unternehmen die twin transformation als vorreiter meistern können (Ernst & Young GmbH Wirtschaftsprüfungsgesellschaft & Institutsteil Wirtschaftsinformatik des Fraunhofer FIT, Eds.).

Crome, C., Meyer-Hollatz, T., Oberländer, A. M., Graf-Drasch, V., Urbach, N., & Hinsen, S. (2023b). Digital und nachhaltig die Zukunft sichern : Wie Unternehmen die Twin Transformation meistern können.

Currie, D., McCracken, M., & Venter, K. (2022). Avoiding the vicious cycle, engendering the virtuous circle: Understanding the interaction of human, social and organizational capitals in non-profit and voluntary organizations. *Journal of Business Research*, *152*, 17–28. https://doi.org/10.1016/j.jbusres.2022.07.022

Dacko, S., & Spalteholz, C. (2014). Upgrading the city: Enabling intermodal travel behaviour. *Technological Forecasting and Social Change*, *89*, 222–235. https://doi.org/10.1016/j.techfore.2013.08.039

Dadhich, M., & Hiran, K. K. (2022). Empirical investigation of extended TOE model on Corporate Environment Sustainability and dimensions of operating performance of SMEs. *Journal of Cleaner Production*, *363*, 132309. https://doi.org/10.1016/j.jclepro.2022.132309

Danneels, L., & Viaene, S. (2022). Identifying digital transformation paradoxes: A design perspective. *Business & Information Systems Engineering*, *64*(4), 483–500. https://doi.org/10.1007/s12599-021-00735-7

Dao, V., Langella, I., & Carbo, J. (2011). From green to sustainability: Information technology and an integrated sustainability framework. *The Journal of Strategic Information Systems*, *20*(1), 63–79. https://doi.org/10.1016/j.jsis.2011.01.002

De Vos, J., Mokhtarian, P. L., Schwanen, T., Van Acker, V., & Witlox, F. (2016). Travel mode choice and travel satisfaction: Bridging the gap between decision utility and experienced utility. *Transportation*, *43*(5), 771–796. https://doi.org/10.1007/s11116-015-9619-9

De Vos, J., Singleton, P. A., & Gärling, T. (2022). From attitude to satisfaction: Introducing the travel mode choice cycle. *Transport Reviews*, *42*(2), 204–221. https://doi.org/10.1080/01441647.2021.1958952

De Vries, A. (2023). The growing energy footprint of artificial intelligence. *Joule*, *7*(10), 2191–2194. https://doi.org/10.1016/j.joule.2023.09.004

Dennehy, D., Griva, A., Pouloudi, N., Dwivedi, Y. K., Mäntymäki, M., & Pappas, I. O. (2023). Artificial intelligence (AI) and information systems: Perspectives to responsible AI. *Information Systems Frontiers*, *25*(1), 1–7. https://doi.org/10.1007/s10796-022-10365-3

Di Vaio, A., Palladino, R., Hassan, R., & Escobar, O. (2020). Artificial intelligence and business models in the sustainable development goals perspective: A systematic literature review. *Journal of Business Research*, *121*, 283–314. https://doi.org/10.1016/j.jbusres.2020.08.019

Dorninger, C., Abson, D. J., Apetrei, C. I., Derwort, P., Ives, C. D., Klaniecki, K., Lam, D. P., Langsenlehner, M., Riechers, M., Spittler, N., & Von Wehrden, H. (2020). Leverage points for sustainability transformation: A review on interventions in food and energy systems. *Ecological Economics*, *171*, 106570. https://doi.org/10.1016/j.ecolecon.2019.106570

Ecovadis. (2024). *Ecovadis*. Retrieved August 22, 2024, from https://ecovadis.com

El Idrissi, S. C., & Corbett, J. (2016). Green IS Research: A Modernity Perspective. *Communications of the Association for Information Systems*, *38*, 596–623. https://doi.org/10.17705/1CAIS.03830

Elkington, J. (1997). Cannibals with Forks: The Triple Bottom Line of 21st Century Business. *Oxford: Capstone*.

Enholm, I. M., Papagiannidis, E., Mikalef, P., & Krogstie, J. (2022). Artificial Intelligence and Business Value: A Literature Review. *Information Systems Frontiers*, *24*(5), 1709–1734. https://doi.org/10.1007/s10796-021-10186-w

Fehrer, T., Meyer-Hollatz, T., Häckel, B., & Röglinger, M. (2024). Integrating and implementing zero defect manufacturing and sustainability: A reference architecture [Working Paper].

Feneri, A.-M., Rasouli, S., & Timmermans, H. J. (2022). Modeling the effect of Mobility-as-a-Service on mode choice decisions. *Transportation Letters*, *14*(4), 324–331. https://doi.org/10.1080/19427867.2020.1730025

Ferrara, E. (2023, April 15). *Fairness And Bias in Artificial Intelligence: A Brief Survey of Sources, Impacts, And Mitigation Strategies*. arXiv: 2304.07683 [cs].

Forum, W. E. (2024, July 22). *AI and energy: Will AI help reduce emissions or increase demand? Here's what to know*. Energy Transition. https://www.weforum.org/agenda/2024/07/generative-ai-energy-emissions/

Frank, B. (2021). Artificial intelligence-enabled environmental sustainability of products: Marketing benefits and their variation by consumer, location, and product types. *Journal of Cleaner Production*, *285*, 125242. https://doi.org/10.1016/j.jclepro.2020.125242

Galaz, V., Centeno, M. A., Callahan, P. W., Causevic, A., Patterson, T., Brass, I., Baum, S., Farber, D., Fischer, J., Garcia, D., McPhearson, T., Jimenez, D., King, B., Larcey, P., & Levy, K. (2021). Artificial intelligence, systemic risks, and sustainability. *Technology in Society*, *67*, 1–10. https://doi.org/10.1016/j.techsoc.2021.101741

Ganju, K. K., Pavlou, P. A., & Banker, R. D. (2016). Does information and communication technology lead to the well-being of nations? A country-level empirical investigation. *MIS quarterly*, *40*(2), 417–430.

Garnett, E. E., & Balmford, A. (2022). The vital role of organizations in protecting climate and nature. *Nature Human Behaviour*, *6*(3), 319–321. https://doi.org/10.1038/s41562-021-01260-z

Garousi, V., Felderer, M., & Mäntylä, M. V. (2019). Guidelines for including grey literature and conducting multivocal literature reviews in software engineering. *Information and Software Technology*, *106*, 101–121. https://doi.org/10.1016/j.infsof.2018.09.006

Gebhardt, L., Krajzewicz, D., Oostendorp, R., Goletz, M., Greger, K., Klötzke, M., Wagner, P., & Heinrichs, D. (2016). Intermodal Urban Mobility: Users, Uses, and Use Cases. *Transportation Research Procedia*, *14*, 1183–1192. https://doi.org/10.1016/j.trpro.2016.05.189

Georgieva, I., Lazo, C., Timan, T., & Van Veenstra, A. F. (2022). From AI ethics principles to data science practice: A reflection and a gap analysis based on recent frameworks and practical experience. *AI and Ethics*, *2*(4), 697–711. https://doi.org/10.1007/s43681-021-00127-3

Gholami, R., Watson, R., Hasan, H., Molla, A., & Bjorn-Andersen, N. (2016). Information systems solutions for environmental sustainability: How can we do more? *Journal of the Association for Information Systems*, *17*(8), 521–536. https://doi.org/10.17705/1jais.00435

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the gioia methodology. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151

Goletz, M., Haustein, S., Wolking, C., & LHostis, A. (2020). Intermodality in European metropolises: The current state of the art, and the results of an expert survey covering Berlin, Copenhagen, Hamburg and Paris. *Transport Policy*, *94*, 109–122. https://doi.org/10.1016/j.tranpol.2020.04.011

Griffin, P. (2017). *The Carbon Majors Database - CDP Carbon Majors Report 2017* (The Carbon Majors Database). CDP; Climate Accountability Institute.

Guandalini, I. (2022). Sustainability through digital transformation: A systematic literature review for research guidance. *Journal of Business Research*, *148*, 456–471. https://doi.org/10.1016/j.jbusres.2022.05.003

Guo, Y., Li, X., & Zeng, X. (2019). Platform Competition in the Sharing Economy: Understanding How Ride-Hailing Services Influence New Car Purchases. *Journal of Management Information Systems*, *36*(4), 1043–1070. https://doi.org/10.1080/07421222.2019.1661087

Hanelt, A., Bohnsack, R., Marz, D., & Antunes Marante, C. (2021). A systematic review of the literature on digital transformation: Insights and implications for strategy and organizational change. *Journal of Management Studies*, *58*(5), 1159–1197. https://doi.org/10.1111/joms.12639

Hedman, J., & Henningsson, S. (2016). Developing ecological sustainability: A green IS response model. *Information Systems Journal*, *26*(3), 259–287. https://doi.org/10.1111/isj.12095

Hevner, March, Park, & Ram. (2004). Design science in information systems research. *MIS Quarterly*, *28*(1), 75. https://doi.org/10.2307/25148625

Hunke, F., Heinz, D., & Satzger, G. (2022). Creating customer value from data: Foundations and archetypes of analytics-based services. *Electronic Markets*, *32*(2), 503–521. https://doi.org/10.1007/s12525-021-00506-y

Ibrahim, A. N. H., & Borhan, M. N. (2020). The Interrelationship Between Perceived Quality, Perceived Value and User Satisfaction Towards Behavioral Intention in Public Transportation: A Review of the Evidence. *International Journal on Advanced Science, Engineering and Information Technology*, *10*(5), 2048. https://doi.org/10.18517/ijaseit.10.5.12818

Javid, M. A., Okamura, T., Nakamura, F., Tanaka, S., & Wang, R. (2016). Peoples behavioral intentions towards public transport in Lahore: Role of situational constraints, mobility restrictions and incentives. *KSCE Journal of Civil Engineering*, *20*(1), 401–410. https://doi.org/10.1007/s12205-015-1123-4

Jeberg, M. H., Sloth, S. H., & Løgtved, J. H. (2021). Development of an Eco-efficiency Distribution Model. In *Advances in Production Management Systems. Artificial Intelligence for Sustainable and Resilient Production Systems* (Vol. 633). Springer International Publishing. https://doi.org/10.1007/978-3-030-85910-7_68

Jochem, P., Lisson, C., & Khanna, A. A. (2021). The role of coordination costs in mode choice decisions: A case study of German cities. *Transportation Research Part A: Policy and Practice*, *149*, 31–44. https://doi.org/10.1016/j.tra.2021.04.001

Jung, T., Miller, M. J., & Palmer, T. N. (2010). Diagnosing the Origin of Extended-Range Forecast Errors. *Monthly Weather Review*, *138*(6), 2434–2446. https://doi.org/10.1175/2010MWR3255.1

Kar, A. K., Choudhary, S. K., & Singh, V. K. (2022). How can artificial intelligence impact sustainability: A systematic literature review. *Journal of Cleaner Production*, *376*, 134120. https://doi.org/10.1016/j.jclepro.2022.134120

Kaur, D., Uslu, S., Rittichier, K. J., & Durresi, A. (2023). Trustworthy Artificial Intelligence: A Review. *ACM Computing Surveys*, *55*(2), 1–38. https://doi.org/10.1145/3491209

Kim, M., Saad, W., Mozaffari, M., & Debbah, M. (2022). On the Tradeoff between Energy, Precision, and Accuracy in Federated Quantized Neural Networks. *ICC 2022 - IEEE International Conference on Communications*, 2194–2199. https://doi.org/10.1109/ICC45855.2022.9838362

Kitchenham, B. (2004). Procedures for performing systematic reviews. *Keele, UK, Keele University*, *33*(2004), 1–26.

Koniakou, V. (2023). From the rush to ethics to the race for governance in Artificial Intelligence. *Information Systems Frontiers*, *25*(1), 71–102. https://doi.org/10.1007/s10796-022-10300-6

Kopka, A., & Grashof, N. (2022). Artificial intelligence: Catalyst or barrier on the path to sustainability? *Technological Forecasting and Social Change*, *175*. https://doi.org/10.1016/j.techfore.2021.121318

Lagna, A., & Ravishankar, M. N. (2022). Making the world a better place with fintech research. *Information Systems Journal*, *32*(1), 61–102. https://doi.org/10.1111/isj.12333

Laifa, H., khcherif, R., & Ben Ghezalaa, H. H. (2021). Train delay prediction in Tunisian railway through LightGBM model. *Procedia Computer Science*, *192*, 981–990. https://doi.org/10.1016/j.procs.2021.08.101

Leong, C., Pan, S. L., Newell, S., & Cui, L. (2016). The Emergence of Self-Organizing E-Commerce Ecosystems in Remote Villages of China. *MIS Quarterly*, *40*(2), 475–484.

Lindenthal, A., Meierhöfer, S., Meyer-Hollatz, T., Oberländer, A., & Bitzer, M. (2024). Leveraging data for innovation archetypes of data-driven innovation [Working Paper].

Liotta, C., Viguié, V., & Creutzig, F. (2023). Environmental and welfare gains via urban transport policy portfolios across 120 cities. *Nature Sustainability*. https://doi.org/10.1038/s41893-023-01138-0

Liu, C., Susilo, Y. O., & Karlström, A. (2017). Weather variability and travel behaviour what we know and what we do not know. *Transport Reviews*, *37*(6), 715–741. https://doi.org/10.1080/01441647.2017.1293188

Loeser, F. (2013). Green IT and green IS: Definition of constructs and overview of current practices completed research paper. *Proceedings of the Nineteenth Americas Conference on Information Systems*. https://doi.org/10.13140/2.1.3065.6962

Lu, Q., Zhu, L., Xu, X., Whittle, J., Zowghi, D., & Jacquet, A. (2023). Responsible AI Pattern Catalogue: A Collection of Best Practices for AI Governance and Engineering. *ACM Computing Surveys*, 3626234. https://doi.org/10.1145/3626234

Malhotra, A., Melville, N. P., & Watson, R. T. (2013). Spurring Impactful Research on Information Systems and Environmental Sustainability. *MIS Quarterly*, *37*(4), 1265–1274. https://doi.org/10.25300/MISQ/2013/37:4.3

Mäntymäki, M., Minkkinen, M., Birkstedt, T., & Viljanen, M. (2022a). Defining organizational AI governance. *AI and Ethics*, *2*(4), 603–609. https://doi.org/10.1007/s43681-022-00143-x

Mäntymäki, M., Minkkinen, M., Birkstedt, T., & Viljanen, M. (2022b). Putting AI Ethics into Practice: The Hourglass Model of Organizational AI Governance. https://doi.org/10.48550/arXiv.2206.00335

Mäntymäki, M., Minkkinen, M., Zimmer, M. P., Birkstedt, T., & Viljanen, M. (2023). Designing an AI governance framework: From research-based premises to meta-requirements. *ECIS 2023 Research Papers*, *295*, 1–18.

Maret, K., Otondo, R. F., & Taylor, G. S. (2013). Assessing the Effects of Benefits and Institutional Influences on the Continued Use of Environmentally Munificent Bypass Systems in Long-Haul Trucking. *MIS Quarterly*, *37*(4), 1301–1312. https://doi.org/10.25300/MISQ/2013/37.4.14

Maslej, N., Fattorini, L., Perrault, R., Parli, V., Reuel, A., Brynjolfsson, E., Etchemendy, J., Ligett, K., Lyons, T., Manyika, J., Niebles, J. C., Shoham, Y., Wald, R., & Clark, J. (2024, April). The AI Index 2024 Annual Report.

Mast, G. (2023, June 20). *Toyota Research Institute Unveils New Generative AI Technique for Vehicle Design*. Toyota USA Newsroom. Retrieved July 18, 2024, from https://pressroom.toyota.com/toyota-research-institute-unveils-new-generative-ai-technique-for-vehicle-design/

Matt, C., Hess, T., & Benlian, A. (2015). Digital transformation strategies. *Business & Information Systems Engineering*, *57*(5), 339–343. https://doi.org/10.1007/s12599-015-0401-5

McKim, C. A. (2017). The Value of Mixed Methods Research: A Mixed Methods Study. *Journal of Mixed Methods Research*, *11*(2), 202–222. https://doi.org/10.1177/1558689815607096

Melville. (2010). Information systems innovation for environmental sustainability. *MIS Quarterly*, *34*(1), 1. https://doi.org/10.2307/20721412

Mesbah, M., Lin, J., & Currie, G. (2015). Weather transit is reliable? Using AVL data to explore tram performance in Melbourne, Australia. *Journal of Traffic and Transportation Engineering (English Edition)*, *2*(3), 125–135. https://doi.org/10.1016/j.jtte.2015.03.001

Microsoft. (2022). *Microsoft Responsible AI Standard, v2* (tech. rep. No. Microsoft Responsible AI Standard, v2). Microsoft.

Mikalef, P., Conboy, K., Lundström, J. E., & Popovi, A. (2022). Thinking responsibly about responsible AI and the dark side of AI. *European Journal of Information Systems*, *31*(3), 257–268. https://doi.org/10.1080/0960085X.2022.2026621

Mishra, R., Singh, R. K., & Song, M. (2022). Managing tensions in resilience development: A paradox theory perspective on the role of digital transformation. *Journal of Enterprise Information Management*. https://doi.org/10.1108/JEIM-08-2022-0271

Nahar, S. (2024). Modeling the effects of artificial intelligence (AI)-based innovation on sustainable development goals (SDGs): Applying a system dynamics perspective in a cross-country setting. *Technological Forecasting and Social Change*, *201*, 123203. https://doi.org/10.1016/j.techfore.2023.123203

Nickerson, R. C., Varshney, U., & Muntermann, J. (2013). A method for taxonomy development and its application in information systems. *European Journal of Information Systems*, *22*(3). https://doi.org/10.1057/ejis.2012.26

Nishant, R., Kennedy, M., & Corbett, J. (2020). Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda. *International Journal of Information Management*, *53*, 102104. https://doi.org/10.1016/j.ijinfomgt.2020.102104

NIST. (2023). *Artificial Intelligence Risk Management Framework (AI RMF 1.0)* (tech. rep. No. NIST AI 100-1). National Institute of Standards and Technology. Gaithersburg, MD. https://doi.org/10.6028/NIST.AI.100-1

OECD. (2019). *Scoping the OECD AI principles: Deliberations of the Expert Group on Artificial Intelligence at the OECD (AIGO)* (OECD Digital Economy Papers No. 291). OECD Publishing. Paris. https://doi.org/10.1787/d62f618a-en

OECD. (2023). *Advancing accountability in AI: Governing and managing risks throughout the lifecycle for trustworthy AI* (OECD Digital Economy Papers No. 349). OECD Publishing. Paris. https://doi.org/10.1787/2448f04b-en

Olsson, N. O., & Haugland, H. (2004). Influencing factors on train punctualityresults from some Norwegian studies. *Transport Policy*, *11*(4), 387–397. https://doi.org/10.1016/j.tranpol.2004.07.001

Olujimi, P. A., & Ade-Ibijola, A. (2023). NLP techniques for automating responses to customer queries. *Discover Artificial Intelligence*. https://doi.org/10.1007/s44163-023-00065-5

Oneto, L., Fumeo, E., Clerico, G., Canepa, R., Papa, F., Dambra, C., Mazzino, N., & Anguita, D. (2018). Train Delay Prediction Systems: A Big Data Analytics Perspective. *Big Data Research*, *11*, 54–64. https://doi.org/10.1016/j.bdr.2017.05.002

Oostendorp, R., & Gebhardt, L. (2018). Combining means of transport as a users strategy to optimize traveling in an urban context: Empirical results on intermodal travel behavior from a survey in Berlin. *Journal of Transport Geography*, *71*, 72–83. https://doi.org/10.1016/j.jtrangeo.2018.07.006

Oreskes, N. (2004). The Scientific Consensus on Climate Change. *Science*, *306*(5702), 1686–1686. https://doi.org/10.1126/science.1103618

Owe, A., & Baum, S. D. (2021). Moral consideration of nonhumans in the ethics of artificial intelligence. *AI and Ethics*, *1*(4), 517–528. https://doi.org/10.1007/s43681-021-00065-0

Papagiannidis, E., Enholm, I. M., Dremel, C., Mikalef, P., & Krogstie, J. (2023). Toward AI Governance: Identifying Best Practices and Potential Barriers and Outcomes. *Information Systems Frontiers*, *25*(1), 123–141. https://doi.org/10.1007/s10796-022-10251-y

Pappas, I. O., Mikalef, P., Dwivedi, Y. K., Jaccheri, L., & Krogstie, J. (2023). Responsible digital transformation for a sustainable society. *Information Systems Frontiers*, *25*(3), 945–953. https://doi.org/10.1007/s10796-023-10406-5

Patterson, D., Gonzalez, J., Holzle, U., Le, Q., Liang, C., Munguia, L.-M., Rothchild, D., So, D. R., Texier, M., & Dean, J. (2022). The Carbon Footprint of Machine Learning Training Will Plateau, Then Shrink. *Computer*, *55*(7), 18–28. https://doi.org/10.1109/MC.2022.3148714

Peffers, K., Tuunanen, T., Rothenberger, M. A., & Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of Management Information Systems*, *24*(3), 45–77. https://doi.org/10.2753/MIS0742-1222240302

Peterson, R. (2004). Crafting Information Technology Governance. *Information Systems Management*, *21*(4), 7–22. https://doi.org/10.1201/1078/44705.21.4.20040901/84183.2

Porter, M. E., & Kramer, M. R. (2011). Creating Shared Value. *Havard Business Review*, (89(1/2)), 62–67.

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustainability Science*, *14*(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5

Reul, J., Grube, T., & Stolten, D. (2021). Urban transportation at an inflection point: An analysis of potential influencing factors. *Transportation Research Part D: Transport and Environment*, *92*, 102733. https://doi.org/10.1016/j.trd.2021.102733

Richardson, K., Steffen, W., Lucht, W., Bendtsen, J., Cornell, S. E., Donges, J. F., Drüke, M., Fetzer, I., Bala, G., Von Bloh, W., Feulner, G., Fiedler, S., Gerten, D., Gleeson, T., Hofmann, M., Huiskamp, W., Kummu, M., Mohan, C., Nogués-Bravo, D., . . . Rockström, J. (2023). Earth beyond six of nine planetary boundaries. *Science Advances*, *9*(37), eadh2458. https://doi.org/10.1126/sciadv.adh2458

Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin, F. S., Lambin, E. F., Lenton, T. M., Scheffer, M., Folke, C., Schellnhuber, H. J., Nykvist, B., De Wit, C. A., Hughes, T., Van Der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P. K., Costanza, R., Svedin, U., . . . Foley, J. A. (2009). A safe operating space for humanity. *Nature*, *461*(7263), 472–475. https://doi.org/10.1038/461472a

Röglinger, M., Fehrer, T., Meyer-Hollatz, T., & Luippold, C. (2024, March). Prädiktive Prozessüberwachung in der Batterieproduktion.

Rohde, F., Wagner, J., Meyer, A., Reinhard, P., Voss, M., Petschow, U., & Mollen, A. (2024). Broadening the perspective for sustainable artificial intelligence: Sustainability criteria and indicators for Artificial Intelligence systems. *Current Opinion in Environmental Sustainability*, *66*, 101411. https://doi.org/10.1016/j.cosust.2023.101411

Sancak, I. E. (2023). Change management in sustainability transformation: A model for business organizations. *Journal of Environmental Management*, *330*, 117165. https://doi.org/10.1016/j.jenvman.2022.117165

Schimanski, T., Reding, A., Reding, N., Bingler, J., & et al. (2023). Bridging the Gap in ESG Measurement: Using NLP to Quantify Environmental, Social, and Governance Communication. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.4622514

Schneider, J., Seidel, S., Basalla, M., & vom Brocke, J. (2023). Reuse, reduce, support: Design principles for green data mining. *Business & Information Systems Engineering*, *65*(1), 65–83. https://doi.org/10.1007/s12599-022-00780-w

Schoormann, T., Strobel, G., Möller, F., Petrik, D., & Zschech, P. (2023). Artificial Intelligence for Sustainability—A Systematic Review of Information Systems Literature. *Communications of the Association for Information Systems*, *52*, 199–237. https://doi.org/10.17705/1CAIS.05209

Schwartz, R., Dodge, J., Smith, N. A., & Etzioni, O. (2020). Green AI. *Communications of the ACM*, *63*(12), 54–63. https://doi.org/10.1145/3381831

Shneiderman, B. (2020). Bridging the Gap Between Ethics and Practice: Guidelines for Reliable, Safe, and Trustworthy Human-centered AI Systems. *ACM Transactions on Interactive Intelligent Systems (TiiS)*, *10*(4), 1–31. https://doi.org/10.1145/3419764

Shneiderman, B. (2021). Responsible AI: Bridging from ethics to practice. *Communications of the ACM*, *64*(8), 32–35. https://doi.org/10.1145/3445973

Simlett, J., & Atalla, G. (2019, November 19). *Welche Rolle spielt die Stadt, wenn Einwohner Mobilität selbst steuern?* (Kurzstudie).

Singapore, P. D. P. C. (2020). *Model Artificial Intelligence Governance Framework: Second Edition* (tech. rep. No. Model Artificial Intelligence Governance Framework: Second Edition). Singapore.

Smith, W. K., & Lewis, M. W. (2011). Toward a theory of paradox: A dynamic equilibrium model of organizing. *Academy of Management Review*, *36*(2), 381–403. https://doi.org/10.5465/AMR.2011.59330958

Soh, C., Yeow, A., & Goh, Q. W. (2023). Shaping digital transformation pathways: Dynamics of paradoxical tensions and responses. *Journal of the Association for Information Systems*, *24*(6), 1594–1617. https://doi.org/10.17705/1jais.00852

Sokalski, M., Klous, D. S., & Chandrasekaran, S. (2019). Controlling AI: The imperative for transparency and explainability.

Sonnenberg, C., & vom Brocke, J. (2012). Evaluation Patterns for Design Science Research Artefacts. In M. Helfert & B. Donnellan (Eds.), *Practical Aspects of Design Science* (pp. 71–83, Vol. 286). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-33681-2_7

Susilo, Y. O., & Cats, O. (2014). Exploring key determinants of travel satisfaction for multimodal trips by different traveler groups. *Transportation Research Part A: Policy and Practice*, *67*, 366–380. https://doi.org/10.1016/j.tra.2014.08.002

Thangavel, K., Spiller, D., Sabatini, R., Amici, S., & et al. (2023). Autonomous Satellite Wildfire Detection Using Hyperspectral Imagery and Neural Networks. *Remote Sensing*, *15*(3). https://doi.org/10.3390/rs15030720

Tirole, J. (2021). Digital dystopia. *American Economic Review*, *111*(6), 2007–2048. https://doi.org/10.1257/aer.20201214

Tomaev, N., Cornebise, J., Hutter, F., Mohamed, S., Picciariello, A., Connelly, B., Belgrave, D. C. M., Ezer, D., Haert, F. C. V. D., Mugisha, F., Abila, G., Arai, H., Almiraat, H., Proskurnia, J., Snyder, K., Otake-Matsuura, M., Othman, M., Glasmachers, T., Wever, W. D., … Clopath, C. (2020). AI for social good: Unlocking the opportunity for positive impact. *Nature Communications*, *11*(1), 2468. https://doi.org/10.1038/s41467-020-15871-z

Tornede, T., Tornede, A., Hanselle, J., Mohr, F., Wever, M., & Hüllermeier, E. (2022). Towards Green Automated Machine Learning: Status Quo and Future Directions. *Journal of Artificial Intelligence Research*. https://doi.org/10.1613/jair.1.14340

TorreBastida, A. I., Del Ser, J., Laña, I., Ilardia, M., Bilbao, M. N., & CamposCordobés, S. (2018). Big Data for transportation and mobility: Recent advances, trends and challenges. *IET Intelligent Transport Systems*, *12*(8), 742–755. https://doi.org/10.1049/iet-its.2018.5188

Touvron, H., Lavril, T., Izacard, G., Martinet, X., Lachaux, M.-A., Lacroix, T., Rozière, B., Goyal, N., Hambro, E., Azhar, F., Rodriguez, A., Joulin, A., Grave, E., & Lample, G. (2023a, February 27). *LLaMA: Open and Efficient Foundation Language Models*. arXiv: 2302.13971 [cs]. Retrieved August 21, 2024, from http://arxiv.org/abs/2302.13971

Touvron, H., Martin, L., Stone, K., Albert, P., Almahairi, A., Babaei, Y., Bashlykov, N., Batra, S., Bhargava, P., Bhosale, S., Bikel, D., Blecher, L., Ferrer, C. C., Chen, M., Cucurull, G., Esiobu, D., Fernandes, J., Fu, J., Fu, W., … Scialom, T. (2023b, July 19). *Llama 2: Open Foundation and Fine-Tuned Chat Models*. arXiv: 2307.09288 [cs]. Retrieved August 21, 2024, from http://arxiv.org/abs/2307.09288

Truong, A., Walters, A., Goodsitt, J., Hines, K., Bruss, C. B., & Farivar, R. (2019). Towards Automated Machine Learning: Evaluation and Comparison of AutoML Approaches and Tools.

2019 IEEE 31st International Conference on Tools with Artificial Intelligence (ICTAI), 1471–1479. https://doi.org/10.1109/ICTAI.2019.00209

Tseng, C.-J., & Lin, S.-Y. (2024). Role of artificial intelligence in carbon cost reduction of firms. *Journal of Cleaner Production*, *447*, 141413. https://doi.org/10.1016/j.jclepro.2024.141413

van Wynsberghe, A. (2021). Sustainable AI: AI for sustainability and the sustainability of AI. *AI and Ethics*, *1*(3), 213–218. https://doi.org/10.1007/s43681-021-00043-6

Van Zanten, J. A., & Van Tulder, R. (2021). Improving companies' impacts on sustainable development: A nexus approach to the SDGS. *Business Strategy and the Environment*, *30*(8), 3703–3720. https://doi.org/10.1002/bse.2835

Vassilakopoulou, P., & Hustad, E. (2023a). Bridging Digital Divides: A Literature Review and Research Agenda for Information Systems Research. *Information Systems Frontiers*, *25*(3), 955–969. https://doi.org/10.1007/s10796-020-10096-3

Vassilakopoulou, P., & Hustad, E. (2023b). Bridging digital divides: A literature review and research agenda for information systems research. *Information Systems Frontiers*, *25*(3), 955–969. https://doi.org/10.1007/s10796-020-10096-3

Veit, D. J., & Thatcher, J. B. (2023). Digitalization as a problem or solution? Charting the path for research on sustainable information systems. *Journal of Business Economics*, *93*(6-7), 1231–1253. https://doi.org/10.1007/s11573-023-01143-x

Venkatesh, V., & Brown, H., Susan A.and Bala. (2013). Bridging the Qualitative-Quantitative Divide: Guidelines for Conducting Mixed Methods Research in Information Systems. *MIS Quarterly*, *37*(1), 21–54. https://doi.org/10.25300/MISQ/2013/37.1.02

Venkatesh, V., Brown, S., & Sullivan, Y. (2016). Guidelines for Conducting Mixed-methods Research: An Extension and Illustration. *Journal of the Association for Information Systems*, *17*(7), 435–494. https://doi.org/10.17705/1jais.00433

Verbeke, A., & Hutzschenreuter, T. (2021). The dark side of digital globalization. *Academy of Management Perspectives*, *35*(4), 606–621. https://doi.org/10.5465/amp.2020.0015

Verdecchia, R., Sallou, J., & Cruz, L. (2023). A systematic review of Green AI. *WIREs Data Mining and Knowledge Discovery*, *13*(4), e1507. https://doi.org/10.1002/widm.1507

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003

Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., Felländer, A., Langhans, S. D., Tegmark, M., & Fuso Nerini, F. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. *Nature Communications*, *11*(1), 233. https://doi.org/10.1038/s41467-019-14108-y

Vivas, R. D. C., SantAnna, A. M. O., Esquerre, K. P. O., & Freires, F. G. M. (2020). Integrated method combining analytical and mathematical models for the evaluation and optimization of sustainable supply chains: A Brazilian case study. *Computers & Industrial Engineering*, *139*. https://doi.org/10.1016/j.cie.2019.01.044

Vom Brocke, J., Loos, P., Seidel, S., & Watson, R. T. (2013). Green IS: Information Systems for Environmental Sustainability. *Business & Information Systems Engineering*, *5*(5), 295–297. https://doi.org/10.1007/s12599-013-0288-y

Wang, H., Gupta, S., Singhal, A., Muttreja, P., & Singh, S. (2022). An Artificial Intelligence Chatbot for Young Peoples Sexual and Reproductive Health in India (SnehAI). *Journal of Medical Internet Research*, *24*(1). https://doi.org/10.2196/29969

Wanner, J., Heinrich, K., Janiesch, C., & Zschech, P. (2020). How much AI do you require? Decision factors for adopting AI technology. *International Conference on Information Systems*.

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS quarterly*, *26*(2), xiii–xxiii.

Wessel, L., Baiyere, A., Ologeanu-Taddei, R., Cha, J., & Blegind Jensen, T. (2021). Unpacking the difference between digital transformation and IT-enabled organizational transformation. *Journal of the Association for Information Systems*, *22*(1), 102–129. https://doi.org/10.17705/1jais.00655

Wiehte, C., Meyer-Hollatz, T., & Ritter, C. (2024). Benchmarking machine learning algorithms for predictive maintenance services with an integrated economic evaluation [Working Paper].

Wieringa, J., Kannan, P., Ma, X., Reutterer, T., Risselada, H., & Skiera, B. (2021). Data analytics in a privacy-concerned world. *Journal of Business Research*, *122*, 915–925. https://doi.org/10.1016/j.jbusres.2019.05.005

Wimelius, H., Mathiassen, L., Holmström, J., & Keil, M. (2021). A paradoxical perspective on technology renewal in digital transformation. *Information Systems Journal*, *31*(1), 198–225. https://doi.org/10.1111/isj.12307

Wirth, R., & Hipp, J. (2000). CRISP-DM: Towards a standard process model for data mining. *Proceedings of the 4th International Conference on the Practical Applications of Knowledge Discovery and Data Mining*.

Wolfswinkel, J. F., Furtmueller, E., & Wilderom, C. P. M. (2013). Using grounded theory as a method for rigorously reviewing literature. *European Journal of Information Systems*, *22*(1), 45–55. https://doi.org/10.1057/ejis.2011.51

World Commission on Environment and Development. (1987). Report of the World Commission on Environment and Development: Our Common Future.

Wormeck, L., Crome, C., Meyer-Hollatz, T., Hinsen, S., & Wassermann, M. E. (2024). Evaluating Digital Sustainability-Oriented Innovations: Criteria for the Frontend of Innovation. *Proceedings of the 32nd European Conference on Information Systems (ECIS)*.

Yang, W., Li, T., & Cao, X. (2015). Examining the impacts of socio-economic factors, urban form and transportation development on CO2 emissions from transportation in China: A panel data analysis of China's provinces. *Habitat International*, *49*, 212–220. https://doi.org/10.1016/j.habitatint.2015.05.030

Yu, X., LeBlanc, S., Sandhu, N., Wang, L., Wang, M., & Zheng, M. (2023). Decarbonization potential of future sustainable propulsionA review of road transportation. *Energy Science & Engineering*, ese3.1434. https://doi.org/10.1002/ese3.1434

Zakeri, G., & Olsson, N. O. E. (2018). Investigating the effect of weather on punctuality of Norwegian railways: A case study of the Nordland Line. *Journal of Modern Transportation*, *26*(4), 255–267. https://doi.org/10.1007/s40534-018-0169-7

Zychowski, A., Junosza-Szaniawski, K., & Kosicki, A. (2018). Travel Time Prediction for Trams in Warsaw. In M. Kurzynski, M. Wozniak, & R. Burduk (Eds.), *Proceedings of the 10th International Conference on Computer Recognition Systems CORES 2017* (pp. 53–62, Vol. 578). Springer International Publishing. https://doi.org/10.1007/978-3-319-59162-9_6

A Appendix

A.1 Research Articles Included in this Dissertation

Research Article #1: Examining Twin Transformation to Balance Digital Transformation and Sustainability Transformation Tensions

Crome, C., Meyer-Hollatz, T., Kreuzer, T., & Oberländer, A. M. (2024b). Examining Twin Transformation to Balance Digital Transformation and Sustainability Transformation Tensions. Working Paper

Research Article #2: Navigating AI for Sustainability in Organizations: Untangling Organizational, Technical, and Sustainable Characteristics

Plank, T., Leuthe, D., & Meyer-Hollatz, T. (2024). Navigating AI for Sustainability in Organizations: Untangling Organizational, Technical, and Sustainable Characteristics. Submitted Working Paper

Research Article #3: Towards Sustainability of AI – Identifying Design Patterns for Sustainable Machine Learning Development

Leuthe, D., Meyer-Hollatz, T., Plank, T., & Senkmüller, A. (2024). Towards Sustainability of AI – Identifying Design Patterns for Sustainable Machine Learning Development. *Information Systems Frontiers*

(VHB-JQ3[1]: B, VHB-JQ4[2]: B, IF[3]: 6.9)

Research Article #4: Linking Sustainability Dimensions in AI Governance: A Review and Collection of Governance Mechanisms

Meyer-Hollatz, T., Willburger, L., Häckel, B., Kratsch, W., & Grüner, V. (2024b). Linking Sustainability Dimensions in AI Governance: A Review and Collection of Governance Mechanisms. Submitted Working Paper

[1] VHB-JQ3: VHB-JOURQUAL3
[2] VHB-JQ4: VHB Publication Media Rating 2024
[3] IF: Impact Factor, 2023

Research Article #5: Punctuality Predictions in Public Transportation: Quantifying the Effect of External Factors

Meyer-Hollatz, T., Schwarz, N., & Werner, T. (2023). Punctuality Predictions in Public Transportation: Quantifying the Effect of External Factors. *Wirtschaftsinformatik 2023 Proceedings*, *73*
(VHB-JQ3: B, VHB-JQ4: B)

Research Article #6: Understanding Information Needs for Seamless Intermodal Transportation: Evidence from Germany

Meyer-Hollatz, T., Kaiser, M., Keller, R., & Schober, M. (2024a). Understanding information needs for seamless intermodal transportation: Evidence from Germany. *Transportation Research Part D: Transport and Environment*, *130*. https://doi.org/10.1016/j.trd.2024.104161
(VHB-JQ3: B, VHB-JQ4: B, IF: 7.3)

Over the course of the dissertation, I also authored and co-authored the following research papers, studies, and reports. These papers are not part of this dissertation.

- Wormeck, L., Crome, C., Meyer-Hollatz, T., Hinsen, S., & Wassermann, M. E. (2024). Evaluating Digital Sustainability-Oriented Innovations: Criteria for the Frontend of Innovation. *Proceedings of the 32nd European Conference on Information Systems (ECIS)*
- Crome, C., Meyer-Hollatz, T., Oberländer, A. M., Graf-Drasch, V., Urbach, N., & Hinsen, S. (2023b). Digital und nachhaltig die Zukunft sichern : Wie Unternehmen die Twin Transformation meistern können
- Fehrer, T., Meyer-Hollatz, T., Häckel, B., & Röglinger, M. (2024). Integrating and implementing zero defect manufacturing and sustainability: A reference architecture [Working Paper]
- Röglinger, M., Fehrer, T., Meyer-Hollatz, T., & Luippold, C. (2024, March). Prädiktive Prozessüberwachung in der Batterieproduktion
- Wiehte, C., Meyer-Hollatz, T., & Ritter, C. (2024). Benchmarking machine learning algorithms for predictive maintenance services with an integrated economic evaluation [Working Paper]
- Lindenthal, A., Meierhöfer, S., Meyer-Hollatz, T., Oberländer, A., & Bitzer, M. (2024). Leveraging data for innovation archetypes of data-driven innovation [Working Paper]
- Fabri, L.; Wenninger, S.; Meyer-Hollatz, T. (2022). You Never Share Alone: Quantifying Sharing Platforms' Evolution. *Proceedings of the International Conference of Center for Business & Industrial Marketing (CBIM)*. Atlanta, USA

A.2 Individual Contribution to the Included Research Papers

This dissertation is cumulative and includes **six** research papers. All research papers were written in teams with multiple co-authors. This section outlines the settings and describes my contribution to the **six** papers. The descriptions follow the Contributor Role Taxonomy (CREDIT) (Allen et al., 2019).

Research Article #1 entitled "Examining Twin Transformation to Balance Digital Transformation and Sustainability Transformation Tensions" (Crome et al., 2024b, Appendix A.3) was written by a team of four authors. I contributed to the conceptualization, methodology, and data investigation. I was responsible for drafting sections of the original manuscript, conceptualizing key elements of the results, and participating in the review and editing of the document. One co-author acted as the lead author, overseeing the project, while the other co-authors and I acted as supporting authors.

Research Article #2 entitled "Navigating AI for Sustainability in Organizations: Untangling Organizational, Technical, and Sustainable Characteristics" (Plank et al., 2024, Appendix A.4) I co-authored this research article with Daniel Leuthe and Tobias Plank. All co-authors participated equally in the conceptualization of the artifact. I was specifically involved in the visualization of the results and writing as well as editing major parts of the manuscript. In addition, Tobias Plank and I were responsible for the data analysis.

Research Article #3 entitled "Towards Sustainability of AI – Identifying Design Patterns for Sustainable Machine Learning Development" (Leuthe et al., 2024, Appendix A.5) was written by a team of four authors. In particular, Daniel Leuthe and I played a pivotal role in the entire research process, including the creation and conceptualization of the research idea, investigation, development, visualization, and evaluation of results. Furthermore, I extensively revised the paper after receiving feedback during the review process.

Research Article #4 entitled "Linking Sustainability Dimensions in AI Governance: A Review and Collection of Governance Mechanisms" (Meyer-Hollatz et al., 2024b, Appendix A.6) was written by a team of five authors. Vanessa Grüner developed the first daft of the research article and conducted the data curation. Lukas Willburger and I equally contributed to the article by extending the literature sample, rewriting the manuscript, extending the contribution, theoretical embedding, and conceptualizing the final artifact. In addition, I focused on developing the visualizations and prepared the final submission.

Research Article #5 entitled "Punctuality Predictions in Public Transportation: Quantifying the Effect of External Factors" (Meyer-Hollatz et al., 2023, Appendix A.7) was developed by a team of three co-authors. We jointly conceptualized the research idea and developed the main artifact of the research article. I was involved in all stages of the development process, from writing the initial draft to reviewing it. Specifically, I was responsible for the data analysis and developed the visualization for the research article.

Research Article #6 entitled "Understanding Information Needs for Seamless Intermodal Transportation: Evidence from Germany" (Meyer-Hollatz et al., 2024a, Appendix A.8) was written by a team of four authors. I contributed to the conceptualization, development of the methodology, data curation, writing of the original draft, and reviewing the article. As the lead author, I managed the project while the three other authors serve as subordinate authors. Additionally, I was responsible for preparing the article's refinement and preparing it for submission.

A.3 Research Article #1: Examining Twin Transformation to Balance Digital Transformation and Sustainability Transformation Tensions

Authors:

C. Crome, T. Meyer-Hollatz, T. Kreuzer, and A. M. Oberländer

Working Paper

Keywords:

Twin Transformation, Tensions, Digital Transformation, Sustainability Transformation

Extended Abstract[4]:

In today's rapidly evolving world, organizations are being shaped by two pivotal transformations: Digital Transformation and Sustainability Transformation. Both transformations bring about profound changes in society and industries but are often considered separate processes as they seem to differ in key characteristics (e.g., Dorninger et al., 2020; Vial, 2019). Each of these transformations generates tensions, which can impede organizational change (Chatterjee & Sarker, 2024; Mishra et al., 2022). Broadly speaking, this is due to (1) Digital Transformation (DT) being primarily economically driven, whereas Sustainability Transformation (ST) follows environmental and social goals (Chatterjee & Sarker, 2024), and (2) potential environmental and social problems related to digital technologies (Berthon & Donnellan, 2011; Veit & Thatcher, 2023). Both single transformations are, however, essential for long-term organizational success and societal longevity. DT helps organizations to adapt their identity to technological changes and thus keeps the organization competitive, while ST enables organizations not to exploit the environment and humans so that future generations will also live in a world worth living in (Sancak, 2023; Wessel et al., 2021). Against this background, the recently emerging concept of integrated DT and ST, namely twin transformation, offers a potential solution approach, suggesting that it could also address the tensions that arise from their interplay (Christmann et al., 2024). However, to effectively shape further research, a comprehensive understanding of the tensions arising at the intersection of digital and sustainability transformations or the mechanisms for balancing them need to be understood. This study aims to explore and elucidate the tensions that arise from simultaneously implementing DT and ST in organi-

[4]As of now, this research article is in preparation for submission to a scientific journal. Hence, an extended abstract of the article is provided here.

zations. Specifically, it investigates how organizations can address these tensions through twin transformation.

To address our research question, we employ a sequential, multi-method research approach (Mingers, 2001). First, we conduct a systematic literature review to conceptualize the ex-ante knowledge on DT and ST tensions (Wolfswinkel et al., 2013). Second, we conduct 24 semi-structured interviews with subject-matter experts to derive response mechanisms for balancing the identified tensions (Gioia et al., 2013; Myers & Newman, 2007). The literature review identifies five key tensions affected by the interplay of DT and ST: societal value vs. organizational performance, radical innovation vs. incremental innovation, competition vs. collaboration, personal employee identity vs. organizational identity, and depth of competence vs. breadth of competence. These tensions were categorized using the well-established tension framework Smith and Lewis (2011). The empirical data collected from interviews reveal three twin transformation response mechanisms to address these tensions: leveraging digitalization to enhance sustainability actions, exploiting sustainability actions to sharpen digitalization, and integrating digital and sustainability actions to provide mutual benefit. These mechanisms provide a structured approach for practitioners to manage and balance the competing demands of DT and ST, thereby fostering effective twin transformations.

This study makes two main contributions. First, it provides a profound understanding of the individual and combined tensions of DT and ST, setting the foundation for integrated tension management. Second, it offers actionable twin transformation response mechanisms, bridging the gap between theory and practice. These findings support practitioners in fostering effective twin transformations and provide researchers with a structured framework to integrate this nascent field with existing Information Systems research streams.

References:

Berthon, P., & Donnellan, B. (2011). The greening of IT: Paradox or promise? *The Journal of Strategic Information Systems*, *20*(1), 3–5. https://doi.org/10.1016/j.jsis.2011.02.001

Chatterjee, S., & Sarker, S. (2024). Toward a better digital future: Balancing the utopic and dystopic ramifications of digitalization. *The Journal of Strategic Information Systems*, *33*(2), 101834. https://doi.org/10.1016/j.jsis.2024.101834

Christmann, A.-S., Crome, C., Graf-Drasch, V., Oberländer, A. M., & Schmidt, L. (2024). The twin transformation butterfly: Capabilities for an integrated digital and sustainability transformation. *Business & Information Systems Engineering*. https://doi.org/10.1007/s12599-023-00847-2

Dorninger, C., Abson, D. J., Apetrei, C. I., Derwort, P., Ives, C. D., Klaniecki, K., Lam, D. P., Langsenlehner, M., Riechers, M., Spittler, N., & Von Wehrden, H. (2020). Leverage points for sustainability transformation: A review on interventions in food and energy systems. *Ecological Economics*, *171*, 106570. https://doi.org/10.1016/j.ecolecon.2019.106570

Gioia, D. A., Corley, K. G., & Hamilton, A. L. (2013). Seeking qualitative rigor in inductive research: Notes on the gioia methodology. *Organizational Research Methods*, *16*(1), 15–31. https://doi.org/10.1177/1094428112452151

Mingers, J. (2001). Combining IS research methods: Towards a pluralist methodology. *Information Systems Research*, *12*(3), 240–259. https://doi.org/10.1287/isre.12.3.240.9709

Mishra, R., Singh, R. K., & Song, M. (2022). Managing tensions in resilience development: A paradox theory perspective on the role of digital transformation. *Journal of Enterprise Information Management*. https://doi.org/10.1108/JEIM-08-2022-0271

Myers, M. D., & Newman, M. (2007). The qualitative interview in IS research: Examining the craft. *Information and Organization*, *17*(1), 2–26. https://doi.org/10.1016/j.infoandorg.2006.11.001

Sancak, I. E. (2023). Change management in sustainability transformation: A model for business organizations. *Journal of Environmental Management*, *330*, 117165. https://doi.org/10.1016/j.jenvman.2022.117165

Smith, W. K., & Lewis, M. W. (2011). Toward a theory of paradox: A dynamic equilibrium model of organizing. *Academy of Management Review*, *36*(2), 381–403. https://doi.org/10.5465/AMR.2011.59330958

Veit, D. J., & Thatcher, J. B. (2023). Digitalization as a problem or solution? Charting the path for research on sustainable information systems. *Journal of Business Economics*, *93*(6-7), 1231–1253. https://doi.org/10.1007/s11573-023-01143-x

Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, *28*(2), 118–144. https://doi.org/10.1016/j.jsis.2019.01.003

Wessel, L., Baiyere, A., Ologeanu-Taddei, R., Cha, J., & Blegind Jensen, T. (2021). Unpacking the difference between digital transformation and IT-enabled organizational transformation. *Journal of the Association for Information Systems*, *22*(1), 102–129. https://doi.org/10.17705/1jais.00655

Wolfswinkel, J. F., Furtmueller, E., & Wilderom, C. P. M. (2013). Using grounded theory as a method for rigorously reviewing literature. *European Journal of Information Systems*, *22*(1), 45–55. https://doi.org/10.1057/ejis.2011.51

A.4 Research Article #2: Navigating AI for Sustainability in Organizations: Untangling Organizational, Technical, and Sustainable Characteristics

Authors:
T. Plank, D. Leuthe, and T. Meyer-Hollatz

Submitted Working Paper

Keywords:
Artificial Intelligence, AI for Sustainability, Taxonomy, Archetypes, AI for Social Good

Extended Abstract[5]:
In the pursuit of the Sustainable Development Goals, the role of digital technologies, especially Artificial Intelligence, has become increasingly vital (Kar et al., 2022; Tseng & Lin, 2024). Organizations leveraging Artificial Intelligence (AI) to contribute to the SDGs are expected to impact sustainability on a faster and broad scale (Kopka & Grashof, 2022). AI stands out as an enabling factor of economic, environmental and social sustainability, encapsulated in the concept of Artificial Intelligence for Sustainability (Frank, 2021; van Wynsberghe, 2021; Vinuesa et al., 2020). Artificial Intelligence for Sustainability (AI4S) is discussed in different research streams, ranging from a fundamental discussion of AI's potential and its future developments for social and environmental good (Cowls et al., 2023; Nahar, 2024; Tomaev et al., 2020) to specific AI4S use cases and their technical characteristics to achieve sustainable development using AI (Wang et al., 2022). In addition, researchers are searching for the structure to capture AI4Ss functionality. Notwithstanding the progress on AI4S, research is lacking a case-driven examination of the connection between a technical, organizational, and sustainable perspective (Di Vaio et al., 2020; Nishant et al., 2020).

To bridge this gap, we adhered to a rigorous four-step process. First, we identified relevant AI4S use cases through a comprehensive multivocal literature review, identifying 158 AI4S use cases. Second, we developed an AI4S taxonomy consisting of three layers, ten dimensions, and 47 characteristics. Based on the taxonomy and the analysis of 158 AI4S use cases, we could derive the predominant features of leading AI4S use cases and how they manifest themselves in the technical (i.e., focus on specific data, algorithms, and AI-skills), organizational

[5]As of now, this research article is undergoing peer review for publication in a scientific journal. Hence, an extended abstract of the article is provided here.

(i.e., especially the distribution along business functions), and sustainability (i.e., a clear focus towards certain SDGs) dimensions. Third, we employed hierarchical and partitioning-based clustering to classify the use cases, resulting in seven distinct AI4S archetypes which encapsulate the tripartite structure of organizational, technical, and sustainability elements. Finally, we introduce a complexity positioning roadmap following Hunke et al. (2022) to disentangle the configurations of the AI4S archetype along their prevailing dimensions and identify two essential drivers that could guide targeted transitions from one AI4S archetype to another to systematically evolve AI4S.

Our study contributes significantly to the structuring and description of AI4S, providing a foundation for future research and practical applications. The seven archetypes and the complexity positioning roadmap offer a comprehensive overview of adoption patterns, thereby paving the way for identifying future research endeavors. In practice, our taxonomy and archetypes serve as robust tools for organizations that want to take advantage of AI4S while promoting economic viability and fulfilling the Sustainable Development Goals (SDGs). Through this work, our goal is to catalyze the adoption of AI4S, fostering sustainable development at the organizational level and beyond.

References:

Cowls, J., Tsamados, A., Taddeo, M., & Floridi, L. (2023). The AI gambit: Leveraging artificial intelligence to combat climate changeopportunities, challenges, and recommendations. *AI & SOCIETY*, *38*(1), 283–307. https://doi.org/10.1007/s00146-021-01294-x

Di Vaio, A., Palladino, R., Hassan, R., & Escobar, O. (2020). Artificial intelligence and business models in the sustainable development goals perspective: A systematic literature review. *Journal of Business Research*, *121*, 283–314. https://doi.org/10.1016/j.jbusres.2020.08.019

Frank, B. (2021). Artificial intelligence-enabled environmental sustainability of products: Marketing benefits and their variation by consumer, location, and product types. *Journal of Cleaner Production*, *285*, 125242. https://doi.org/10.1016/j.jclepro.2020.125242

Hunke, F., Heinz, D., & Satzger, G. (2022). Creating customer value from data: Foundations and archetypes of analytics-based services. *Electronic Markets*, *32*(2), 503–521. https://doi.org/10.1007/s12525-021-00506-y

Kar, A. K., Choudhary, S. K., & Singh, V. K. (2022). How can artificial intelligence impact sustainability: A systematic literature review. *Journal of Cleaner Production*, *376*, 134120. https://doi.org/10.1016/j.jclepro.2022.134120

Kopka, A., & Grashof, N. (2022). Artificial intelligence: Catalyst or barrier on the path to sustainability? *Technological Forecasting and Social Change*, *175*. https://doi.org/10.1016/j.techfore.2021.121318

Nahar, S. (2024). Modeling the effects of artificial intelligence (AI)-based innovation on sustainable development goals (SDGs): Applying a system dynamics perspective in a cross-country setting. *Technological Forecasting and Social Change*, *201*, 123203. https://doi.org/10.1016/j.techfore.2023.123203

Nishant, R., Kennedy, M., & Corbett, J. (2020). Artificial intelligence for sustainability: Challenges, opportunities, and a research agenda. *International Journal of Information Management*, *53*, 102104. https://doi.org/10.1016/j.ijinfomgt.2020.102104

Tomaev, N., Cornebise, J., Hutter, F., Mohamed, S., Picciariello, A., Connelly, B., Belgrave, D. C. M., Ezer, D., Haert, F. C. V. D., Mugisha, F., Abila, G., Arai, H., Almiraat, H., Proskurnia, J., Snyder, K., Otake-Matsuura, M., Othman, M., Glasmachers, T., Wever, W. D., ... Clopath, C. (2020). AI for social good: Unlocking the opportunity for positive impact. *Nature Communications*, *11*(1), 2468. https://doi.org/10.1038/s41467-020-15871-z

Tseng, C.-J., & Lin, S.-Y. (2024). Role of artificial intelligence in carbon cost reduction of firms. *Journal of Cleaner Production*, *447*, 141413. https://doi.org/10.1016/j.jclepro.2024.141413

van Wynsberghe, A. (2021). Sustainable AI: AI for sustainability and the sustainability of AI. *AI and Ethics*, *1*(3), 213–218. https://doi.org/10.1007/s43681-021-00043-6

Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., Felländer, A., Langhans, S. D., Tegmark, M., & Fuso Nerini, F. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. *Nature Communications*, *11*(1), 233. https://doi.org/10.1038/s41467-019-14108-y

Wang, H., Gupta, S., Singhal, A., Muttreja, P., & Singh, S. (2022). An Artificial Intelligence Chatbot for Young Peoples Sexual and Reproductive Health in India (SnehAI). *Journal of Medical Internet Research*, *24*(1). https://doi.org/10.2196/29969

A.5 Research Article #3: Towards Sustainability of AI – Identifying Design Patterns for Sustainable Machine Learning Development

Authors:

D. Leuthe, T. Meyer-Hollatz, T. Plank, and A. Senkmüller

Published as:

Leuthe, D., Meyer-Hollatz, T., Plank, T., & Senkmüller, A. (2024). Towards Sustainability of AI – Identifying Design Patterns for Sustainable Machine Learning Development. *Information Systems Frontiers*

Abstract:

As artificial intelligence (AI) and machine learning (ML) advance, concerns about their sustainability impact grow. The emerging field "Sustainability of AI" addresses this issue, with papers exploring distinct aspects of ML's sustainability. However, it lacks a comprehensive approach that considers all ML development phases, treats sustainability holistically, and incorporates practitioner feedback. In response, we developed the sustainable ML design pattern matrix (SML-DPM) consisting of 35 design patterns grounded in justificatory knowledge from research, refined with naturalistic insights from expert interviews and validated in three real-world case studies using a web-based instantiation. The design patterns are structured along a four-phased ML development process, the sustainability dimensions of environmental, social, and governance (ESG), and allocated to five ML stakeholder groups. It represents the first artifact to enhance each ML development phase along each ESG dimension. The SML-DPM fuels advancement by aggregating distinct research, laying the groundwork for future investigations, and providing a roadmap for sustainable ML development.

Keywords:

Artificial Intelligence; Design Patterns; ESG; Machine Learning; Sustainability of AI

A.6 Research Article #4: Linking Sustainability Dimensions in AI Governance: A Review and Collection of Governance Mechanisms

Authors:

T. Meyer-Hollatz, L. Willburger, B. Häckel, W. Kratsch, and V. Grüner

Submitted Working Paper

Keywords:

Artificial Intelligence Governance, Sustainability, Multivocal Literature Review, Environmental, Ecological, Social

Extended Abstract[6]**:**

The potential of AI-driven projects is increasingly visible across various domains, offering organizations opportunities to enhance business models, optimize processes, and increase revenue (e.g, Maslej et al., 2023, 2024). Despite these advantages, many organizations struggle to achieve economically successful AI-driven projects while maintaining a balance across sustainability dimensions. The focus on economic profits often results in adverse effects on ecological and social sustainability, raising concerns about privacy, discrimination, and significant energy consumption (De Vries, 2023; Galaz et al., 2021). Thus, there is a critical need for a comprehensive approach that integrates and balances social, environmental, and economic sustainability in AI governance.

Previous research has attempted to address this issue by providing AI governance frameworks designed to facilitate sustainable AI development along the AI lifecycle (Mäntymäki et al., 2023). However, AI Governance (AIG) research predominately focuses on social sustainability, often excluding environmental aspects, leading to fragmented and overlapping recommendations (Kunkel et al., 2023; Owe & Baum, 2021; Papagiannidis et al., 2023). Although some frameworks, such as those of NIST (2023) and OECD (2023), adopt a holistic approach, they often overlook the interconnections between the three dimensions of sustainability, which can result in mutually reinforcing risks or missed synergies (Purvis et al., 2019; Rohde et al., 2024). Addressing this gap, this research article aims to analyze the sustainability orientation of existing governance frameworks and derive governance mechanisms that integrate multiple

[6] As of now, this research article is undergoing peer review for publication in a scientific journal. Hence, an extended abstract from the article is provided here.

sustainability dimensions, thereby forming the Sustainable AI Governance Framework Extension (SAIG-FE).

To address the research question, we conducted two multivocal literature reviews (Multivocal Literature Reviews (MLRs)). The first MLR aimed to analyze AIG frameworks through a sustainability lens, laying the foundation for the second MLR. The second MLR focused on identifying AIG mechanisms that unify multiple dimensions of sustainability, leading to the development of the SAIG-FE. This framework comprises 28 sustainable AI (SAI) governance mechanisms that integrate multiple sustainability dimensions.

This paper makes two key contributions. First, it provides a comprehensive analysis of existing AIG frameworks through a sustainability lens (Veit & Thatcher, 2023). This analysis enables researchers to identify new research avenues and shifts the focus of AIG research toward a balanced definition of sustainability (Galaz et al., 2021; Owe & Baum, 2021). For practitioners, our analysis facilitates the selection and combination of AIG frameworks based on their sustainability values. Second, it identifies and categorizes 28 SAI governance mechanisms that integrate multiple dimensions of sustainability. This unified approach offers practitioners a structured method to incorporate sustainability into AIG efforts, thereby fostering a more comprehensive and effective governance strategy. From a research perspective, this work has the potential to conduct in-depth analyzes of the interactions between sustainability dimensions in AI governance mechanisms, thus contributing to the management of tensions between these dimensions (Chatterjee & Sarker, 2024; Crome et al., 2024).

References:

Chatterjee, S., & Sarker, S. (2024). Toward a better digital future: Balancing the utopic and dystopic ramifications of digitalization. *The Journal of Strategic Information Systems*, *33*(2), 101834. https://doi.org/10.1016/j.jsis.2024.101834

Crome, C., Meyer-Hollatz, T., Kreuzer, T., & Oberländer, A. M. (2024). Examining Twin Transformation to Balance Digital Transformation and Sustainability Transformation Tensions.

De Vries, A. (2023). The growing energy footprint of artificial intelligence. *Joule*, *7*(10), 2191–2194. https://doi.org/10.1016/j.joule.2023.09.004

Galaz, V., Centeno, M. A., Callahan, P. W., Causevic, A., Patterson, T., Brass, I., Baum, S., Farber, D., Fischer, J., Garcia, D., McPhearson, T., Jimenez, D., King, B., Larcey, P., & Levy, K. (2021). Artificial intelligence, systemic risks, and sustainability. *Technology in Society*, *67*, 1–10. https://doi.org/10.1016/j.techsoc.2021.101741

Kunkel, S., Schmelzle, F., Niehoff, S., & Beier, G. (2023). More sustainable artificial intelligence systems through stakeholder involvement? *GAIA - Ecological Perspectives for Science and Society*, *32*(1), 64–70. https://doi.org/10.14512/gaia.32.S1.10

Mäntymäki, M., Minkkinen, M., Zimmer, M. P., Birkstedt, T., & Viljanen, M. (2023). Designing an AI governance framework: From research-based premises to meta-requirements. *ECIS 2023 Research Papers*, *295*, 1–18.

Maslej, N., Fattorini, L., Brynjolfsson, E., Etchemendy, J., Ligett, K., Lyons, T., Manyika, J., Ngo, H., Niebles, J. C., Parli, V., Shoham, Y., Wald, R., Clark, J., & Perrault, R. (2023). Artificial Intelligence Index Report 2023. https://doi.org/10.48550/ARXIV.2310.03715

Maslej, N., Fattorini, L., Perrault, R., Parli, V., Reuel, A., Brynjolfsson, E., Etchemendy, J., Ligett, K., Lyons, T., Manyika, J., Niebles, J. C., Shoham, Y., Wald, R., & Clark, J. (2024, April). The AI Index 2024 Annual Report.

NIST. (2023). *Artificial Intelligence Risk Management Framework (AI RMF 1.0)* (tech. rep. No. NIST AI 100-1). National Institute of Standards and Technology. Gaithersburg, MD. https://doi.org/10.6028/NIST.AI.100-1

OECD. (2023). *Advancing accountability in AI: Governing and managing risks throughout the lifecycle for trustworthy AI* (OECD Digital Economy Papers No. 349). OECD Publishing. Paris. https://doi.org/10.1787/2448f04b-en

Owe, A., & Baum, S. D. (2021). Moral consideration of nonhumans in the ethics of artificial intelligence. *AI and Ethics*, *1*(4), 517–528. https://doi.org/10.1007/s43681-021-00065-0

Papagiannidis, E., Enholm, I. M., Dremel, C., Mikalef, P., & Krogstie, J. (2023). Toward AI Governance: Identifying Best Practices and Potential Barriers and Outcomes. *Information Systems Frontiers*, *25*(1), 123–141. https://doi.org/10.1007/s10796-022-10251-y

Purvis, B., Mao, Y., & Robinson, D. (2019). Three pillars of sustainability: In search of conceptual origins. *Sustainability Science*, *14*(3), 681–695. https://doi.org/10.1007/s11625-018-0627-5

Rohde, F., Wagner, J., Meyer, A., Reinhard, P., Voss, M., Petschow, U., & Mollen, A. (2024). Broadening the perspective for sustainable artificial intelligence: Sustainability criteria and indicators for Artificial Intelligence systems. *Current Opinion in Environmental Sustainability*, *66*, 101411. https://doi.org/10.1016/j.cosust.2023.101411

Veit, D. J., & Thatcher, J. B. (2023). Digitalization as a problem or solution? Charting the path for research on sustainable information systems. *Journal of Business Economics*, *93*(6-7), 1231–1253. https://doi.org/10.1007/s11573-023-01143-x

A.7 Research Article #5: Punctuality Predictions in Public Transportation: Quantifying the Effect of External Factors

Authors:

T. Meyer-Hollatz, N. Schwarz, and T. Werner

Published as:

Meyer-Hollatz, T., Schwarz, N., & Werner, T. (2023). Punctuality Predictions in Public Transportation: Quantifying the Effect of External Factors. *Wirtschaftsinformatik 2023 Proceedings*, *73*

Abstract:

Increasing availability of large-scale datasets for automatic vehicle location (AVL) in public transportation (PT) encouraged researchers to investigate data-driven punctuality prediction models (PPMs). PPMs promise to accelerate the mobility transition through more accurate prediction of delays, increased customer service levels, and more efficient and forward-looking planning by mobility providers. While several PPMs show promising results for buses and long-distance trains, a comprehensive study on external factors' effect on tram services is missing. Therefore, we implemented four machine learning (ML) models to predict departure delays and elaborate on the performance increase by adding real-world weather and holiday data for three consecutive years. For our best model (XGBoost) the average MAE performance increased by 17.33% compared to the average model performance when only trained on AVL data enriched by timetable characteristics. The results provide strong evidence that adding information-bearing features improve the forecast quality of PPMs.

Keywords:

Punctuality Prediction; Public transportation; Machine Learning; Automatic Vehicle Location

A.8 Research Article #6: Understanding Information Needs for Seamless Intermodal Transportation: Evidence from Germany

Authors:

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Abstract:

Cities worldwide are seeking to enhance their sustainable mobility by reducing individual motorized transportation. While intermodal mobility – combining multiple transportation modes in one journey – is a key solution, individuals encounter challenges initiating intermodal journeys owing to the proliferation of mobility services. Providing accurate information at the right time is crucial amidst this complexity. While research has examined information needs for each mobility mode independently, the relationships between modes, phases, and information needs have barely been empirically investigated. Through a sequential mixed-method approach involving a literature review and a survey of >500 participants, this study identifies and validates the concept of phase- and mode chain-sensitive information needs. The findings provide initial insights, emphasizing phase relationships, mode chain relationships, and the interplays between phases and mode chains – a holistic understanding. This research can guide the design of more effective traveler information systems, aiding the shift toward sustainable urban mobility.

Keywords:

Intermodal mobility; Sustainable mobility; Traveler support systems